Biomass and Agriculture

SUSTAINABILITY, MARKETS AND POLICIES



OECD

Biomass and Agriculture:

SUSTAINABILITY, MARKETS AND POLICIES

OECD

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996), Korea (12th December 1996) and the Slovak Republic (14th December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

© OECD 2004

Permission to reproduce a portion of this work for non-commercial purposes or classroom use should be obtained through the Centre français d'exploitation du droit de copie (CFC), 20, rue des Grands-Augustins, 75006 Paris, France, tel. (33-1) 44 07 47 70, fax (33-1) 46 34 67 19, for every country except the United States. In the United States permission should be obtained through the Copyright Clearance Center, Customer Service, (508)750-8400, 222 Rosewood Drive, Danvers, MA 01923 USA, or CCC Online: *www.copyright.com*. All other applications for permission to reproduce or translate all or part of this book should be made to OECD Publications, 2, rue André-Pascal, 75775 Paris Cedex 16, France.

Biomass and agriculture: sustainability, markets and policies

FOREWORD

The OECD Workshop on Biomass and Agriculture, hosted by the Austrian authorities, was held on 10-13 June 2003 in Vienna. The Workshop was part of the OECD work programme on agriculture and the environment under the auspices of the Joint Working Party on Agriculture and the Environment (JWP). It offered an opportunity to share knowledge and experiences on a range of issues regarding biomass and agriculture, in particular the Workshop:

- Examined the sustainability – economic, environmental, social – dimensions of agricultural biomass production and use.

- Reviewed current policy and market approaches used by OECD countries to promote agricultural biomass and use.

- Explored possible policy options and market approaches to address policy and market failures in agricultural biomass markets.

Over 100 participants, including representatives from 24 OECD countries and two non-OECD countries, attended. In addition, there were participants from academia, and a range of international government and non-governmental organisations, representing farmers, consumers, biomass associations, agri-business and environmental interests.

The Workshop covered two broad themes: examining the contribution of agricultural biomass to sustainability; and the policy approaches, including market-based initiatives, impacts and options for developing agricultural biomass. Each theme was explored in depth supported by specific country examples, with background to the discussions provided by general overview papers. Included in the Workshop was a one-day study visit to various agricultural bioenergy plants and related research facilities.

In this collection of papers, the reader will find a wealth of material relating to agricultural biomass, bioenergy and biomaterials in OECD countries. It is hoped this book will contribute to the current and future debate on agricultural biomass, particularly in the context of agricultural policy reform and the advancement of policies for sustainable development. It is not an exhaustive analysis of the issues. Many questions and issues remain, with the need for further multi-disciplined analysis. This work is published under the responsibility of the Secretary-General of the OECD.

ACKNOWLEDGEMENTS

These proceedings bring together papers from the OECD Workshop on Biomass and Agriculture, held on 10-13 June 2003 in Vienna, Austria. The Secretariat gratefully acknowledges the voluntary financial contribution from the host country, Austria, as well as Canada, which made this Workshop possible.

The Workshop was organised by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management in close collaboration with the OECD. For the OECD Kevin Parris was responsible for the structure and content of the Workshop and assistance provided by Wilfrid Legg, Françoise Bénicourt, Iain Gillespie, and Lew Fulton from the International Energy Agency. Johannes Becker and Johannes Kresbach of the Austrian Ministry of Agriculture, Forestry, Environment and Water Management co-ordinated the Austrian input, with the help of Christa Bauer. Thanks to all those who provided papers and contributed to the success of the discussions, including all the Workshop Chairs and Discussants. Kevin Parris edited the papers together with Theresa Poincet, who also prepared the final publication.

TABLE OF CONTENTS

Page

Executive Summary *15*

OVERVIEW

Agriculture, Biomass, Sustainability and Policy: an Overview
Kevin Parris, OECD, France *27*

Biomass, Bioenergy and Biomaterials: Future Prospects
Ralph E.H. Sims, Massey University, New Zealand *37*

Energy from Biomass: a Promising Option for a Future Sustainable Energy System
Josef Spitzer, Joanneum Research, Austria *63*

An Overview of Biomaterials
Melvyn F. Askew, Central Science Laboratory (CSL), United Kingdom *77*

Part I
BIOMASS AND AGRICULTURE:
ECONOMIC, ENVIRONMENTAL AND SOCIAL DIMENSIONS

1. Economic Dimension

The Triple Bottom Line Benefits of Bioenergy for the Community
Ralph E.H. Sims, Massey University, New Zealand *91*

International Energy Agency (IEA) Biofuels Study – Interim Report:
Results and Key Messages So Far
Lew Fulton, International Energy Agency (IEA), France *105*

The Brazilian Ethanol Programme – Impacts on World Ethanol and Sugar Markets
Tatsuji Koizumi, Food and Agriculture Organization of the United Nations, Italy *113*

The Possibility of Agricultural Biomass Utilisation in Japan
Yukihiko Matsumura, Hiroshima University, Japan *129*

Energy Crops in Flemish Agriculture: Possibilities and Limits
Frank Nevens, Visi Garcia Cidad, Dirk Reheul and Erik Mathijs,
Flemish Policy Research Centre for Sustainable Agriculture, Belgium *139*

2. Environmental Dimension

Page

A Framework for Evaluating the Environmental Impact of Biofuel Use
Jane Feehan and Jan-Erik Petersen, European Environment Agency (EEA), Denmark *151*

Utilisation of Grass for Production of Fibres, Protein, and Energy
Stefan Grass, Biomass Project Services, Switzerland *169*

Linking Bioenergy with Carbon Storage: a Sequential Decision Approach to the Threat of Abrupt Climate Change
Peter Read, Massey University, New Zealand *179*

The Effects of Bioenergy Crops on Farmland Birds in the United Kingdom – a Review of Current Knowledge and Future Predictions
G.Q.A. Anderson, L.R. Haskins and S.H. Nelson, Royal Society for the Protection of Birds, United Kingdom *199*

Powerswitch! The Role of Bioelectricity in the Future of Sustainable Energy
Giulio Volpi, WWF, Belgium; and Thomas Cross, XYLOWATT sa, Belgium *219*

Harvesting Energy with Fertilisers
Christian Pallière, European Fertilizer Manufacturers Association, Belgium, representing the International Fertilizer Industry Association *223*

Potential for Agricultural Biomass to Produce Bioenergy in the Czech Republic
Sergej Usťak and Marie Usťaková, Research Institute of Crop Production, Czech Republic *229*

Emissions from Biogas Plants in Austria
Werner Pölz and Gerhard Zethner, Federal Environment Agency Ltd., Austria *241*

Biogas Production from Pig Slurry in Korea
Jong-sik Lee, Woo-kyun Park, Dong-gyu Im and Mun-hwan Kho, National Institute of Agricultural Science and Technology (NIAST), Republic of Korea *251*

3. Social Dimension

Integrated Renewable Energy Farms for Sustainable Development in Rural Communities
Nasir El Bassam, Integrated Research Centre for Renewable Energy (IFEED), Germany *263*

Small-sized Commercial Bioenergy Technologies as an Instrument of Rural Development
Giuliano Grassi, European Biomass Industry Association (EUBIA), Belgium; Gianluca Tondi, ETA Renewable Energies, Italy; and Peter Helm, WIP-Munich, Germany *277*

Page

A Global Bioenergy Network and its Impact on OECD Countries
Rainer Janssen, WIP-Renewable Energies/(LAMNET), Germany;
Peter Helm, WIP-Munich, Germany; Angela Grassi, ETA Renewable Energies, Italy;
Giuliano Grassi, European Biomass Industry Association (EUBIA), Belgium;
J.R. Moreira, Centro National de Referência em Biomassa (CENBIO), Brazil; and
O. Masera, Universidad Nacional Autonóma de México, Mexico *289*

Agriculture and Renewable Resource Chains in Wallonia, Belgium
Didier Marchal, ValBiom, Belgium; and Yves Schenkel,
Centre de recherches agronomiques de Gembloux (CRA), Belgium *301*

Key Factors for the Successful Market Development of Bioenergy – Experiences from Austria
Christian Rakos, Austrian Environment Agency, Austria *307*

Part II
BIOMASS AND AGRICULTURE:
POLICY APPROACHES, IMPACTS AND OPTIONS

1. Europe

European Commission Policies for the Promotion of Bioenergy
Kyriakos Maniatis, European Commission, Belgium *317*

Renewable Raw Materials and European Union Research Policy
Ciaran Mangan, European Commission, Belgium; and Jim Coombs,
BioMatNet, c/o CPL Press, United Kingdom *335*

Biomass from Agriculture: the Viewpoint of European Farmers
Horst Jauschnegg, Austrian Biomass Association,
on behalf of the International Federation of Agricultural Producers, Austria *349*

Austrian Policy Approaches Towards Biomass in Agriculture
Valerie Zacherl, Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, Austria *355*

Bioenergy Policies and Tools in Belgium
Yves Schenkel and Romain Crehay, Centre de recherches agronomiques de Gembloux (CRA), Belgium *359*

Agricultural Biomass in Greece: Current and Future Trends
M. Mardikis, A. Nikolaou, N. Djouras and C. Panoutsou,
Centre for Renewable Energy Sources (CRES), Greece *363*

Page

Long-term Perspective of the Use of Biomass for Energy in Hungary as a Part of the European Union Accession Procedure
Károly Kocsis, St. Stephen's University, Hungary *377*

Review of Current Policy Approaches Towards Bioenergy Production from Agriculture in Northern Ireland and the Republic of Ireland: a Perspective from the Irish BioEnergy Association
Michael Doran, Irish BioEnergy Association, and Rural Generation Ltd., United Kingdom *387*

Favourable Policy Conditions to the Development of Biogas Production as a Sustainable Form of Energy in Luxembourg
Gérard Conter, Ministry of Agriculture, Luxembourg *405*

Bioenergy and Agriculture: the Norwegian Policy Perspective
Frode Lyssandtrae, Ministry of Agriculture, Norway *417*

State of the Art of Bioenergy in Poland – Barriers and Opportunities
M. Rogulska, A. Oniszk-Popławska, M. Pisarek and G. Wisniewski, EC Baltic Renewable Energy Centre and Centre of Excellence and Competence in Renewable Energy in Poland, Poland *423*

Conditions for Increased Market Penetration of Short Rotation Coppice for Energy Purposes in Sweden
Björn Telenius and Paul Westin, Swedish Energy Agency, Sweden *435*

Biomass Use and Potential in Turkey
F. Taner, I. Ardic, B. Halisdemir and E. Pehlivan, University of Mersin, Turkey *439*

United Kingdom Government Energy Policy: Aims and Support for Sustainable Energy Production
Melvyn F. Askew, Central Science Laboratory (CSL), United Kingdom *455*

2. North America

The Canadian Situation – Biomass and Agriculture
Dave Tupper, Agriculture and Agri-Food Canada, Canada *465*

United States Support for the Agricultural Production of Biomass: the Challenge of Integrating Energy, Agricultural, Environmental and Economic Policies
Terry Nipp, AESOP Enterprises, Ltd., United States *477*

A Vision and Roadmap for the Bioeconomy in Iowa (United States)
Jill Euken, Iowa State University, United States *511*

Genencor and the Biobased Economy of the Future: an International Biotechnology Company's Perspective on Biomass and Agriculture
Jack Huttner, Genencor International, United States *531*

3. Other OECD Countries

Page

The Australian Approach to Biomass
Richard Sisson, Minister-Counsellor, Delegation of Australia to the OECD, France *541*

The New Zealand Policy Approach to Enhance Bioenergy
Ralph E.H. Sims, Massey University, New Zealand *547*

Biomass Nippon Strategy in Japan – Why "Biomass Nippon" Now?
Yasuhiko Kurashige, Ministry of Agriculture, Forestry and Fisheries, Japan *559*

Information related to the OECD Workshop on Biomass and Agriculture, on which this publication is based, is available on the OECD website at: www.oecd.org/agr/env including the following background documents not presented at the Workshop:

Energy and Biodiversity: Understanding Complex Relationships
Jeffrey A. McNeely, IUCN-The World Conservation Union, Switzerland

Biomass-Nippon Strategy
Yasuhiko Kurashige, Ministry of Agriculture, Forestry and Fisheries, Japan

Bioenergy, Carbon, Sequestration and the Clean Development Mechanism of the Kyoto Protocol
Jens Mackensen, UN Environment Programme, Kenya

ABBREVIATIONS

AIJ	Activities Implemented Jointly (Kyoto Protocol)
AUD	Australian dollar
Bau	business as usual
BIGCC	biomass integrated gasification combined cycle
BMDH	biomass district heating plants
BRL	Brazilian real
C	carbon
c	cents
CAP	Common Agricultural Policy of the European Union
CCGT	combined cycle gas turbine
CCS	carbon capture and storage
CDM	Clean Development Mechanism
CHP	combined heat and power
gC	grams of carbon
gC/kWh	grams of carbon released/kWh of electricity generated
CO_2	carbon dioxide
COD	chemical oxygen demand
DHP	district heating system
DKK	Danish kroner
Dm	dry matter
DPSIR	driving force-pressures-states-impacts-responses framework
E-10	motor fuel blend with 10% ethanol
EAGGF	European Agricultural Guarantee and Guidance Fund

EJ	exajoule
ETBE	ethyl tertiary butyl ether
EUR	Euro
ffes	fossil free energy scenario
FTE	full-time labour equivalent
GEF	Global Environment Facility
GHG	greenhouse gas
GJ	gigajoules
Gtc	gigatonnes of carbon
GW	gigawatts
GWh	gigawatt-hours
ha	hectare
HUF	Hungarian forints
ICE	internal combustion engine
IEA	integrated environmental assessment
IGCC	integrated gasification combined cycle
IPCC	International Panel on Climate Change
JI	joint implementation (Kyoto Protocol)
km	kilometres
ktc	kilo-tonnes of carbon
ktoe	kilo-tonnes of oil equivalent
kWe	kilowatt electricity
kWh	kilowatt-hours
l	litre
LCA	life cycle assessment/analysis
LCI	life cycle inventory

LCM	life cycle management
m^3	cubic metres
MJ	megajoule
MJ/m^3	megajoules per cubic metre natural pressure
Mtc	megatonnes of carbon
MTBE	methyl tertiary butyl ether
Mtoe	million tonnes of oil equivalent
MW	megawatts
MWe	MW power electricity
MWh	megawatt-hours
MWth	MW thermal
N	nitrogen
NFFO	non-fossil fuel obligation
NH_3	ammonia
N_2O	nitrous oxide
NO_x	nitrogen oxides
NPK	nitrogen, phosphate, potash
odt	oven dry tonnes
O and M	operation and maintenance
ORC	organic rancine cycle
pH	power of hydrogen
PJ	petajoules
PLN	Polish zloty
ppm	parts per million
PV	photovoltaic
RES	renewable energy sources

RES-E	renewable energy sources electricity
RFS	renewable fuel standard
RVP	reid vapour pressure
R&D	research and development
SAPARD	Special Accession Programme for Agriculture and Rural Development
SO_2	sulphur dioxide
SRC	short rotation coppice
SRF	short rotation forestry
t	tonne
TJ	terajoule
toe	tonnes of oil equivalent
TWh	terawatt-hours
UNFCCC	UN Framework Convention on Climate Change
USD	United States dollar
yr	year

EXECUTIVE SUMMARY[1]

Highlights

This century could see a significant switch from a fossil fuel to a biobased economy, with agriculture as one of the leading sources of biomass feedstocks for renewable bioproducts, both bioenergy (*e.g.* biodiesel) and biomaterials (*e.g.* bioplastics). But bridging the gap between fossil fuel prices and the relatively high prices for most agricultural biomass feedstocks (with the exception of agricultural crop and processing wastes) and bioproduct substitutes for fossil fuel derivatives remains a major constraint.

When will agricultural biomass feedstocks become competitive with fossil fuel based alternatives? How can external costs and benefits be better evaluated? What is the role of governments and markets in developing the biobased economy?

The OECD Workshop on Biomass and Agriculture (Vienna, June, 2003) addressed these and other questions by drawing together a wide range of stakeholders representing agricultural, environmental, industrial and energy interests from government, the private sector, International Governmental Organisations and Non-Governmental Organisations.

Bioproducts currently account for a small but growing share of the total market for energy and industrial materials. Even so, the International Energy Agency's projected prices for fossil fuels over the next 30-50 years suggest the fossil fuel based economy will continue to dominate, based on current policies and market trends.

Care is required when comparing prices for biomass feedstocks and bioproducts with those derived from fossil fuels because some of the socio-economic and environmental costs and benefits (*i.e.* the externalities) are not taken into account. Valuing the costs and benefits of reducing air pollution, lowering greenhouse gas emissions, improving soil and water quality, delivering biodiversity benefits and maintaining rural communities is difficult for externalities as markets rarely exist for them.

The environmental benefits often attributed with biomass production and bioproducts, however, vary according to the type of biomass feedstock and methods of production. Woody materials, grasses and agricultural by-products (*e.g.* crop and livestock wastes) yield much improved carbon balances compared with today's traditional cereal grain and sugar crop biomass feedstocks.

Various subsidies for both bioproducts (*e.g.* excise tax exemptions for blended bioethanol fuels) ***and fossil fuel based products*** (*e.g.* coal, oil exploration and aviation fuel subsidies) ***further complicates price comparisons between renewable and non-renewable energy and materials***. This is against the background of the high level of OECD support for the agricultural sector, with support to OECD farmers totalling nearly USD 235 billion in 2002, representing 31% of total farm revenue.

The prices of some niche market bioproducts such as plastics derived from arable crops are already competitive with petroleum-based plastics at the top end of the market, even without factoring in externalities. Certain transportation biofuels, such as bioethanol produced from sugar and grains and used in existing engines with little modification, are easier to exploit than other alternative fuels such as hydrogen for fuel cells. At the same time, technological change and innovation are reducing the price of biomass and bioproducts closer to those of fossil-based products.

1. This Executive Summary has been prepared under the responsibility of the OECD Secretariat and does not necessarily reflect the views of the OECD member countries and participants at the Workshop.

There is growing interest by OECD governments and the private sector, as well as across many developing countries, in expanding the use of bioproducts derived from agricultural biomass. Government rationale for policy intervention in bioproduct markets is usually based on the objectives of:

- reducing greenhouse gas emissions;
- encouraging greater energy supply diversification and security;
- enhancing environmental benefits, for example biodiversity conservation; and
- fostering a range of socio-economic opportunities, such as diversifying and maintaining rural incomes and employment.

Most OECD countries are implementing measures to develop agricultural biomass markets, with emphasis mainly on bioenergy products and services rather than on biomaterials, despite the higher market value of the latter.

Many countries employ a range of policy tools and have adopted a policy strategy that seeks to bridge the price gap between biomass and bioproducts with fossil fuel alternatives, through using financial support that is often unrelated to the externality benefit of avoided emissions. This approach, however, is likely to lead to market distortions and long term market dependence on subsidies.

An alternative approach could be to focus policies on encouraging technological innovation and reducing technology costs. Also governments need to implement standards and guidelines so that biomass and bioproducts are produced in a manner that protects, and where possible enhances, soil, water and biodiversity resources and ensures that they deliver real carbon savings compared with fossil fuels.

Developing market based approaches, such as establishing carbon markets which provide credits to biomass producers for both fossil fuel displacement and greenhouse gas sinks, also shows promise.

The Workshop concluded that countries need to (forestry was outside the scope of the Workshop):

- ***evolve a new policy strategy for biomass production*** that works with markets in facilitating a balance between stimulating demand for bioproducts and developing appropriate feedstock supply, and addresses those cases where fossil fuel and derivate product industries are favoured through subsidies;
- ***promote targeted policy options and market approaches*** that encourage industry innovation and provide maximum long-run benefits to society, (such as using feedstocks and implementing processes with very low net greenhouse gas emissions), rather than continuing with a policy strategy that just seeks to close the gap between production costs and market prices for biomass versus fossil fuel products;
- ***ensure that biomass and bioproducts are produced to appropriate international standards***, especially in view of increasing international trade in these feedstocks and products, and that there are codes of best practice in place to ensure that carbon savings are delivered and wider environmental benefits are maximised;
- ***improve assessment of the costs and benefits of using agricultural biomass feedstocks and related bioproducts*** to meet economic, trade, environmental and social objectives in the agricultural, energy, and industrial sectors in the context of sustainable development;
- ***establish clear lines of communication between technology and feedstock suppliers***, processors and potential users, and also across relevant government agencies responsible for the bio-economy, especially agriculture, environment, energy, industry, science and technology; and,
- ***develop public education, awareness and understanding of the biomass sector*** and its contribution to the biobased economy.

Background

The focus of the OECD Workshop, hosted by the Austrian government and held in Vienna, June 2003, which drew together a wide range of stakeholders representing agricultural, environmental, industrial and energy interests from government, the private sector, International Governmental Organisations and Non-Governmental Organisations, was to:

- take stock of the current and potential market situation for agricultural biomass and related bioproducts in OECD countries;
- review policy approaches and options, including market based instruments, to address policy and market failures in agricultural biomass markets; and
- discuss the role of agricultural biomass in contributing to the economic, environmental and social dimensions of sustainable agriculture.

Glossary of key terms used in this report

Biomass: any organic material, of plant and animal origin, derived from agricultural and forestry production and resulting by-products, and industrial and urban wastes, used as feedstocks for producing bioenergy and biomaterials (only agricultural biomass was considered at the Workshop).

Agricultural biomass: a subset of biomass produced directly from agricultural activities, including cereal grains; sugar crops; oilseeds; other arable crops and crop by-products such as straw; vegetative grasses; farm forestry (*e.g.* willow and poplar); and livestock by-products, for example, manure and animal fats.

Bioenergy: renewable energy produced from biomass when used to produce heat and/or power and transport fuels. Bioenergy produced from agricultural biomass includes ***biofuels*** such as bioethanol, mainly derived from cereal grains and sugar, and biodiesel from vegetable oils and animal fats; ***biopower*** in the form of electricity; and bioheat generated from processing mainly agro-forestry products (*e.g.* willow), crop and livestock by-products (*e.g.* straw and manure) and grasses (*e.g.* elephant grass).

Biomaterials: renewable industrial raw materials and derived processed products produced from biomass. Biomaterials produced from agricultural biomass mainly include ***industrial oils*** for paints, inks, etc. from oilseed crops; ***starch and sugar*** from, for example, cereals, potatoes, sugarbeet and sugarcane, used to produce polymers, detergents, paper, etc.; ***fibres*** from crops such as cotton and hemp; and ***high-value low-volume products*** derived from a variety of crops, and used in the production of, for example, cosmetics, flavourings, and healthcare products.

Bioproducts: includes both bioenergy and biomaterials.

Biobased economy: an economy that uses renewable biomass resources, bioprocesses and eco-industrial clusters to produce sustainable bioproducts and provide employment and income.

How large are agricultural biomass and bioproduct markets and what is their potential?

Bioenergy

Bioenergy and biomaterials (see glossary) ***derived from agricultural biomass currently contribute a very small share of the total OECD energy and raw material markets.*** But this OECD average statistic masks considerable variation within and across countries. The biobased economy is expected to grow rapidly in many countries over the next few years, in part due to new policies to promote or require greater use of renewable products, for example, bioenergy.

Bioenergy derived from agricultural biomass includes bioethanol and biodiesel which currently account for under 1% (energy basis) of the total EU and US vehicle fuel market. Regional variation within countries is highlighted by the example of the US where two states, Iowa and Illinois, supply over 50% of the US total agricultural biomass feedstock used in biofuel production.

The share of agricultural bioenergy in OECD heat and power generation is higher, accounting for about 7% of total heat and 1% of total electricity generated. In specific countries it ranges from over 10% of total consumer energy in Austria to under 1% in Japan. In developing countries the situation is different, with non-commercial biomass (firewood and animal dung) representing 25% of total energy demand, mainly derived from fuel wood, but agricultural by-products are also important.

Biomass use in electricity generation is projected by the International Energy Agency (IEA) to be one of the fastest-growing primary energy sources in OECD countries, expanding at over 4% annually up to 2030, under current policy assumptions. As this growth is from a very low base, however, the market share of bioenergy derived from agricultural biomass will remain small, reaching only about 2% of total electricity generation by 2030. Government targets for production of bioenergy in many countries, for example the US and EU member states, aim to substantially expand production levels over the next 10−15 years, with bioenergy likely to become a major source of primary energy supplies in some localities and regions within OECD countries.

Biomaterials

For biomaterials derived from agricultural biomass current usage is very small compared with products derived from fossil fuel feedstock for most OECD countries. There are some exceptions, such as natural fibres (*e.g.* cotton, flax), vegetable oil-based products, and cereal/sugar-based starch mainly for the paper industry. Global trade in these products is in excess of USD 250 billion annually.

The potential for future growth of biomaterials derived from agricultural biomass is uncertain, because of the large diversity of feedstock and products, the complexity of technologies needed to transform the feedstock into industrial products, and the fact that most biomaterials are substitutes for fossil fuel based products. Even so, projections, although limited, would suggest that the growth in certain biomaterials could be substantial over the next 10 years.

These projections are underscored by the fact that some multinational chemical companies (e.g. Cargill-Dow, Bayer, Dupont) are rapidly increasing investment in biomaterial product development and processing plants, especially bioplastics derived from cellulosic plant material. Automobile manufacturers are also using more biomaterials in vehicle construction.

Is agricultural biomass production sustainable?

Agriculture has the potential to help meet the growing energy and raw material needs of society in a sustainable manner as part of the vision towards a biobased economy (see glossary). This can include, for example, lowering greenhouse gas (GHG) emissions, and bringing benefits to soil and water quality and biodiversity. Agricultural biomass can only be considered sustainable if it is economically efficient and profitable; socially viable; provides a net benefit to improving environmental performance and rural development; and is compatible with policy goals for agriculture, environment, energy, industry, in the wider context of trade liberalisation and sustainable development.

A cross-cutting strategic approach is required to ensure that all these goals are achieved. Even so, it may not be possible to achieve all these goals simultaneously and choices may need to be made. Small scale bioenergy generation, for example, may be less resource efficient but give more socio-economic benefits to the local community. Likewise biomass feedstock production managed to maximise yield may result in environmental damage.

Is agricultural biomass feedstock use economically viable?

The economics of biomass feedstock and use are dominated by considerations of costs relative to fossil fuel-based products. At present bioenergy derived from agricultural biomass feedstock in most situations (but with the notable exceptions of agricultural crop by-product and processing wastes) is usually competitive only where governments provide production subsidies, tax exemptions and other forms of support. Moreover, this support is against the background of the high level of support for the OECD agricultural sector, with the OECD (see the *Agricultural Policies in OECD Countries: Monitoring and Evaluation* report 2003), estimating that the total support cost to OECD farmers was nearly USD 235 billion in 2002, representing 31% of total farm revenue.

Market opportunities exist for biomass and bioproducts, particularly where using biological approaches can reduce production costs and environmental impacts. Even so, energy-based projections, such as the 2002 IEA *Energy Outlook*, indicate that changes in fossil fuel prices over the next 30 years are not expected to be large enough to drive widespread use of biomass for energy production.

Other options and opportunities will need to be found if the biomass feedstock and bioproduct industry is to become commercially viable and free of subsidies. But in making price comparisons between bioenergy and non-renewable energy sources it will also be important to make a critical analysis of the negative externalities and subsidies received by the coal, aviation fuel, oil exploration and nuclear power industries in some OECD countries.

Improved technologies and economies of scale, however, are narrowing the price gap between biomass and competing fossil fuel based products, especially through greater efficiencies in both biomass feedstock delivery to processing plants and also biomass conversion technologies. But this is only part of the solution to bridging the price gap. There is a need to develop longer-term strategies that recognise local/regional resources and potential and move toward multi-feedstock production and multi-product bio-refineries. Such complexes would be capable of producing both energy and materials, with emphasis on optimising the use of all agricultural biomass feedstocks, including recycling farm by-products, as well as using grains, oilseeds, sugar and other crops.

The economics of agricultural biomass could also be altered, vis-à-vis fossil fuels, by establishing markets for carbon offsets (*i.e.* bioenergy) ***and carbon sinks*** (*i.e.* for certain forms of biomass feedstock, such as agro-forestry). Furthermore since the supply chains for agricultural biomass are poorly developed, these could be improved through vertical and horizontal integration of the biomass industry to exploit synergies across different activities, such as agriculture, forestry, and municipal waste all supplying biomass feedstocks, and to develop institutional infrastructures for research and development, transport, marketing and sales networks.

Is agricultural biomass feedstock use environmentally sound?

The net balance between costs and benefits of biomass products compared with fossil fuel alternatives depends critically on how the environmental benefits and costs (*i.e*. externalities) ***are valued***. But few, if any benefits, have a suitable market in which to establish their price, and there remains a lack of information and agreement as to how to measure environmental externalities. Frameworks and assessment tools are being developed that will help improve measurement of externalities, such as life-cycle analysis (LCA). The use of LCA and other assessment tools, however, is not widespread throughout industries using bioprocesses or developing bioproducts. Hence, use of the LCA tool should be encouraged to identify the most efficient approaches in developing the bio-economy.

Some recent LCA studies indicate that compared to the use of cereal grains and sugar crops, the use of cellulosic plant material, such as grasses or woody crops for bioethanol production, result in substantial net economic and environmental benefits when all externalities are taken into account and valued. The use of cellulosic crop by-products, such as straw, can also reduce waste and involves using the whole plant crop and not just the grain, while using perennial grasses and woody crops can reduce fertiliser and pesticide use compared to arable crops. Processes using cellulosic materials as both the feedstock and the process fuel could potentially eliminate the use of fossil fuel process energy, yielding much improved carbon balances compared to the current use of cereal grains and sugar crops.

A critical issue concerning the future environmental sustainability of agricultural biomass relates to the interaction with other land uses. The availability of marginal land that could be used to produce woody crops is in some areas much greater than the limited cropland available to grow arable crops for non-food purposes. But large-scale changes in land use to produce biomass feedstock, may not always be appropriate or desirable as they could have adverse impacts on food production, soil quality, marginal and fragile land, biodiversity and landscape either within OECD countries or more globally.

The land requirements for biomass will in part depend on substitution with agriculture cropping and other land uses, improvements in yields of the principal biomass crops, and the extent to which agricultural by-products are utilised. These issues require further assessment, especially the consequences of increasing agricultural biomass production on food production and prices, effects on biodiversity, and the impact on soil quality and nutrient status from the removal of crop by-products for biomass feedstock instead of incorporating them back into the soil. Moreover, all these factors need examining in the light of reform of the existing agricultural support framework.

Is agricultural biomass feedstock use socially beneficial?

Assessing if agricultural biomass production is socially beneficial is probably the least well understood and most difficult dimension of sustainability to quantify. Estimating the social benefits and costs of expanding biomass production and products may require complex modelling of the net effects on farm incomes, rural employment and the economy as a whole. There are also difficulties of gauging public perceptions of biomass when there is a lack of knowledge of the industry. This highlights the importance of engaging local and regional communities into biomass projects to improve understanding of the industry and its potential benefits, and also to attract investors so that communities have ownership of projects.

What are the objectives for policy intervention in agricultural biomass markets by OECD countries?

Most OECD countries are implementing measures to develop the markets for the use of agricultural biomass, with current emphasis on bioenergy. A range of policy tools are employed and many countries have adopted a policy strategy that seeks to bridge the price gap between biomass and bioproducts with fossil fuel alternatives rather than providing incentives and information for processors and consumers. Given cross-country differences in natural resources, industry, infrastructure, policy approaches and mixes towards developing a biobased economy, no one policy solution will fit all cases, but sharing experiences can help.

Government rationale for policy intervention in the agricultural biomass and bioproduct markets in most OECD countries is usually focused on three main objectives to:

- meet the broader goals of sustainable development linked to the vision of moving toward a biobased economy and recycling society;
- support the development of an "infant industry" as it moves down the experience chain; and to,
- ensure the provision of environmental and health benefits.

Vision toward a biobased economy and creation of a recycling society

Within the context of broader national goals of sustainable development and sustainable agriculture, ***a number of governments have articulated a vision for the biobased economy as an engine of growth and market innovation.*** The goals of this vision mainly include establishing sectoral contributions (*e.g.* agriculture, forestry), identifying directions for technology development, opening possibilities for export potential based on biobased technologies, developing business opportunities through carbon markets, and providing infrastructure and institutional frameworks.

The emphasis of this vision differs across countries. Some focus upon meeting renewable energy targets, others on material production from growing agricultural biomass crops, and others still on the recycling of agricultural by-products and waste minimisation. Energy importers, for example, may value more highly bioenergy production for reasons of energy security than an energy exporter. While some localities and countries may place a higher value on using bioethanol to achieve clean air goals, than meeting other environmental objectives.

Policies have often been directed at maintaining and diversifying farm incomes through supporting the production of agricultural biomass, rather than targeting the development of the biobased economy that would address the industrial demand for agricultural biomass feedstock as well as broader environmental and social goals. This latter approach necessitates the development of a coherent and integrated biomass policy framework that cuts across traditional ministerial boundaries (*e.g.* environment, agriculture, transport, industry, science and technology), and also engages local communities as the prime drivers in biomass projects. Such a strategic approach may be more demanding in the short term, but is more likely to deliver greater benefits in the long term.

The creation of a recycling society in many countries, reflects changing values and improvements in the efficiency of energy and raw material use. Policies to expand bioproduct output from agricultural biomass feedstock in some cases target the increased use of farm by-products to help reduce costs of their disposal and to encourage the reduction in use and disposal costs of non-renewable products. Some countries, concerned with the reliability of oil supplies, are also adopting measures to increase the diversification and security of domestic energy and raw material supplies, including expanding bioenergy and biomaterial production.

Infant industry and market failure

Government support to the biomass market on the basis of the "infant-industry" argument emphasises that initial research and development costs can be prohibitive or involve too high a risk to be supported solely by the private sector. This rationale is weaker for some areas of agricultural biomass production and processing, such as the use of cereal grains and sugar to produce bioethanol which has a relatively long history. Other areas of biomass conversion processes and technologies are only at the research and development stage, for example, biomass gasification processes and developing biomaterials from plant cellulose feedstock, such as from perennial grasses and cereal straw, although depending on how research and development costs are supported can have implications for competitiveness and trade.

The market failure justification for governments to support the development of the use of biomass is based on cases where the market does not remunerate the environmental and social benefits (externalities) generated from biomass production and processing. Some countries are implementing measures that seek to stimulate rural and regional industrial development and employment through expansion of agricultural biomass feedstock for regional bioproduct processing plants. In some localities this may help to diversify farm income and rural employment opportunities, while the uptake of appropriate technologies at different local/regional scale, may maximise environmental benefits.

Environmental and health benefits

Governments are also adopting measures to develop agricultural biomass to help meet a range of environmental and health objectives, such as improving soil and water quality, and biodiversity conservation. Greater use of bioenergy, especially biodiesel, is also being encouraged by some governments to meet air quality and health objectives, such as using bioethanol in fuel blends to reduce road vehicle exhaust particulates, with resulting improved health effects, although burning bioethanol can result in higher emission levels of other pollutants, such as nitrogen oxide.

Whether agricultural biomass production can meet environmental objectives depends on the current farming system that biomass production replaces, and the extent to which production displaces valued farming habitats or results in the intensification of land use and resulting harm to soil, water and biodiversity resources. Over the longer term the method of producing and harvesting biomass from agriculture can also affect soil and water quality, water resources and biodiversity conservation.

A key environmental objective for most countries is the commitment to reduce greenhouse gas emissions under the UN Framework Convention on Climate Change. Bioenergy provides a source of renewable energy with zero or low carbon dioxide (CO_2) emissions compared to fossil fuels. But this is highly variable between different bioenergy feedstocks, with cellulosic feedstocks such as perennial woody crops normally with lower net CO_2 emissions compared with cereal grains, sugar crops and oilseed crops which require higher energy inputs. Carbon certification schemes offer a way of establishing the net impact of biomass systems on emissions and ensuring that biomass technologies deliver carbon savings compared to fossil fuel or other renewable technologies.

What policy instruments and market approaches are OECD countries using to develop the biobased economy?

Financial incentives

Financial incentives are the most common policy instrument OECD countries have used to stimulate biomass markets. Typically this involves indirect production support for agricultural biomass crops, such as cereal grains, sugar and oilseeds, by reducing sales tax on bioethanol and biodiesel fuel blends; the use of set-aside land for energy and raw material crops; grants and other investment subsidies for developing biomass processing technology and capacity, especially bioenergy plants; higher tariffs for biopower fed into the national power grid (*i.e.* "feed-in tariffs"); and excise tax credits for using biofuel blended fuels instead of fossil fuels.

The emphasis of many financial incentive measures tends to be on closing the gap between production costs and market prices for biomass products relative to those based on fossil fuels. Instead policies should be more focused on maximising environmental benefits, encouraging innovation and reducing technology costs in the utilisation of biomass to stimulate the industry. Payments or low-interest loans granted to reduce risks of biomass projects, if not provided as a lump sum or gradually reduced over time, can introduce market distortions and long-term market dependence on subsidies.

Indirect production support for agricultural biomass feedstock can also lead to production, trade and price distortions with other food and raw material commodity markets. In some cases, the use of trade barriers to protect agricultural biomass feedstock producers may further exacerbate these market distortions. For example, sugar production is one of the most highly supported and protected agricultural commodities across OECD countries. Also, the loss of previously uncultivated land or land managed for conservation to intensive biomass cultivation, such as for land under diversion schemes, could have a negative impact on biodiversity.

Market-based approaches

More recently some countries have explored the development of market-based approaches to stimulate the biobased economy. A number of governments are establishing carbon markets which provide credits to biomass producers for fossil fuel displacement and GHG sinks. As opposed to providing subsidies, creating a market for carbon places a monetary value on the external benefits of reducing GHG emissions. Creating carbon markets will in future be sensitive to the GHG accounting and trading schemes that result from the process of international greenhouse policy negotiations.

Good practice guidelines, research and communication strategy

Good practice guidelines have been developed by some countries to assist different stakeholders involved in developing commercial biomass projects (*e.g.* landowners, feedstock producers, transporters, processors). In only a few cases have governments developed standards and labelling specifically for biomass projects. Guidelines and standards could greatly help a newly created biomass industry. For example, by enhancing vertical and horizontal integration to improve feedstock supply reliability, and guarantee product quality, especially by certifying carbon savings and environmental benefits and providing international standards for traded biomass feedstocks and bioproducts.

Improving biomass research and development, education and public awareness is an area requiring a greater policy response than at present for many countries. Targeting research and development on innovation and market-focused projects, such as large-scale pilot testing, can yield rapid results. A better understanding of the external benefits and costs of biomass use and bioproducts, and of those fuels and materials they compete with is necessary.

A clear communication strategy is needed for technology and feedstock providers and potential users, including across different government agencies with responsibility for the biomass industry, such as agriculture, environment, energy, and industry. This strategy should be extended to improve public education, awareness and understanding of the biomass sector. Such a strategy would be beneficial in the local communities where projects are established, as an important prerequisite to gain local acceptance and involvement in biomass projects. This strategy might be further developed by OECD countries to improve interactions and exchange of biomass information and technologies with developing countries.

Recommendations for future OECD work

The Workshop made suggestions for further work that could be undertaken within the OECD and in co-operation with the International Energy Agency. These include:

- developing assessment frameworks and indicators to help countries in monitoring and evaluating the biobased economy, including closer co-operation with other international organisations;
- valuing the costs and benefits (economic, social and environmental) of different agricultural biomass feedstocks and bioproducts produced from these feedstocks;
- reviewing country experiences in the role of policies and market led approaches to address biomass market opportunities and externalities, including quantifying biomass market subsidies;
- examining the implications for agricultural commodity markets, the environment and land use, of a substantial increase in biomass production and changes in bioproduct policies;
- establishing international standards and codes of best practice for the biobased economy, especially in view of emerging international trade in biomass feedstocks and bioproducts; and,
- facilitating information exchange on the biobased economy amongst OECD countries and between OECD and developing countries.

OVERVIEW

Page

Agriculture, Biomass, Sustainability and Policy: an Overview
Kevin Parris, OECD, France *27*

Biomass, Bioenergy and Biomaterials: Future Prospects
Ralph E.H. Sims, Massey University, New Zealand *37*

Energy from Biomass: a Promising Option for a Future Sustainable Energy System
Josef Spitzer, Joanneum Research, Austria *63*

An Overview of Biomaterials
Melvyn F. Askew, Central Science Laboratory (CSL), United Kingdom *77*

AGRICULTURE, BIOMASS, SUSTAINABILITY AND POLICY: AN OVERVIEW

Kevin Parris[1]

Introduction[2]

The economies of many OECD countries in the 19th century were based on coal, with the emergence of increasingly oil-based economies over the 20th century. But **the 21st century could see the switch from the fossil fuel to the biological-based economy**, where agriculture would be rejuvenated as a source of bioenergy and biomaterials, as well as fulfilling its traditional role in providing food and fibre. But is the birth of the so called "bioeconomy" a false dawn according to some sceptics?

Costs will clearly play a key role. Projected prices of fossil fuels over the next 30 to 50 years might be expected to ensure the dominance of the hydrocarbon economy over much of this century. Even so, the price of bioplastics is already competitive with petroleum-based plastics at the top end of the market. Also, some biofuels, such as ethanol are easier to exploit for their market potential than fuel cells. Existing engines can use ethanol with little alteration, and the current fuel distribution infrastructure would not need major change (Carr, 2003).

There is growing interest by both governments and the private sector, across OECD and many non-OECD member countries, in developing markets for bioenergy and biomaterials produced from agricultural biomass. Within this context the **overall purpose of the Workshop** is to:

- ***examine the sustainability of producing biomass from agriculture*** (including agro-forestry, but not commercial forestry *per se*), covering the economic, social and environmental issues; and,

- ***review current policy approaches used by OECD member countries*** to promote biomass production from agriculture in terms of their economic efficiency and environmental effectiveness;

- ***explore possible policy options and market led-approaches*** to address policy and market failure in agricultural biomass markets, with recommendations to the OECD for possible future policy analysis in this area.

---

1. Directorate for Food, Agriculture and Fisheries, OECD, Paris, France.

2. The author wishes to thank Wilfrid Legg, Françoise Bénicourt, Theresa Poincet and other OECD colleagues for their comments and assistance in preparing this paper. Any remaining errors in the paper are the responsibility of the author, and the views expressed do not necessarily reflect those of the OECD or its member countries.

This paper provides a background to the Workshop, being held as part of the work programme on agriculture and environment under the auspices of the OECD Joint Working Party on Agriculture and the Environment. The Workshop not only intends to contribute to the OECD work on agri-environmental policy issues, but other activities concerned with the Workshop theme, in particular, the OECD Working Party on Biotechnology and its Task Force on Biotechnology for Sustainable Industrial Development; and the Executive Committee of the International Energy Agency (IEA) Bioenergy Implementing Agreement.

Box 1. What is agricultural biomass and its role in the bioeconomy?

Agricultural biomass role in the "bio-economy" involves producing ***biomass feedstock*** — mainly crops, grasses, trees, crop and livestock wastes — that are ***converted through a range of processes*** — for example fermentation, gasification, and combustion — ***to produce****: fuels*, such as ethanol, renewable diesel, hydrogen; *power*, electricity and heat; and a wide range of *chemical and fibre-based products*, for example, plastics, adhesives, paints, detergents, pharmaceutical and healthcare products, cotton, and linen.

Bioenergy from agricultural biomass is derived from two main sources, agricultural crops and agricultural waste products. ***Energy production from agricultural crops*** can be divided into two main groups, liquid and solid energy forms. *Liquid energy*, covers energy sources such as ethanol burned in engines, usually derived from annually harvested agricultural crops such as sugar, wheat, maize and rapeseed. *Solid energy*, covers energy sources for power generation through electricity and heat, usually produced from agro-forestry products such as poplar and willow, and grass production, for example, elephant grass. ***Energy production from agricultural wastes*** includes wastes from both plants (*e.g.* straw) and livestock wastes (*e.g.* manure, slurry), which are mainly converted to produce heat and electrical power.

Biomaterials are renewable raw materials, which cover the following main groups: ***Industrial oils*** derived from oilseed crops, such as rapeseed and sunflowerseed, and used to manufacture lubricants, surfactants, printing inks, paints, coatings and fragrances; ***Starch and sugar*** from cereals, potatoes, and sugarbeet and cane, used to produce pharmaceuticals, cosmetics, detergents, paper, and healthcare products; ***Fibres*** mostly from fibre crops, such as hemp, flax, cotton, and miscanthus, used to manufacture textiles, paper and panel products, and in combination with synthetic fibres in fibre composites; ***High-value, low-volume products*** derived from a large variety of plant species, used in pharmaceuticals and healthcare products, crop protection and food preservation products, and flavours and fragrances.

1. Biomass and agriculture: an important policy issue

Policy drivers to promote agricultural biomass production

Many OECD member countries have now established policy goals and targets to develop bioenergy and biomaterial production from agriculture. There appear to be a number of common policy drivers across countries that explain the growing interest by governments in promoting agricultural biomass production. These can be grouped under six main headings.

1. **Climate change**: with many countries committed to reduce greenhouse gas (GHG) emissions under the Kyoto Protocol of the UN Framework Convention on Climate Change, bioenergy provides a source of renewable energy associated with low carbon dioxide emission levels compared to the use of fossil fuels. In addition, there are possible future business opportunities from carbon offsets (such as bioenergy) and carbon sinks through international carbon markets.

2. **Energy security**: with recent concerns raised over the reliability of petroleum oil supplies, many countries are seeking to increase the security of their domestic energy supplies by expanding bioenergy production.

3. **Environmental effectiveness**: the expansion of bioenergy and biomaterials production are seen to help toward achieving other government environmental objectives, such as improving air quality (*e.g.* reducing smoke particulates), and benefiting biodiversity conservation.

4. **Rural development**: the increase in biomass feedstock offers the potential to expand market opportunities for agriculture, while providing a raw material to stimulate rural and regional industrial development and employment.

5. **Economic efficiency**: bioenergy and biomaterial production offers the opportunity to use agricultural wastes and reduce costs of their disposal, but also, through using less non-renewable products, lowering costs of non-recyclable and hazardous wastes. With the creation of a recycling society, there is a determination by many governments to improve economic efficiency of energy and raw material use in households and industry.

6. **Market innovation**: interest by some governments in agricultural biomass, is also associated with the development of a bioeconomy as an engine of growth and market innovation. This can offer possibilities in developing local solutions to energy needs and industrial development, but also the opportunity for export potential based on new and emerging biobased technologies.

Current use of agricultural biomass products and future potential

The current use of bioenergy and biomaterials derived from agriculture is very small for most OECD countries, compared with energy and materials derived from fossil fuels and other sources. Agriculture, however, has enormous potential in most OECD countries to increase the production of biomass. Even so, while projections over the next 10 to 30 years reveal the growth in supplies of bioenergy and biomaterials from agriculture may be substantially above that for fossil fuel-based products, their market share will remain small.

The major uncertainties around these projections, excluding for example changes in macro-economic conditions and the price of oil, concern the pace of development and investment in bioenergy/material processing technologies, and also government policies which are currently promoting the expansion of agricultural biomass production in many cases.

In the case of **bioenergy**, in the European Union and United States, for example, ethanol and biodiesel currently account for under 1% of the total petrol/diesel fuel market (energy basis) (see Fulton in this report). The share of agricultural bioenergy in power generation is higher, accounting for about 7% of heat and 1% of electricity generated (OECD, 2000).

Wind power and biomass energy supplies are projected to be the fastest-growing primary energy source in OECD countries, growing at over 3% per annum, up to 2030 (IEA, 2002). As this growth is from a very low base it is anticipated to make only a very small impact on global energy supplies by 2030. Government targets for increasing the production of bioenergy from agricultural biomass, reveal that in many OECD countries they are seeking to more than double current production levels over the next 10 to 15 years (see Maniatis for the EU and Nipp for the US in this report).

For **biomaterials**, excluding traditional products, such as plant fibres, the market for "new" products is also extremely limited at present. While data for market shares of the "new" biomaterial products are limited, estimates in the EU (see Mangan and Coombs in this report) and the US (see Huttner in this report) suggest that these products in the plastic market, for example, currently provide under 1% of total production. Projections, although limited, would suggest that the growth in biomaterials could be substantial over the next 10 years.

In **developing countries** the situation is very different, with non-commercial biomass representing 25% of total energy demand (IEA, 2002). Much of the biomass used in developing countries is derived from fuelwood, but agricultural waste, especially livestock manure, is important in many contexts. IEA projections to 2030 indicate that the share of biomass in developing countries total primary energy demand will fall, although production is likely to become more commercial. These projections do not include traditional biomass use in developing countries, which are difficult to estimate (see Taner in this report).

2. Biomass, agriculture and sustainability

The expanded production and use of bioenergy and biomaterials from agriculture is inextricably linked with the broader societal challenges and opportunities of contributing toward sustainable development. Sustainability is a complex and wide-ranging concept and is not linked to any one prescribed approach. But the basic objective for a sustainable agriculture is to optimise agriculture's net contribution to society, by making better use of physical and human resources. Sustainable farming systems are those that contribute to long-term welfare by providing food, raw materials and other goods and services in ways that are (OECD, 2003*a*):

- **economically viable** – responding efficiently and innovatively to current and future demands for adequate, safe and reliable supplies of food and raw materials;

- **environmentally sound** – conserving the natural resource base of agriculture to meet the foreseeable needs of future generations, while maintaining or enhancing other ecosystems influenced by agricultural activities; and

- **socially beneficial** – meeting the wider values of society, such as supporting rural communities and addressing cultural and ethical issues, such as animal welfare concerns.

A key question for this Workshop is how and to what extent agricultural biomass production can contribute to sustainability? The following sections address this question by outlining some of the key issues that need to be considered in determining the contribution that biomass production from agriculture can make to sustainability.

Is agricultural biomass production economically viable?

The economics of biomass production and use are dominated by considerations of costs relative to fossil fuel-based products. Basically consumers in general are unwilling to pay more for ethanol or bioplastics than regular engine fuel or plastics. At present, bioenergy and biomaterials in most OECD countries are only commercially competitive where governments provide production subsidies, tax exemptions and other forms of support, although in a few cases niche market opportunities exist, such as selling into markets that command high prices, for example, specialised chemicals and polymers.

The critical economic factors for enhancing the competitiveness of agricultural biomass feedstock with fossil fuel-based products, encompass:

- ***Technologies****:* improving the design of **current** processing technologies for converting agricultural biomass feedstock into energy and raw materials.

- ***Scale effects****:* many biomass based industries, especially the bioenergy sector, are considered too small to take advantage of economies of scale with larger processing units that lead to reduced unit costs. Also increasing the overall scale of the biomass production and processing industry can help the growth of supporting research and development, specialist advisers, etc., which may lead to the creation of a positive loop, as the industry generates more investment (Roos *et al.*, 1999).

- ***Integration****:* through vertical and horizontal integration the biomass industry can exploit synergies, across different activities supply***i***ng feedstock, such as agriculture, forestry, and municipal waste, and also develop institutional infrastructures for research and development, transport, marketing and sales networks.

- ***Competition****:* by developing competition both within the ***biomass*** sector and with other business can lead to product innovation, improvements in productivity, and induce investment in the sector, leading to an overall reduction in costs and lower prices to consumers (Roos *et al.*, 1999).

In strict economic terms the response to the question, is agricultural biomass production economically viable, is not at present without government support in most cases. There are two main caveats to this response, which are further explored in the following sections.

1. Comparisons of bioproduct prices with product prices derived from fossil fuels do not take into account, in most cases, the environmental pollution, or negative externalities, associated with using fossil fuels, in particular air pollution and climate-change impacts from GHG.

2. There are a number of environmental and social benefits, or positive externalities, associated with the use of biomass that are difficult to value in a conventional manner, as markets do not usually exist for these benefits, such as clean air or the viability of rural communities (see Tupper in this report).

Is agricultural biomass production environmentally sound?

Two of the main drivers for using biomass are to displace fossil fuels and reduce GHG emissions, and in the case of ethanol to improve urban air quality. Using life-cycle analysis (LCA) ethanol, used in blends with petrol, produced from maize or wheat will reduce GHG emissions by about 4%, and ethanol produced from cellulose, such as straw or wood waste, is calculated to reduce emissions at twice that rate, by 6-8%. Similarly ethanol can provide air quality benefits through its oxygenate properties which can lead to a more complete combustion of engine fuel and reduction of exhaust emissions (see Tupper in this report).

Other environmental benefits are also attributed to agricultural biomass production. These cover a range of issues, including the recycling of wastes, improving resource use efficiency, reducing rates of soil erosion, especially when grasses and short rotation woodlands are cultivated, improvements in water quality through reducing fertiliser and pesticide use. Growth of grass and wood biomass feedstock can also help biodiversity conservation (see Sims in this report).

While the production and use of biomass can generate environmental benefits it can also impose environmental costs. For biomass production this will to a large extent depend on the choice of crops and how the crops are cultivated. On the one hand, monocultural intensive production of energy crops produced from cereals, oilseeds and sugarbeet or cane, can lead to nutrient and pesticide leaching into rivers, increase soil erosion, and result in harmful impacts on biodiversity. On the other hand, biomass produced from agricultural wastes, perennial grasses and wood tends to have much higher energy output to input ratios than for arable crops.

Greater biomass production may also lead to an increase in transport vehicles and hence, higher energy demands and GHG emissions. While within the current range of biobased processing technologies environmental performance varies considerably, with some technologies leading to a greater burden on the environment through higher effluent and emission levels.

A critical issue in the environmental assessment of agricultural biomass production relates to land requirements. There are concerns that a substantial increase in global biomass supplies would lead to competition with traditional food and fibre products, and potentially involve the destruction of native forests. The land area required will ultimately depend on the relative prices for competing food, fibre and biomass crops, and also biomass crop yields, which vary from 1 to over 30 tonnes/hectare/annum.

Given the large areas of agricultural land currently under set-aside programmes, especially in the EU and the US, this would appear to be less of a constraint to the large-scale expansion of biomass production. Bringing some of this set-aside land back into production could have detrimental environmental effects, such as farming on marginal and fragile land, and eliminating the biodiversity gains that have been achieved with certain areas of set-aside land.

In judging whether agricultural production is environmentally sound, that is do the environmental benefits outweigh the costs, is an unresolved question. This is because of the lack of information and the complexity of measuring all the benefits and costs. The development of LCA and multi-sectoral life-cycle assessment are being developed to overcome some of these difficulties. Some of the LCA studies that have been tested indicate that overall certain agricultural biomass systems, especially involving grasses or woody crops for energy, result in substantial environmental benefits compared to costs when all externalities are taken into account and valued (Carlson, 2002).

Is agricultural biomass production socially beneficial?

The development of biomass offers the prospect of raising agricultural incomes and acting as a driver for rural employment opportunities and economic growth. The production and use of biomass can also bring benefits by improving the quality of life in rural communities and enhance rural community relationships by involving producers, processors and consumers at the local level (Paine *et al.*, 1996; and Sims in this report).

An incentive for farming to expand biomass production is the prospect that the increased demand for feedstock will lead to higher prices and, *ceteris paribus*, higher incomes. Increasing the demand for biomass feedstock, especially cereals and oilseeds, has a complex effect within the agricultural sector as both producers and consumers substitute commodities with changing price relationships. The conclusion of varies studies suggests that the increased demand for any one commodity (*e.g.* maize for ethanol production) will not benefit from a full price response, and may even lead to adverse price outcomes in the agricultural sector (see Tupper in this report).

Estimating the employment effects of developing biomass production and processing is also complex. While new biomass processing installations may have a multiplier effect in terms of employment creation, the effect on the local or regional economy will depend on the extent of substitution of already deployed resources. Also the location of new biomass processing plant might be sited close to existing industrial and urban locations, rather than remote rural areas, as plants are closer to a ready available pool of labour and consumer markets (see Tupper in this report).

Some of the social barriers to developing biomass product markets include possible employment shortage of semi-skilled workers to harvest, collect and operate conversion plants, especially in the energy sector (see Sims in this report). There are also difficulties of promoting the bio-economy with the public, partly linked to associated concerns with the use of biotechnology, especially the use of genetically modified organisms for agricultural biomass production. In some localities there is also the public perception that biomass plants are dirty, polluting and unhealthy (see Sims in this report). More widespread is the lack of public knowledge of even what the term biomass means, let alone the complexities of the biomass production and processing industry.

Assessing if agricultural biomass production is socially beneficial, is probably the least well understood and most difficult dimension of sustainability to quantify. Estimating the social benefits and costs of expanding biomass production and products requires complex modelling of net effects on farm incomes and rural employment. But equally, there are also the difficulties of gauging public perceptions of biomass when there is a clear lack of knowledge of the industry.

Is agricultural biomass production sustainable?

The calculus of biomass sustainability, by taking into account the net economic, environmental benefits of production and processing, is complex and difficult as this section of the paper has described. The net balance between costs and benefits of biomass products compared with fossil fuel alternatives to a large extent depends on how the benefits are valued. As many benefits have no market price, such as GHG gas emission reductions, air quality improvements, and biodiversity conservation, their monetary valuation is controversial and uncertain (see Fulton; Sims; and Tupper in this report).

Frameworks and assessment tools are beginning to be developed that will help to respond to answer the question, is agricultural biomass production is sustainable. Papers at this Workshop point to some possible future directions in this context, including the use of LCA (see Mangan and Coombs; and Nevens *et al.* in this report), and integrated environmental assessment frameworks (see Feehan and Petersen in this report).

3. Biomass, agriculture and policy

There are a wide range of government policies that impact on biomass production and use, covering agricultural, environmental, energy and industrial policies, as many Workshop papers have examined in detail. The relevance of these policies varies in importance for agricultural biomass and across countries. But there are a number of key elements that are widely recognised as important toward developing a coherent policy framework for biomass and the development of related bioenergy and biomaterial industries.

Agricultural policy reform

Support to farmers reached USD 235 billion in 2002, representing 31% of farm receipts in the OECD area, which is down from 38% in 1986-88 (OECD, 2003*b*). A key element of a sustainable action plan for agriculture, is to reform current agricultural support policies. Such policies have generated production surpluses; led to a misallocation of resources both between agriculture and other sectors, and within agriculture; helped larger-scale farmers significantly more than small-scale farmers; raised food prices to consumers; diverted budgetary funds from expenditure on health, education and social welfare; and, limited the possibilities for many poorer countries to develop their agricultural sectors.

Recognising the problems associated with high levels of support, OECD Agriculture Ministers in 1987 committed themselves to a progressive reduction in the level of support and to move away from the most distorting forms of support. However, progress towards reform has been slow and variable. There has been some reduction in the level of agricultural support, as noted above. Market price support, output payments and input payments, the most distorting forms of support, have fallen from over 90% of producer support in the mid-1980s to under 80% in recent years. These averages, however, conceal wide variations among countries and commodities (OECD, 2003*b*).

Further reform would have implications for agricultural biomass production. Some are difficult to predict, such as how relative prices between commodities would change, in particular those where support levels tend to be relatively high in some OECD countries, such as sugar, cereals, and oilseeds, and which are also important biomass feedstocks. Reductions in the most distorting forms of support, however, may encourage a shift toward more extensive production systems, including some grass and woody based biomass systems. To the extent that reform reduces land prices, the costs for farmers of extending the area for biomass production would decrease. Reductions in support would also free up funds that consumers, taxpayers or government could use to buy, *inter alia*, goods and services including biomass products.

High agricultural support levels and their reduction can, however, have some direct consequences for biomass production and use. In Japan, for example, where agricultural support levels are amongst some of the highest across OECD member countries, this has acted as a disincentive to developing bioenergy production. For example, the domestic price of maize in Japan is about 16 times above the US maize export price (see Matsumura in this report). For the EU, following the 1992 Common Agricultural Policy Reforms, reached under the WTO Uruguay Round, this led to lower support for EU cereal producers through production controls and a switch to area payments, with an increase in set-aside land. Limited subsidy schemes were then introduced that enabled some set-aside land to be used for growing industrial crops, especially sunflowerseed and rapeseed, for which the main end use was biofuel (see Mangan and Coombs in this report).

Policy incentives

If biomass production and use is to be developed, especially in the context of government's bioenergy and biomaterial strategies outlined at the beginning of this paper, it will require continued government incentives, at least in the short term to bridge the price gap between renewables and fossil fuels. This may entail both the continuation of commodity support programmes for biomass production, and tax exemptions and investment incentives, plus standards and regulations to develop biomass product use.

To provide an additional push to the biomass industry may only require, however, fairly small changes in policy incentives. For example, the existing US subsidy of about USD 0.14/litre is sufficient to encourage substantial production and sales of ethanol fuel. An adjustment to this subsidy that would vary according to fossil fuel displacement and/or GHG reductions could provide a strong incentive for changes in production practices (see Fulton in this report).

Market approaches

A number of governments are beginning to explore the possibilities of developing biomass production through establishing trading systems which provide credits to producers for fossil fuel displacement and GHG reductions (see Grass in this report). Establishing international market trading systems will be sensitive to the GHG accounting and trading schemes that result from the process of international greenhouse policy negotiations.

Policy integration

At present biofuel policies are perceived as largely driven by agriculture interests, rather than by concerns for energy savings, the environment and industrial development (see Doran; and Fulton in this report). Rather than developing the industry through promoting biomass supply from agriculture, it may prove more beneficial to develop biomass through the demand for renewable energy and materials, and environmental and social benefits. This would necessitate the better integration of agricultural, energy, industrial, environmental and social policies, into a more coherent policy framework for biomass crops and products (see Huttner; Mangan and Coombs; and Nipp in this report).

Research and development

Expanding biomass research and development (R&D) is expected to foster an acceleration in the industry. More specifically, focusing R&D on innovation and market-focused, large-scale pilot tests, is viewed by many as yielding results more quickly. This is particularly the case for developing products from cellulosic feedstock, notably grass and woody crops, which are viewed as holding considerable potential as the biomass crops of the future (see Grass in this report).

Institutional infrastructure and public education

The rate of development of agricultural biomass and related bioproducts, are also considered to be influenced by institutional infrastructures and public education. Developing a sound institutional infrastructure for the biomass industry can act as an engine of growth, particularly if the institutional links are developed both horizontally and vertically in the industry. Raising public awareness of the benefits of biomass, particularly for the local communities where production and processing capacity might be developed, is also viewed as an important prerequisite to engage local communities in trying to achieve the success of these projects (see Doran; Rakos; and Sims in this report).

4. Some questions for the Workshop

In order to consider the possible role of government to promote biomass production from agriculture in the context of sustainability objectives it may be useful for the Workshop to consider some of the following questions:

- Is there market failure in producing biomass, and if so, what mix of government and market-based approaches should be used to overcome the market failure?

- Biomass products *vs* fossil fuel-based products: are governments giving the right signals to producers?

- Should a greater area of set-aside land in Europe and the United States be devoted to biomass production?

- What policy failures are a barrier to the development of bioenergy/biomaterials (*e.g.* promotion of fossil energy sources, short-term policies)?

- What are the roles of production support and tax incentives for the biomass sector and market regulation as a tool for passing higher production costs on to consumers?

- What are the possibilities to establish market-led approaches to encourage biomass production, such as international carbon trading schemes?

- To what degree will new and emerging biomass technologies, for energy and materials, have a major impact over the next 10 years?

- In what ways can OECD countries help in the development and transfer of biomass technology to developing countries?

- What aspects of the agricultural biomass production and product market require further analysis?

BIBLIOGRAPHY

Carlson, A. (2002), "Energy system analysis of the inclusion of monetary values of environmental damage", *Biomass and Bioenergy*, 22, pp. 169-177.

Carr, G. (2003), "Climbing the helical staircase", a survey of biotechnology in *The Economist*, 29 March.

IEA [International Energy Agency] (2002), *World Energy Outlook 2002*, Paris, France.

OECD (2003*a*), *Organic Agriculture: Sustainability, Markets and Policies*, proceedings from the OECD Workshop on Organic Agriculture, Washington, D.C., United States, September, 2002, Publications Service, OECD, Paris, France.

OECD (2003*b*), *Agricultural Policies in OECD Countries: Monitoring and Evaluation Report 2003*, Publications Service, OECD, Paris, France.

OECD (2000), *Information Note on the Use and Potential of Biomass Energy in OECD Countries*, General Distribution document, OECD, Paris, France.

Paine, L.K., T.L. Peterson, D.J. Undersander, K.C. Rineer, G.A. Bartelt, S.A. Temple, D.W. Sample and R.M. Klemme (1996), "Some ecological and socio-economic considerations for biomass energy crop production", *Biomass and Bioenergy*, 10, pp. 231-242.

Roos, A., R.L. Graham, B. Hektor and C. Rakos (1999), "Critical factors to bioenergy implementation", *Biomass and Bioenergy*, 17, pp. 113-126.

BIOMASS, BIOENERGY AND BIOMATERIALS: FUTURE PROSPECTS

Ralph E.H. Sims[1]

Abstract

The socio-economic potential for bioenergy is not always being fully realised in many OECD countries and sector growth is slower than anticipated. Conversion technologies are well developed but mainly utilise feedstocks from solid and liquid organic waste streams which have limited supplies. Energy cropping is becoming better understood but it must be ecologically sustainable, environmentally acceptable to the public, and the delivered costs (USD/GJ) need to be lower than for fossil fuels. Production of biomaterials is also limited by the costs of the biomass feedstock which need to be reduced by higher crop yields, lower inputs, more sustainable production and improved transport methods. More efficient conversion plant designs, simplified resource consent procedures and feedstock supply security will reduce project investment risks and reduce reliance on government support mechanisms in the longer term. Carbon trading will provide additional revenue, as will seeking higher-value multi-products from the biomass resource. Future opportunities for biomass include development of bio-refineries, atmospheric carbon "scrubbing" and the growing trend towards small-scale, distributed energy systems leading towards a hydrogen economy.

Introduction

The use of biomass to produce bioenergy in order to provide a wide range of energy services (heat, light, comfort, entertainment, information, mobility, etc.), and to produce biomaterials as substitutes for those presently manufactured from petro-chemicals, is an integrating response to a number of global problems. These include equity, development, energy supply security, rural employment, and climate change mitigation. Biomass provides fuel flexibility to match a wide range of energy demands and is a renewable energy source that can be stored, which is an advantage over other forms of renewable energy. It has been identified by the European Union (EU) as a significant contributor to the 12% renewable energy target and to its ambitious goal of substituting 20% of road transport fuels with alternatives, including biofuels by 2020.

Currently, solid biomass represents 45% of primary renewable energy in OECD countries (IEA, 2002). Globally nearly 84 TWh (terawatt-hours) of electricity were generated from biomass in 2000, half being in the United States, 11.3 TWh in Japan and 8.5 TWh in Finland. Growth has been around 2.5% per year. A further 565 PJ (petajoules) of heat (including co-generation), 245 PJ of gaseous energy from biomass and 227 PJ of biofuels were also produced worldwide in 2000.

1. Massey University, Palmerston North, New Zealand.

The term “biomass” relating to agriculture and as discussed in this paper includes:

- crop residues (*e.g.* cereal straw, rice husks and bagasse for co-generation);
- animal wastes (*e.g.* anaerobic digestion to produce biogas or inter-esterification of tallow to give biodiesel);
- woodlot arisings (*e.g.* from agro-forestry and farm woodland silviculture after log extraction, and used mainly for heating); and
- energy crops (*e.g.* vegetable oil crops to produce biodiesel, or sugarcane, beet, maize and sweet sorghum for bioethanol, or miscanthus and short rotation coppice for heat and electricity generation).

Other non-agricultural sources of biomass such as municipal solid waste, landfill gas, large-scale forest arisings, wood process residues, and sewage gas are not considered here.

In developing countries, traditional biomass remains the main source of energy. Several countries, particularly in Africa (*e.g.* Kenya) and Asia (*e.g.* Nepal), derive over 90% of their primary energy supply from traditional biomass. In India and China it provides 45% and 30% respectively. A report from the World Bank (1996) concluded that energy policy makers in developing countries will need to be more concerned about the supply and use of biomass and should support methods for using it efficiently and sustainably. It is now better recognised that promising modern commercial biomass projects can provide opportunities for rural industries and rural employment (Hall and Rosillo-Calle, 1998). The technical transfer of modern bioenergy technologies to developing countries will be encouraged by the Clean Development Mechanism (CDM), but it will remain a challenge to implement them successfully. Where this has occurred it has led to better and more efficient utilisation of biomass that, in many instances, complements the use of traditional fuels. For example, liquid fuel produced from corn husks in China by a small-scale Fischer-Tropsch process is used for traditional cooking (Larson and Jin, 1999) but the electricity co-product can also be generated by passing unconverted syn-gas through a combined cycle gas turbine.

Wealthier OECD countries, such as Sweden, the United States, Canada, Austria and Finland, better appreciate the benefits of biomass and are already using it widely to displace fossil fuels. Currently in the US, for example, agricultural and forest product residues are utilised in hundreds of heat and power plants totalling almost 10 GW (gigawatts) of installed capacity, the largest being the 54 MW_{th} (megawatt thermal) McNeil generating station in Vermont (Moomaw *et al*., 1999) and in Sweden over 90 PJ/year of imported oil equivalent is displaced with biomass (SVEBIO, 1998).

Calculations of the available biomass resource have been made in many regions. A range of mature conversion technologies exist which can be matched to the local resource characteristics, including combustion for dry material, anaerobic digestion for wet material, and inter-esterification and fermentation of oils and sugars to produce liquid biofuels. Several less mature technologies are still being demonstrated but are considered to be close to full commercialisation (such as gasification). Others, such as pyrolysis, enzymatic hydrolysis, bio-refining of chemicals, production of biomaterials and hydrogen production, show promise but are still at the pilot-plant stage of development.

Taking a proposed bioenergy project through the contractual and consenting processes that are needed to reach commercial reality can be a major challenge, even if based on a mature and well-proven technology. Issues to be resolved include land availability, transporting large volumes of biomass, environmental impact consents, controlling emissions, producing energy crops sustainably,

recycling nutrients, minimising water demand, energy input/output ratios, employment opportunities, the growing public resistance towards monoculture cropping and the use of woody biomass (even if from managed plantation forests), perceived threats to indigenous forests, emissions and economic competition from cheap fossil fuels. When taking all of these into account and when attempting to obtain long-term fuel supply contracts, then the *socio-economic potential* for biomass becomes a lot lower than its technical potential, which is based purely on simple resource analysis (IPCC, 2001). This overview paper will discuss these issues and identify some exciting future opportunities for biomass.

Carbon mitigation

Climate change is now generally accepted as a serious global problem and the world is waiting for the Kyoto Protocol to come into force as the first small step towards solving it. The likelihood of Russia ratifying it to ensure this occurs seems, at the time of writing (mid-May 2003), slightly greater than the possibility that it will not (Pachauri, 2003). Once in force, the Protocol will become a key driver for governments, local authorities, industries and communities to move towards a world with reduced dependence on fossil fuels. More sustainable methods of food and fibre production, including reducing the direct and indirect energy inputs, will also become an international goal.

Biomass will have an increasing role to play as a result of carbon trading activities. It may receive carbon offset credits from displacing fossil fuels; earn carbon sink credits from biological carbon sequestration; or enable physical sequestration of atmospheric carbon to occur by capturing carbon dioxide after biomass combustion and transporting it to permanent geological stores (Read, 2003). Overall, bioenergy projects, if carefully planned and managed, can be carbon neutral, although there are circumstances where fossil fuel based energy inputs for growing, harvesting, transporting and processing large volumes of the biomass feedstock can exceed the bioenergy outputs obtained.

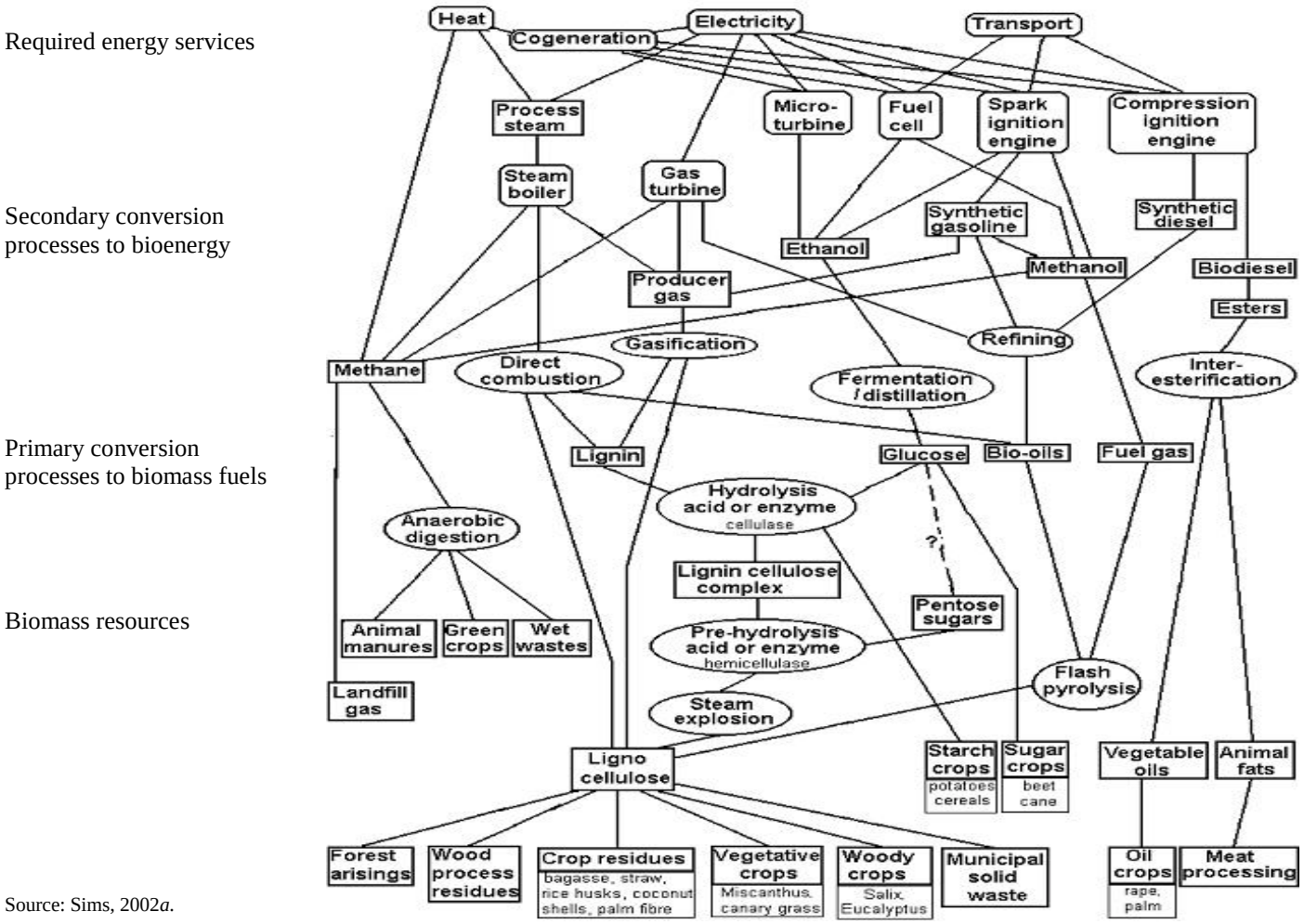
Biomass projects will be included in the CDM of the Kyoto Protocol. Special fast-track procedures to allow small projects (<15 MW) to keep the transaction costs low will help to encourage their uptake. In developing countries, where traditional biomass (firewood and dung) continues to be the major energy source, cultural acceptance and understanding of modern biomass production and conversion technologies may be easier to achieve than for other renewable energy sources (Wilkins, 2002). OECD countries must first increase their successful use of biomass domestically in order to demonstrate to governments of developing countries its reliability, environmental acceptance, social benefits, and economic feasibility. The development of joint implementation bioenergy projects would certainly give them increased credibility when negotiating to build similar bioenergy plants in non-Annex 1 countries under the CDM.

The biomass resource

The annual global primary production of biomass is 220 billion oven dry tonnes (odt), or 4 500 EJ (exajoules) of solar energy captured each year. From this, an annual bioenergy market of 270 EJ could be possible on a sustainable basis (Hall and Rosillo-Calle, 1998). The challenge is to sustainably manage the resource, its conversion and the delivery of bioenergy to the market place in the form of modern and competitive energy services.

The agricultural biomass resource available arises from a wide range of sources. These can be classified into crop residues, animal wastes, woodland residues, food and fibre processing by-products and purpose grown energy crops. A large number of conversion routes to provide useful bioenergy products and services have been demonstrated (Figure 1). Most have reached the commercial stage where under certain conditions their economic viability can compete with fossil fuel use (though often requiring government support mechanisms to do so).

Figure 1. Biomass resources and conversion routes available to produce bioenergy products and services



Source: Sims, 2002*a*.

Biomass can also provide a renewable source of hydrogen and a wide range of bio-materials and chemical feedstocks (Chisholm, 1994). In essence, all products that currently result from the processing of petro-chemicals can, in theory, be produced from biomass feedstocks. These include lubricants, polymers, high matrix composites, textiles, biodegradable plastics, paints, adhesives, thickeners, stabilisers, and a range of cellulosics.

Agricultural residues and wastes

Wastes arising from agricultural production or farm woodlots often have a disposal cost. Therefore their conversion from waste-to-energy has good economic and market potential, particularly in rural community applications (Hall and Rosillo-Calle, 1998). A significant portion of this waste resource is already utilised for energy purposes, but being the waste products of other processes, the supply is finite. It is also under possible threat from improved waste minimisation practices. Energy crops can be grown to supplement this limited resource but they have higher delivered energy costs (in terms of USD/GJ) compared with fossil fuels.

Large quantities of crop residues are produced annually worldwide and often dumped. These include rice husks, bagasse, maize cobs, coconut husks (copra), groundnut and other nut shells, sawdust, and cereal straw. Rice husks and bagasse are usually accumulated in large volumes at one site. These wastes tend to be relatively low in moisture content (10-30% moisture content, wet basis [mcwb]) and are more suited to direct combustion than to anaerobic digestion which, in turn, is better suited to wet wastes such as animal manure, meat cuttings or reject fruit.

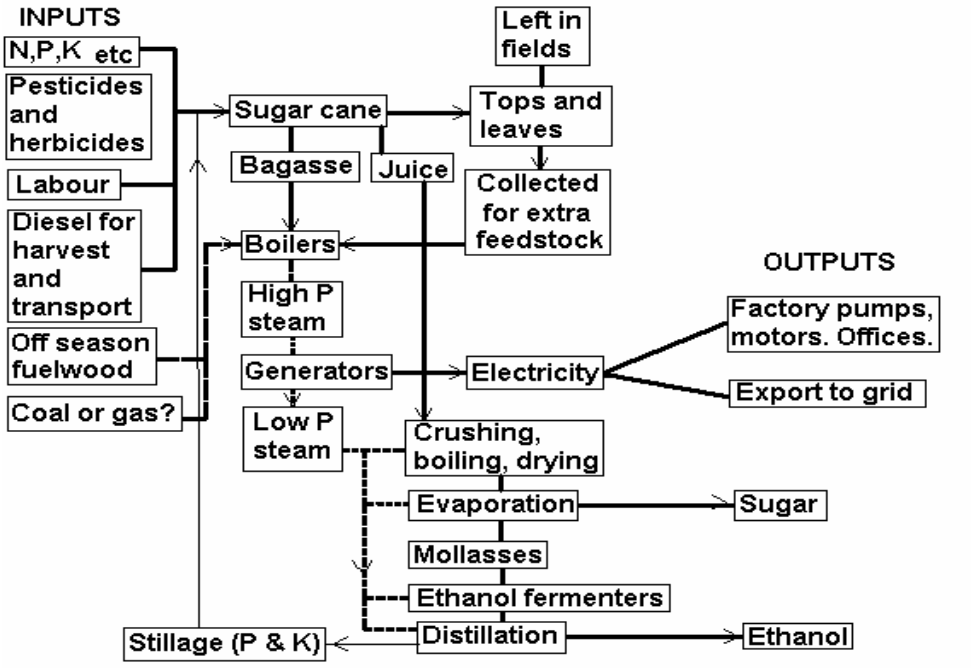
Rice husks are among the commonest agricultural residue. They make up 20-25% of the harvested rice grains on a weight basis and are usually separated out at the processing centre. Indonesia alone, for example, produces around 8 Mt (millions of tonnes) per year. The husks have a relatively high silica content that, on combustion, can cause an ash problem and possible slagging within the boiler. However, their homogeneous nature lends this biomass resource to more efficient conversion technologies, such as gasification, that require a uniform fuel quality for best results. Several commercial conversion plants exist.

Bagasse

Sugarcane is a C4 plant with a better photosynthetic efficiency than the more common C3 plants and it requires fewer inputs of pesticides and herbicides. Whether or not it is grown on a truly sustainable basis is debatable, as nutrients need to be added to replace those removed with the crop. However, if the stillage or effluent from the crushing and distillation process and the ash from the combustion of the bagasse (the residual fibre left after sugar extraction with an energy content of around 10 MJ [megajoules]/kg) were to be returned to the fields (particularly when the cane trash is also removed for biomass), then only nitrogen would be in deficit.

The flow of materials and energy in the sugarcane processing industry are worth highlighting with regard to potential bioenergy supplies as co-products (Figure 2) in the form of heat, power or bioethanol production, as in Brazil. Sugarcane factories have many decades of logistical experience in transporting and handling large bulky volumes of biomass, typically around 300 000 tonnes/year. Each fresh tonne of sugarcane brought into the factory for processing yields around 250 kg of bagasse. Since there are such large volumes to dispose of, historically sugar companies tend to “waste it efficiently” by burning it in large, inefficient boilers. They use only a portion, however, of the available bioenergy to produce heat for raising steam to “cook” the cane and extract the sugar, in addition to possibly generating around 2-3 MW of electricity for use on-site. This is a cheap form of disposal and avoids accumulation of surplus material. Any agricultural region that grows sugarcane therefore has a significant biomass energy resource available, already collected and delivered to the processing plant (in effect, free-on-site).

Figure 2. Energy and material flows during the sugarcane production and processing operation



Source: Sims, 2002*a*.

Where privatisation of the electricity industry has occurred, some sugar companies have become independent power producers (often in joint ventures with their local utilities). They now combust all their bagasse in efficient co-generation plants and export significant quantities of surplus power to the grid. Operational and contractual difficulties from generating power during the 6 to 7-month cane-crushing season only were solved by using forest or municipal solid green wastes in the non-crushing season. The potential to develop a new business from generating 20-30 MW_e (MW power electricity) all year round has been realised. Bagasse combustion, in association with collecting and using the cane trash, could provide biomass fuel for up to 50 GW of generating capacity worldwide.

The growing links between the electricity and the sugar industries will lead to different sugarcane management practices and the need for partnerships and third party investments in capital plants. A power generating company has to consider the risk that the sugar industry is not always buoyant and that a sugar company it partners with in a new co-generation development may not survive the whole term of the project.

Cereal straw

Small cereal crops produce around 2.5 to 5 tonnes/ha of straw depending on crop type, variety and the growing season. Maize and sorghum stover is higher yielding. These residues range from 10-40% mcwb and have a heating value between 10-16 MJ/kg. In terms of comparative gross energy values, one tonne of straw approximately equates to 0.5 tonne of coal or 0.3 tonne of oil. It has a high silica content leading to ash contents of up to 10% by weight.

The utilisation of straw for energy purposes has increased, following a ban on burning in the fields after harvest. Denmark has thousands of straw-burning facilities for district heating (3-5 MW), industrial processing (1-2 MW), and domestic heating (10-100 kW [kilowatt]) purposes. At the on-farm scale, it can be utilised for grain drying or heating animal houses as well as supplying dwellings with space and water heating.

If straw is assumed to have zero economic value and the costs of collection are around EUR 30/tonne for raking, baling, *etc*., then large round or square bales would be around EUR 3/GJ. Cartage of 25 kms to a central conversion plant site would add another EUR 4-6/GJ. Conversion of straw to electricity would therefore cost around EUR 7-10 c/kWh (grams of carbon released/kWh of electricity generated) (electricity costs as cents per kWh), which is viable only in OECD countries where wholesale power prices are relatively high. Direct combustion of the straw for process heat in nearby applications (such as barley malting plants) may be more viable except where cheap coal or natural gas are available.

A range of straw pellets and wafers with a greater mass density than bales have been produced in an attempt to reduce transport costs and enable automatic feeding to occur, particularly at the domestic scale (10-30 kW heat output). Many specialised pellet burners are on the market but the cost of the total system is relatively high. The pellets can be delivered in bulk by small trucks to the dwelling or small business as required. Pellets are also made from sawdust as no comminution is required and they are easy to manufacture. A large number of pellet stove manufacturing businesses have been established, mainly in Canada, Austria, and Scandinavia, and the pellets are being exported in growing volumes.

Animal wastes

Pig manure, cattle manure and chicken litter are useful biomass sources because these animals are often reared in confined areas, which produces a considerable concentration of organic matter. In the past, many of these animal wastes have been recovered and sold as fertiliser or simply spread back onto agricultural land. However, the introduction of tighter environmental controls on odour and water pollution means that better forms of waste management are now required. This provides incentives to consider anaerobic digestion of the material, but the annual supply volume, seasonal variations and specific characteristics of the resource should be carefully assessed before developing a plant.

Energy cropping

Growing energy crops is a non-traditional land use option which may boost farm incomes and the rural economy in general (Askew and Holmes, 2001). A number of annual and perennial species convert solar energy into stored biomass relatively efficiently. High-yielding vegetative grasses, short rotation forest crops, and C4 crop plants grown on a commercial scale can produce over 400 GJ/ha/year under good growing conditions, leading to positive input/output energy balances for the overall system. Correct species selection to meet specific soil and climatic site conditions can result in even higher energy yields (Sims *et al*., 1999). To exemplify what can be achieved as a result of traditional species selection, the average saccharose yield of sugarcane grown in Brazil for bioethanol production increased by 10% to 143 kg/tonne of fresh cane (70% mcwb) between 1990 and 2001.

The future role for “Designer Biomass” by developing suitable genetically modified crops cannot be ignored. Certainly the possibility of genetically modified organisms entering the environment without full and proper evaluation is of considerable concern. However, genetic modification does indeed hold great promise. Imagine having several attractive, high-yielding C4 plants which have

nitrogen fixing ability, consume relatively little water, are easy to harvest, and can be grown extensively to produce protein, carbohydrates, fibres and lignin which can all be processed through a "bio-refinery" into a range of industrial, edible and energy products. The issues of sustainable production, biodiversity and monocultures would still need to be carefully considered.

Agricultural grants and subsidies continue to be a major cost item of the EU budget under the Common Agricultural Policy and many energy crop producers have received considerable benefit as a result. Growers of oilseed rape for biodiesel in Europe and of maize and other cereals in the US for ethanol depend upon continued government support as the crops are costly to grow and are prone to commodity price fluctuations. For example, the costs of growing and producing biofuels in terms of USD/GJ can be more than double the ex-refinery cost of petrol and diesel, even where the crop energy yield is high in terms of GJ/ha/year. However, trade reforms and continuing pressure to reduce subsidies which serve to encourage excess food and fibre production means that in the future there can be no guarantees that agricultural support mechanisms will remain at their current levels. So bioenergy from energy crops may need to compete with fossil fuels on its own merits. Future carbon mitigation credits will help.

A high gross margin is necessary to attract growers to change from traditional land uses, but this increases the relative price of the biomass when delivered to the conversion plant. Conversely, plant operators want feedstock delivered as cheaply as possible to compete with low-priced fossil fuels. Recognising the carbon sink and carbon offset values from producing and using the energy crops may enable the goals of both growers and plant operators to be met.

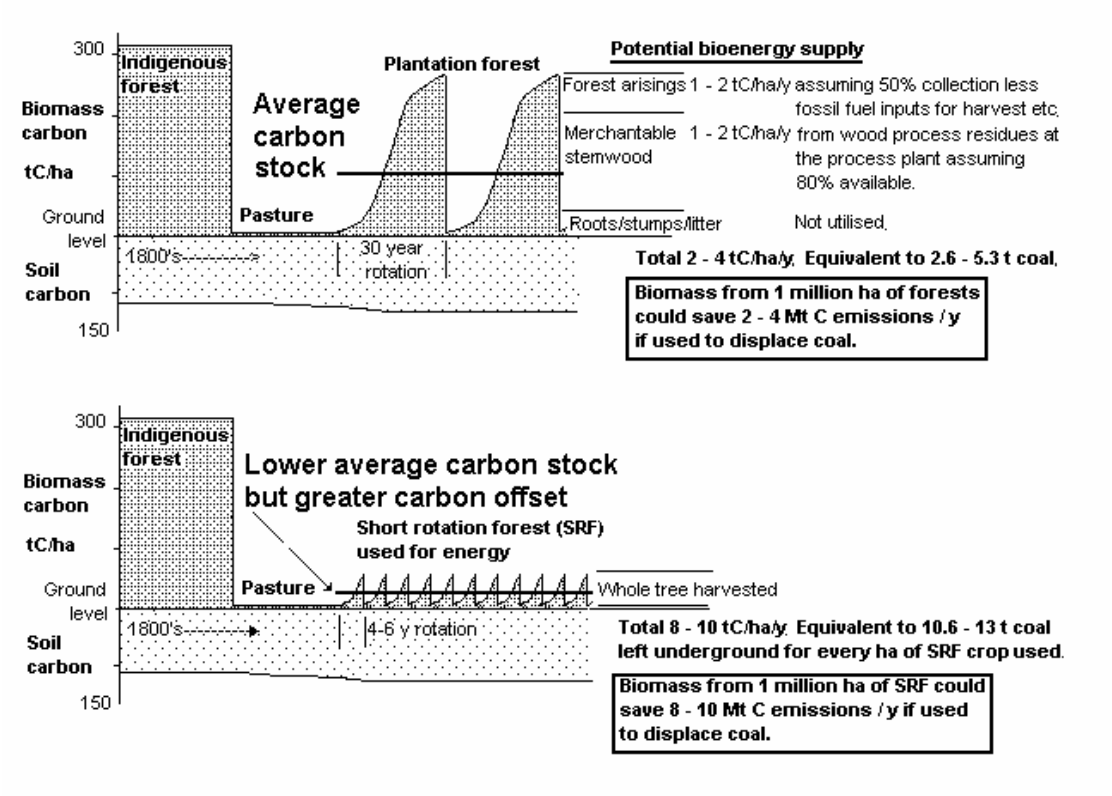
All forms of bioenergy, when substituted for fossil fuels, will directly reduce CO_2 emissions. Therefore, a combination of energy crop production with carbon sink and offset credits can result in maximum benefits from carbon mitigation strategies. This can be achieved by planting energy crops such as short rotation eucalyptus, miscanthus or reed canary grass into previously arable or pasture land, which will lead to an increase in the average carbon stock on that land, while also yielding a source of biomass (Figure 3). Utilising the accumulated carbon in the biofuels for energy purposes, and hence recycling it, alleviates the critical issue of maintaining the biotic carbon stocks over time, as is the case for a permanent forest. Increased levels of soil carbon may also result from growing perennial energy crops but the data are uncertain and further research including detailed life-cycle assessments is needed for specific crops grown in various regions.

Land availability

Large-scale production of energy crops in future must not compete for land needed for food and fibre production. Careful calculations have been made to ensure there is enough suitable land available to provide the world's population with all its needs for food, fibre and energy throughout this century (Hall and Scrase, 1998). (Equitable distribution of these basic necessities is another issue yet to be resolved.) In some regions, the availability of water will be the constraining factor to growing energy crops rather than available land.

The global land area thought to be available for biomass production by 2050 is shown in Table 1. Of the 2.495 giga hectares (Gha) of total land area with crop production potential, 0.897 Gha was cultivated for food and fibre production in 1990. The increasing world population will require an additional 0.416 Gha by 2050, leaving 1.28 Gha available for growing energy crops. The technical potential of producing biomass from energy crops grown on this available land is 396 EJ/year based on current yield data and known water supplies. By 2100, the global land requirement for food and fibre production is estimated to reach about 1.7 Gha, with a further 0.69-1.35 Gha needed to support future biomass energy requirements in order to meet a high-growth energy scenario. This exceeds the 2.495 Gha total cropping land available, so land-use conflicts could arise.

Figure 3. Carbon stocks in the biomass and top soil on a one-hectare plot of land with land-use changes over time from indigenous forest to pasture, to plantation forest or short rotation forests



Source: 2002*b*.

Bioenergy conversion

Combustion is well proven from 1 kW to 100 MW, but is relatively inefficient when linked with power generation from steam turbines. New conversion technologies show promise but there are no international industry standards or consumer tests for developers to select which specific plant to purchase. Decisions are often based solely on the hearsay of experienced operators of other similar plants even though there are usually local variations in the biomass feedstocks used which have to be taken into account when determining plant design, handling and storage facilities.

Gasification

Development of efficient biomass integrated gasification combined cycle (BIGCC) plants using gas turbines is approaching commercial realisation, particularly for woody biomass and bagasse feedstocks. Several pilot and demonstration projects have been evaluated with varying degrees of success. BIGCC technology has good potential at the 10-75 MW_e range, with economies of scale and improvements in generation efficiency occurring at the top end (Overend, 2000). However, the low heat value gas usually requires modification of the turbines. Alternatively, oxygen blown gasification systems produce a more suitable higher quality gas of 15-20 MJ/Nm^3 (megajoules per cubic metre natural pressure).

Table 1. Projection of technical energy potential from energy crops grown by 2050

Region	Population in 2050	Total land with crop production potential	Cultivated land in 1990	Additional cultivated land required in 2050	Available area for biomass production in 2050	Maximum additional amount of energy from biomass[a]
	billion	Gha	Gha	Gha	Gha	EJ/year
Industrialised[b]	-	0.820	0.670	0.050	0.100	30
Latin America						
Central and Caribbean	0.286	0.087	0.037	0.015	0.035	11
South America	0.524	0.865	0.153	0.082	0.630	189
Africa	0.698	0.251	0.063	0.068	0.120	36
Eastern						
Middle	0.284	0.383	0.043	0.052	0.288	86
Northern	0.317	0.104	0.04	0.014	0.050	15
Southern	0.106	0.044	0.016	0.012	0.016	5
Western	0.639	0.196	0.090	0.096	0.010	3
China[c]	-	-	-	-	-	2
Western	0.387	0.042	0.037	0.010	-0.005	0
South – Central	2.521	0.200	0.205	0.021	-0.026	0
Eastern	1.722	0.175	0.131	0.008	0.036	11
South – East	0.812	0.148	0.082	0.038	0.028	8
Total for all regions	8.296	2.495	0.897	0.416	1.28	396
TOTAL BIOMASS ENERGY POTENTIAL, EJ/year						**441**[d]

Notes:
a Assumed 15 odt/ha/year and 20GJ/odt.
b OECD and Economies in Transition.
c For China, the numbers are projected values from D'Apote (1998) and not maximum estimates.
d Includes 45 EJ/year of current traditional biomass.
Source: IPCC, 2001, derived from Fischer and Heilig, (1998); D'Apote, (1998); IIASA/WEC, (1998).

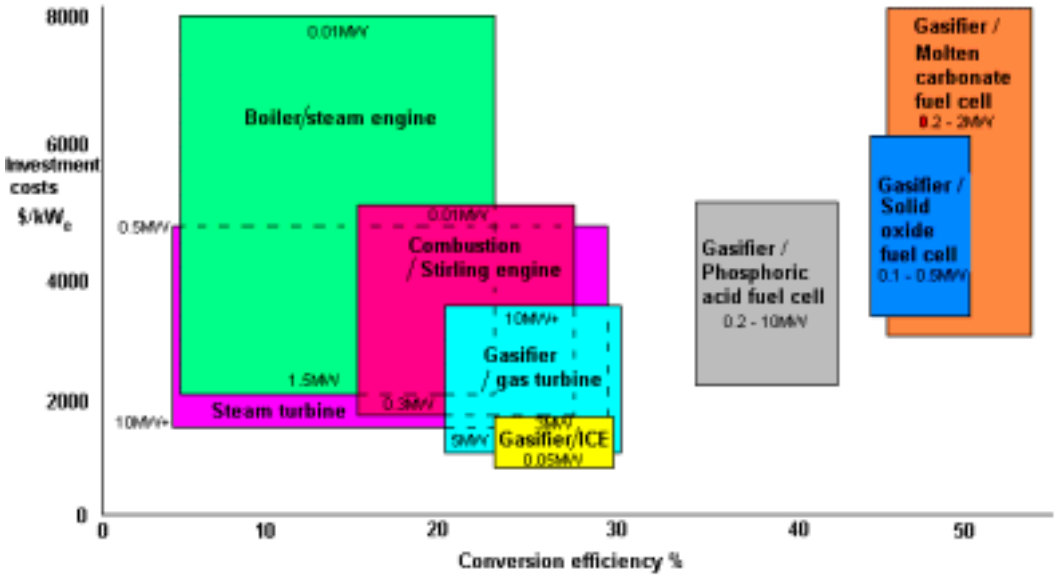
Biomass resources are generally easier to gasify than coal at both the large and small scale and the process is well understood (Gigler *et al.*, 2001). Development of 10-30 MW_e efficient BIGCC systems is nearing commercial realisation, although gas cleaning problems still remain. Several pilot and demonstration projects have been evaluated with varying degrees of success (see, for example, Stahl and Neergaard, 1998; Irving, 1999; Lundberg *et al.*, 1998; Pitcher *et al.*, 2002). Capital investment for a high pressure, direct gasification, combined cycle power plant of this scale was anticipated to fall from the present USD 2 000/kW to around USD 1 100/kW by 2030, as a result of plant manufacturing and installation experience. Total operating costs (including supplying the biomass fuel) will also decline from 3.98c/kWh to 3.12c/kWh (EPRI/DOE, 1997). By way of comparison, capital costs for traditional combustion boiler/steam turbine technology were also predicted to fall from USD 1 965/kW to USD 1 100/kW in the same period, with the operating costs of 5.50c/kWh lowering to 3.87c/kWh (reflecting the poor fuel efficiency compared with gasification).

A Swedish TPS atmospheric circulating fluidised bed gasifier using hot gas cleaning was successfully tested using a range of fuels including short rotation *Salix*. The English 10 MW_e ARBRE project, supported by a 15-year NFFO (non fossil fuel obligation) contract, went into liquidation when nearing completion. The ALSTOM turbine was run successfully for short periods but the problems of gas clean-up, feed handling and the evaporator cooler had not been fully resolved (Pitcher *et al.*, 2002). These technologies were in the process of being upgraded by Kelda, the developer, when the plant was sold to Energy Power Resources Ltd (along with other projects) which decided to terminate the project. Capital costs of the plant were high at around USD 2 700/kW, but it was anticipated this would be halved with further project experience.

A review of combined heat and power technologies at the smaller 2-3 MW_e scale more suited for rural community use (Gigler *et al.*, 2001) confirmed the inefficiency of steam turbines compared with other technologies. Emerging small-scale, distributed bioenergy power technologies have a wide range of claimed manufacturing costs and efficiencies as shown by the ranges given in Figure 4. The typical range of investment costs for a single plant is shown for each technology. Using several modular devices in parallel enables a greater capacity to be achieved. Many of these technologies are at the prototype or demonstration stage but once demand increases and mass production occurs, then the investment costs could well decline.

Small-scale biomass systems show good potential to become significant contributors to distributed energy systems and a possible source of "green" hydrogen for use in fuel cells. Increased integration of bioenergy with other distributed energy resources such as wind and solar could further enhance technology improvement in this sector, but the environmental impacts from use of such small-scale systems is not clear. For example, gasification in poorly designed down-draft plants can lead to the formation of carcinogenic condensates that would need careful disposal.

Figure 4. Investment cost and conversion efficiency ranges based on manufacturers' claims for a selection of small (<10 MW) capacity bioenergy conversion devices and hydrogen or methane-powered fuel cells suitable for on-farm or rural community use and compared with a gasifier/internal combustion engine (ICE)



Note: $/kWe are New Zealand dollars: NZD 1 = EUR 0.50 approximately.
Source: Gigler *et al.*, 2001.

Co-firing of biomass

Combustion of woody biomass is common when blended with pulverised coal at up to 10-15% of the fuel-mix based on total thermal input. Several studies, however, have shown co-firing to be uneconomic due to the very cheap coal price compared with growing, harvesting, storing, and delivering the biomass, plus the additional combustion plant feed conveyors and conversion costs (Sulilatu, 1998). However, major environmental benefits can result, including the reduction of SO_2 and NO_x emissions, as was demonstrated when operating a small 350 kW_t bubbling fluidised bed plant (van Doorn *et al.*, 1996). In this study, various blends of both anthracite and bituminous coals were mixed with hardwood chips and co-combusted. For all blends, emissions of CO_2, NO_x and SO_2 were reduced significantly, decreasing as the blend of wood fuel was increased by volume in steps from 10% to 100%.

Crop residues, woody biomass and vegetative grasses can also be used successfully when co-combusted with coal or natural gas in appropriately designed conversion plants (Nuusbaumer, 2002). Although co-firing is well understood the plant may require specialist feedstock and ash handling equipment and the ash may contain heavy metals from the coal and preclude its use in fertilisers. Where biomass fuel is free on-site and has a negative disposal cost, or environmental benefits are factored into the economic analysis, it is likely that co-firing will be viable, even with low fossil fuel prices. Under these conditions, in the US alone co-firing of biomass has the potential to generate 10-20 GWh of electricity by 2015 (EPRI/DOE, 1997).

Anaerobic digestion

There have been few, if any, significant technological developments in anaerobic digestion for either small-scale plants suitable for on-farm use, or at the larger scale requiring up to 500 m^3 feedstock per day. Several of the large centralised biogas plants in Denmark have been closely monitored and technical problems have not been uncommon (Lindboe, 1995). A gas production level of 30-35 m^3 per m^3 of feedstock is necessary for economic viability but it is not always achieved. Nevertheless, over 25 plants continue to operate in Denmark.

India and China are both moving away from traditional small-scale family biogas plants to the more efficient community and industrial scales, assisted by financial incentives, technology advances, their dissemination, and training of operating personnel (Hall and Scrase, 1998).

Transport biofuels

Transport fuel production from biomass is technically feasible, and liquid and gaseous biofuels can be derived from a range of biomass sources. For example, biomethanol, bioethanol, di-methyl esters, pyrolytic oil, and biodiesel can all be produced from a variety of energy crops. Bioethanol production using sugarcane fermentation techniques has been commercially undertaken in Brazil since the 1980s (Moreira and Goldemberg, 1999). Production from maize and other cereals has occurred in several US states for over a decade. Ethanol can be used as a straight fuel, as an oxygenate, or blended with petrol at up to 26% by volume, as in Brazil. In the US, anhydrous bioethanol is used as a 10% blend to reduce ozone emissions and replace the octane enhancer, methyl tertiary butyl ether (MTBE) which has possible carcinogenic properties. Ethyl tertiary butyl ether (ETBE) production from bioethanol has a promising market in Europe, but the production costs for hydrolysing cereals or sweet sorghum crops, followed by fermentation of the sugars remain high (Grassi, 1998). The process of enzymatic hydrolysis of ligno-cellulosic feedstocks such as bagasse, rice husks, municipal green waste, wood and straw (EPRI/DOE, 1997) has been evaluated in a 1t/day pilot plant at the National Renewable Energy Laboratory in Golden, Colorado. The project successfully reached the commercial

scale-up phase (Overend and Costello, 1998) and several companies, such as the Canadian IOGEN Corporation, supported by Shell, have since made substantial investments. A wide range of bacteria and fungi actinomytes and their genetic manipulation are also being investigated but all have found only limited commercial success to date (Sims, 2002*a*).

The cost of producing biofuels from crops usually far exceeds the current price of diesel or petrol due mainly to the high cost of growing the crops, even if grown on set-aside land. In Brazil, the production of dedicated ethanol-fuelled cars running on 95% ethanol/5% water produced from sugarcane fermentation achieved 96% market share in 1985, but declined to 3.1% in 1995 and to 0.1% in 1998. Meanwhile, the Brazilian government approved a 26% blend level in petrol and hence the production of bioethanol continued to increase, achieving a peak of 15 300m^3 in the 1997/98 sugarcane harvesting season. This represented 42.73% of the total fuel consumption in all Brazilian Otto cycle engines, giving an annual net carbon emission abatement of 11% of the national total from the use of fossil fuels (IPCC, 2001).

Research into producing biomethanol from woody biomass continues and several different processes have been evaluated (Adams and Sims, 2002). Successful conversion of around 50% of the original chemical energy stored in the biomass to methanol has been obtained in the US at a cost estimate of around USD 0.90 per litre of methanol (USD 34/GJ) (Saller *et al.*, 1998). In Sweden, production of methanol from either short rotation *Salix* or forest residues was estimated to cost only USD 0.22/litre, whereas bioethanol would cost USD 0.54/litre (Elam *et al.*, 1994). At these costs, using woody biomass feedstocks for heat and power generation would be a preferable alternative (Rosa and Ribeiro, 1998). In addition, since the volumetric energy density (MJ/l) of biomethanol is around 50% that of petrol and bioethanol around 65%, then larger storage tanks would be needed to give the same vehicle range between refills. By comparison, biodiesel has an energy content around 90% of standard mineral diesel.

Commercial biodiesel processing plants have been constructed in France, Germany, Italy, Austria, Slovakia, and the US (CEC, 2001) and many small-scale plants also exist (BDA, 2002). Around 1.5 million tonnes are produced each year with the largest plant having a capacity of 120 000 tonnes/year. A compression ignition engine needs no modification to run efficiently on biodiesel either as a neat fuel or blended with mineral diesel. National biodiesel fuel standards are in place in Germany and many engine manufacturers such as Volkswagen now maintain existing warranties when biodiesel is used (Schindlbauer, 1995; BABFO, 2002). Environmental benefits from running biodiesel rather than mineral diesel in the same engine include a 99% reduction of sulphur oxide emissions, a reduction in greenhouse gas emissions of at least 3.2 kg of CO_2 per kg of biodiesel, a 39% reduction in particulate matter, and a high level of biodegradability (Korbitz, 1998).

A positive energy ratio was claimed in that each energy unit from the fossil fuel inputs to produce the biodiesel from an oilseed rape crop gave 3.2 biodiesel energy units (Korbitz, 1998). Conversely other older studies suggest more energy is consumed during the process than is produced (Ulgiati *et al.*, 1994). The differences in the two analyses between the oilseed crop grown, the oil yield obtained, and the assumed method of production and processing are the reasons for this discrepancy, so further life-cycle analyses are required.

Due to the low oil yields and relatively high production costs, biodiesel has only been commercially implemented in countries and states where significant government incentives exist. Biodiesel production from purpose-grown oilseed crops exceeds the ex-refinery costs of mineral diesel by a factor of three or four. This is mainly due to the high costs of crop production, even when grown in the US or Europe on set-aside land receiving additional farm subsidies (Venendal *et al.*, 1997). Production is unlikely to become more cost effective for several years (Scharmer, 1998). However, modified pressurised continuous production facilities, such as that at Zistersdorf, Vienna (Gapes,

2002), which processes 40 000 tonnes/year, could help drive production costs down. The use as feedstock of inedible tallow, a by-product from the meat industry, would be a cheaper proposition (Calais and Sims, 2000).

Increasing the oil yield per hectare would also bring down costs. Energy yields from oilseed crops grown under temperate climatic conditions tend to be only around 1 500-2 000 litres of oil per ha, so production costs per litre are relatively high. These energy yields of around 60-80 GJ/ha/year are low compared with growing short rotation forests or starch/sugar crops on the same land which can produce 300-400 GJ/ha/year. This, together with the poor energy ratios of some systems, led the US National Research Council to advise against any further research investment (NRC, 1999).

Most transport biofuels, other than perhaps those produced from waste by-products from other processes, will likely become competitive with cheap mineral oil products if significant government support is provided by way of fuel tax exemptions or subsidies (such as when using set-aside land to grow energy crops), or if additional values are placed on the resulting environmental benefits. New biomass developments such as growing specialist energy crops, producing transport biofuels and designing small-scale distributed generation systems will often require some form of government mechanism or subsidy to incentivise the implementation of such innovative projects. The expectation is that they will become fully commercial over time as they follow down the standard experience curve. This will also be the case should biomass be used as a renewable source of hydrogen in the future (Dalta *et al.*, 2002; Maniatis, 2003).

Biomass project contracts

A bioenergy project developer will need to secure a fuel supply over a term of 10-20 years if the project investment risk is to be reduced. For plants depending on energy crops as feedstocks this will often be challenging as landowners are not used to fulfilling such long-term contracts. The British Project ARBRE successfully achieved contracting over 2000 ha of coppice willow for 15 years but it needed considerable effort to convince the growers. (After the liquidation of the project in July 2002, the farmers have since formed their own company, “Renewable Energy Growers” to supply the new US plant owners, Biodevelopment International). Securing crop or process residues over this long period may also be a challenge since crop rotations and processes change over time, which may affect the total annual residual biomass volume available. In addition other competing markets for the biomass material may eventuate (for example biomaterials, composting mulch, building panels) so that the existing “waste” product then has a higher value.

Developing a bioenergy project often proves more difficult to achieve than when developing a new wind farm or small hydro scheme of similar capacity. For example, a co-generation plant recently constructed at a sugar mill in New South Wales, Australia, using bagasse in the 7-month cane-crushing season and municipal green waste in the 5- month off-season, required four fuel supply contracts and several other contracts and agreements to be negotiated (Coombes, 2002). These included a power purchase agreement, electrical connection provision contract, steam sales contract, water supply contracts, five joint venture agreements with plant manufacturers, financing information memoranda, finance agreements, site leases, site sub-divisions, fuel supply and transmission easements, grid connection agreements, a development consent licence, operating licence, asset management agreement, and an operation and maintenance agreement. It may be easier to obtain project closure in less regulated countries, but the time and effort required should not be under-estimated.

Resource consenting process

The time and costs involved in obtaining resource consents to operate and supply a bioenergy plant can be very expensive for a developer since often the objections are numerous and the process is lengthy. To reduce this cost and to enable the biomass industry to expand responsibly in the United Kingdom, British Biogen (the industry association) jointly developed a series of planning "Good Practice Guidelines" based on a consensus procedure with all stakeholders. Three were produced [short rotation crops (ETSU, 1996), anaerobic digestion (ETSU, 1997), and forest wood products (ETSU, 1998)] by what proved to be a very successful approach. It included planners, developers, equipment manufacturers, researchers and environmental groups working together over a 4 to 6-month period. Initially they all met for a one-day meeting to outline the issues; a sub-group was formed to prepare a draft assisted by a facilitator; the draft was circulated several times for comment and amendment; and a final meeting held at which consensus was reached on all issues. The documents are now a useful tool for developers to use to shorten the consents process as many of the concerns expressed by individual local authorities will have already been agreed by all stakeholders.

Specific re-occurring issues such as emissions resulting from biomass combustion (especially dioxins from municipal solid waste) need further research studies to determine the extent of the problem and enable comparisons to be made with other sources. Atmospheric emissions are also a source of debate for transport biofuels and further analysis is required.

Transporting the biomass

A key part of a biomass system involves delivering the material to the energy conversion plant or biomaterial processing plant as cheaply as possible. The supply chain link between biomass resource and bioenergy plant is shown in Figure 5. The interactions between biomass moisture content, dry matter loss, bulk density, delivered energy content, drying rate, storage location and period, distance between resource and plant, and truck payload constraints are complex but need to be evaluated in order to deliver the material cheaply and efficiently.

The importance of this interaction is illustrated by a 40 m^3-capacity, high-sided truck and trailer unit but with a 26-tonne maximum payload. When used for carrying biomass with high moisture content, between 50 to 70% mcwb (Figure 6a), the load is weight constrained, whereas below 50% mcwb it becomes volume constrained and the energy carried per load remains between 200-250 GJ. Based on a cartage distance of 35 kms and a charge of NZD 0.60/tonne/km, the cost per tonne delivered increases as the load lightens due to the lower moisture content (Figure 6b), but the more important NZD/GJ delivered cost is reduced. It stabilises when the load is below 50% mcwb.

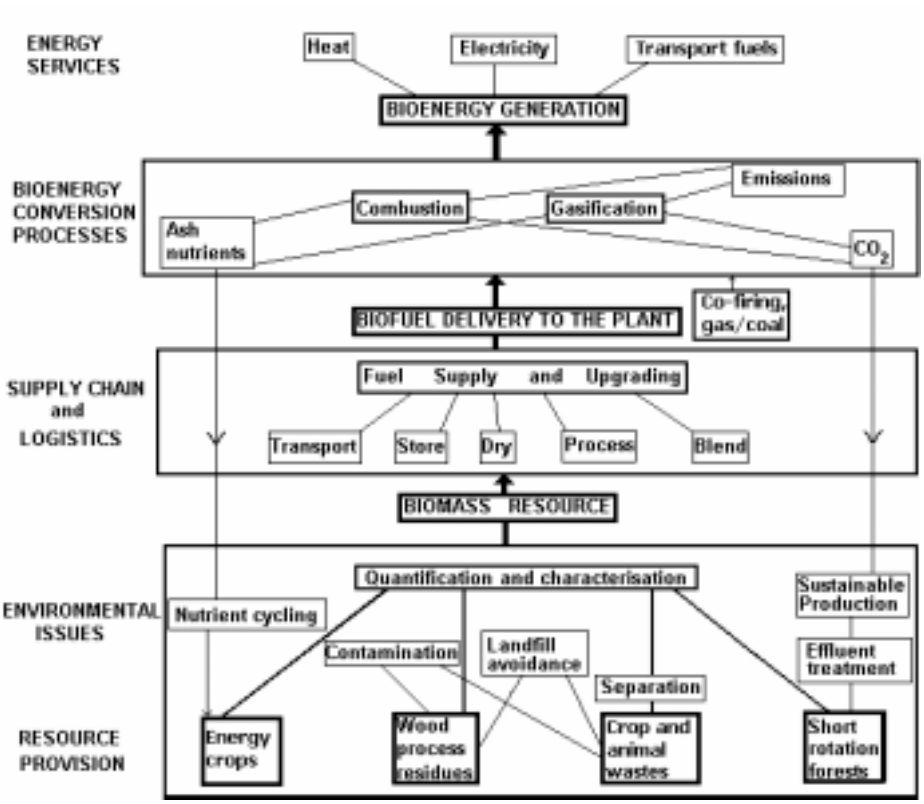
Detailed modelling studies of biomass transport options have been carried out for a range of harvesting and processing systems. Each study (see, for example, Sims and Culshaw, 1998) has shown there to be a wide range of delivered costs resulting from selecting different supply chain systems to harvest, collect and deliver the biomass material. For example, short rotation coppice *Salix* based on British conditions was compared using several harvesting options (Figure 7). Delivered costs varied between EUR 45 to 75/odt. Purchase price for the biomass was taken to be EUR 20/odt, the slight variations shown resulting from the model calculating the need to purchase a greater quantity to overcome any dry matter losses during transport and storage in order to end up with the same total energy being delivered to the plant gate.

Sustainable production

A major challenge when using biomass is its production and use in a sustainable manner in order to provide an acceptable future supply of bioenergy and biomaterials with minimal inputs of water, agri-chemicals, fertilisers or fossil fuel energy. With careful design of the overall system this might be achieved by: recycling nutrients through the ash; optimising (rather than maximising) crop yields per hectare; linking effluent treatment with energy crop production; growing mixed-species tree crops; and returning to the traditional crop rotations, including use of leguminous species. Increasing public concerns cannot be ignored regarding monoculture crops nor can scientific evidence that some biomass crops such as short rotation *Eucalyptus* consume an excessive amount of fertiliser and water (over 35 litres per day uptake for a 2-year-old tree on a sunny day [Sims *et al.*, 1997]).

Whether the use of biomass is sustainable and environmentally sound is determined by the source of the biomass, production methods and land use, alternative treatments when biomass is in the form of organic wastes, and the type of energy conversion processes involved. Life-cycle analyses to determine the environmental impacts of modern biomass have shown that the overall system can be relatively benign in terms of greenhouse gases. In the longer term there are good opportunities for biomass to be used in environmentally sound, small-scale, distributed generation systems including fuel cells and micro-turbines, suitable for both developed and developing countries.

Figure 5. The biomass system includes delivering the biomass resource to the conversion plant gate



Source: Sims, 2002*a*.

Figure 6. Example of the delivered energy content of a truck-load of biomass being carted a distance of 35kms at various moisture contents

Figure 6a

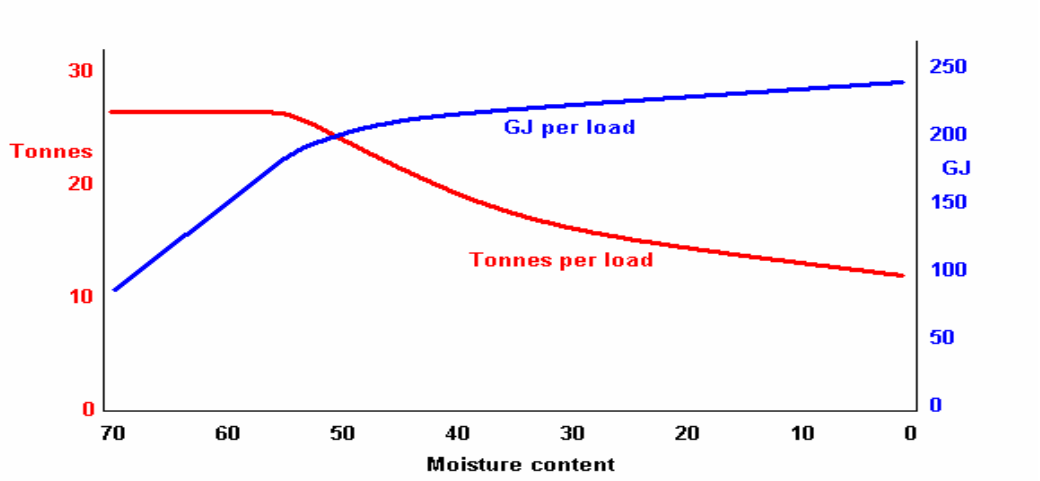
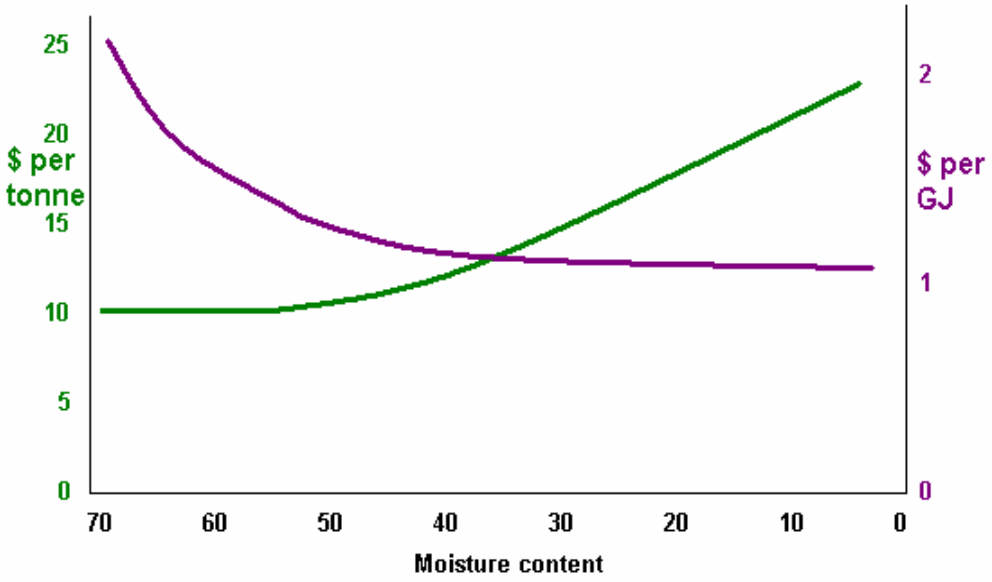
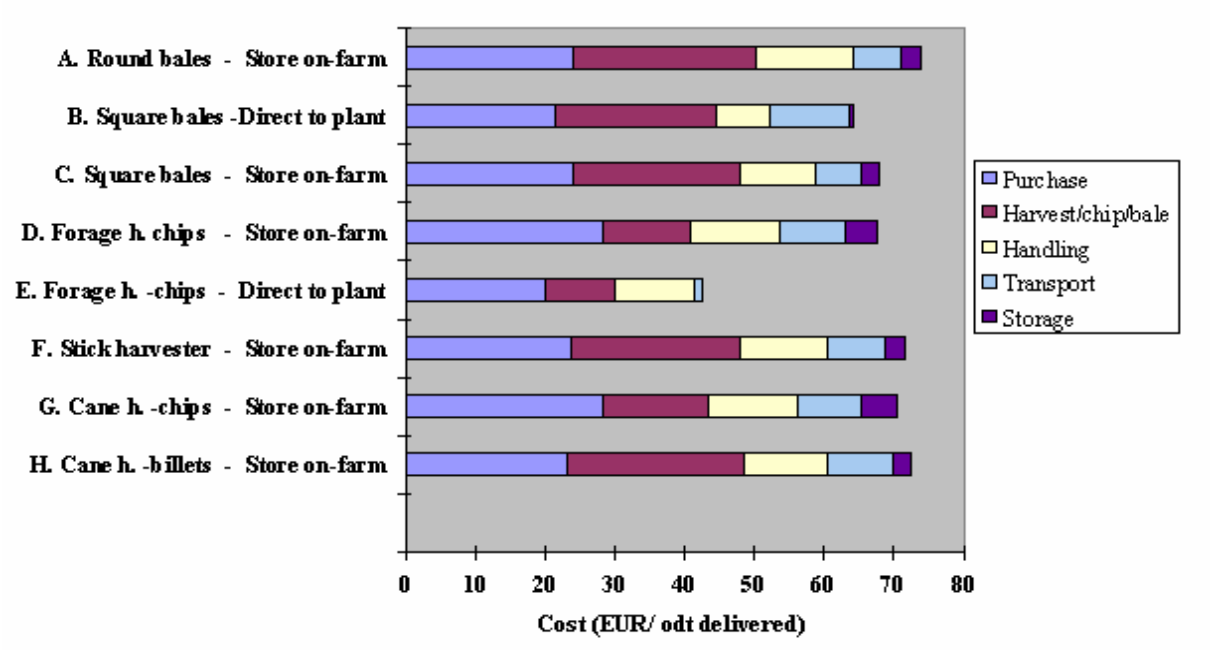


Figure 6b



Note: $ are New Zealand dollars: NZD1 = EUR 0.50 approximately.
Source: Hall, 2001.

Figure 7. Comparative costs of short rotation coppice *Salix* delivered an average of 40.5 km to the power plant



Source: Sims and Culshaw, 1998.

Genetically modified energy crops are under investigation and may well become an acceptable means of capturing and storing solar energy in future decades. Their impact on the environment and "sustainable" production is complex and requires careful evaluation before widespread energy crop production begins.

The international collaborative IEA Bioenergy Agreement aims to realise the use of environmentally sound and cost-competitive bioenergy on a sustainable basis (Tustin, 2002). The programme has moved towards commercialisation of bioenergy systems and with particular emphasis on greenhouse gas balances. Biomass use is not a panacea for the huge problems of climate change, development and equity. However, it certainly will have a key role to play throughout this century to help mitigate these problems.

Social benefits and barriers

Analysing the socio-economic impacts of biomass produced from agriculture is a major, but often under-estimated component when aiming to implement more bioenergy projects. The question needs to be addressed as to whether people really want biomass and bioenergy, or are scientists and developers just assuming they do? The social benefits from the use of biomass include improved health from reduced air pollution, employment opportunities, social cohesion in rural communities and greater security of energy supply. These are covered elsewhere in this workshop in more detail (Sims, 2003).

Comparative costs of bioenergy

The economic benefits of utilising biomass feedstocks are often viable where a waste product is produced and utilised on-site (as in a bagasse co-generation plant or an on-farm biogas plant). The alternative cost of disposal is therefore avoided. In such commercially viable projects, there can be win/win opportunities in terms of saving energy costs and avoiding greenhouse gas emission reductions. These result in a good comparative return on investment in terms of "USD/tonne of carbon equivalent avoided". For example, when comparing alternative power generation options with constructing a new pulverised coal power station (Table 2), the opportunity for BIGCC plants to produce power at competitive prices and also reduce carbon emissions compared with coal becomes apparent.

Table 2. Cost ranges for greenhouse gas reduction technologies compared with a conventional coal-fired power plant and the potential for carbon reduction

Power station type	Carbon emissions	Emission savings	Generating costs	Carbon avoided	Reduction potential to 2010-20
	(gC/kWh)	(gC/kWh)	(cents/kWh)	(USD/tonne)	(MtC/year)
Pulverised coal – as base case	229		4.9		
IGCC[a] – coal	190 - 198	31 – 40	3.6 - 6.0	-10 – 40	49 - 140
CCGT[b] – natural gas	103 - 122	107 – 126	4.9 - 6.9	0 - 156	38 - 240
CCGT gas + CO_2 capture	14 – 18	211 – 215	6.4 - 8.4	71 - 165	Uncertain
Hydro	0	229	4.2 - 7.8	-31 – 127	26 - 92
Solar thermal and solar photovoltaic (PV)	0	229	8.7 - 40.0	175 - 1400	2.5 - 28
Wind – good to medium sites	0	229	3.0 - 8.0	-82 – 135	63 - 173
Bioenergy IGCC – wood wastes	0	229	2.8 - 7.6[c]	-92 – 117	14 - 90

Notes:
* (gC/kWh): grams of carbon released/kWh of electricity generated.
a) Integrated gasification combined cycle.
b) Combined cycle gas turbine.
c) Biomass fuels as delivered range from USD 0/GJ for on-site waste requiring disposal costs to USD 4/GJ for purpose grown energy crops.
Source: IPCC, 2001; Sims *et al.*, 2003.

Where high costs for collection, transport and processing are involved (as when using straw or plantation woodlot arisings such as thinnings, prunings and branches), it is difficult to compete with cheap fossil fuels. Improved economic viability for bioenergy and biomaterial production will result from carbon charges already being imposed globally on fossil fuel use. In addition, a range of fiscal and non-fiscal government policy support mechanisms exist, including renewable energy certificates and feed-in tariffs for electricity and heat; excise tax reduction for transport fuels; and research support for, say, the integrated production of multi-products from one resource through a bio-refinery process.

In OECD countries where agricultural and energy subsidies are minimal or do not exist, biomass produced from purpose-grown crops (rather than from waste organic products) competes better with coal and natural gas in the heat market rather than with traditional forms of generation in the electricity market. In the transport fuel market there is a considerable gap between the ex-refinery price for diesel and petrol and the cost of producing biodiesel and bioethanol (though this gap is closed somewhat when biodiesel is produced from the tallow by-product of the meat industry and bioethanol from the whey by-product of the dairy industry). In order to stimulate the modern biomass industry in its infancy, government financial incentives have often been required. This is partly because the

environmental externalities from competing fossil fuel use have not been accounted for in comparative economic analyses. Rather than offer grants and subsidies over the longer term, the value of carbon mitigation and waste disposal avoidance should be included when comparing energy supply options. As a result, more potential bioenergy and biomaterial production projects would become viable without depending on government support mechanisms that can change over time. This approach could result in a more secure investment.

Future opportunities for biomass

Biomass and biofuels were identified by a US Department of Energy study (Interlaboratory Working Group, 1997) as critical technologies for minimising the costs of reducing carbon emissions. Co-firing in coal-fired boilers, biomass-fuelled integrated gasification combined cycle units for the forest industry, and ethanol from the hydrolysis of ligno-cellulosics, were the three areas specifically recognised as having most potential. Estimates of annual carbon offsets in the US alone for each technology ranged between 16-24 Mt, 4-8 Mt, and 12.6-16.8 Mt, respectively by the year 2010. The near-term energy savings from the implementation of each of these technologies should cover the associated costs (Moore, 1998) with co-firing giving the highest return and lowest technical risk (see above).

Bio-refining

The concept of using different fractions of the whole crop for food, stock feed, industrial, and chemical feedstocks and energy is under development and a wide range of products and materials could be produced (Rexen and Blicher-Mathiesen, 1998). For example, a closed-loop pilot plant was constructed in New Zealand to fractionate biomass into a number of components (Sims, 2002*c*). After washing and pre-heating, the hemicellulose was hydrolysed to produce chemicals such as furfural, and the lignin and cellulose was dried and prepared for hardboards, activated carbon, animal feed or bioenergy feedstock. The concept was based on the entrained flow-drying of biomass particles suspended in superheated steam passing through several distinct sets of pressure and temperature conditions. Unfortunately, the pilot plant was closed down in 1999 due to lack of further funding, but it had it successfully demonstrated the technical potential for jointly producing biomaterials and bioenergy.

Multi-product benefits

Where feasible it makes sense that a biomass resource be “value-added” by producing a range of products and benefits, and not just bioenergy, which tends to have a lower value. For example, the “Integrated Oil Mallee” project in Western Australia, with the state utility company Western Power as a major joint venture partner, is based on more than heat and power generation. The biomass resource will come from growing short rotation eucalyptus mallee crops in 4 to 5 m-wide strips to help solve the growing dryland salinity problem on cropping lands that are rapidly becoming infertile, by driving the water table (and hence the salt) back down. A carbon credit from the forest sink benefit may also be claimed in future (once Australia ratifies the Kyoto Protocol). Harvesting the trees on a 3 to 4-year cycle will provide feedstock for a pilot plant currently under development and designed to obtain revenue from extracting fine oils for pharmaceutical purposes, producing activated carbon for use in air filters, generating heat and power for export, and consequently earning tradeable renewable energy certificates for the “green” power produced. It is anticipated other larger-scale plants will follow, since the dryland salinity problem resulting from tree removal by early settlers extends over millions of hectares of arable land and across several states.

A less ambitious multi-product example perhaps is the growing of oilseed crops to provide a biodiesel feedstock, a high protein animal feed after oil extraction, and using the straw to provide heat and power to drive the process and then export any electricity surpluses off-site.

Carbon sequestration

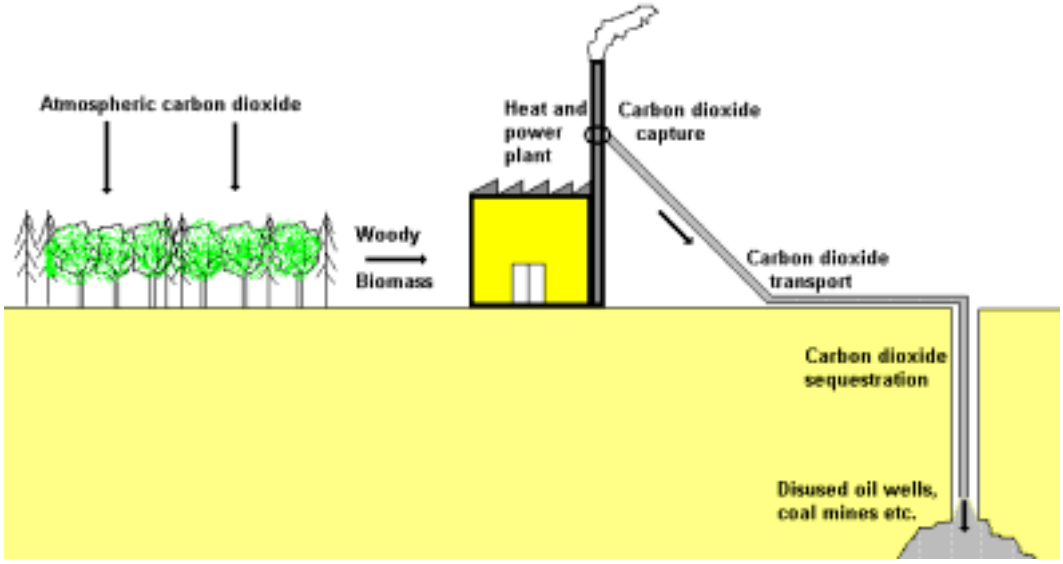
Growing energy crops may be linked with an atmospheric carbon "scrubbing" process. The trees or crops in effect act as carbon pumps, by absorbing atmospheric carbon dioxide as they grow, then releasing it during combustion, when it is captured, transported and permanently sequestered underground or in deep saline aquifers (Figure 8), based on a similar process being advocated for fossil fuels (IPCC, 2001). Atmospheric concentrations are therefore reduced over time. The concept hinges on the development of reliable and cheap methods of physical geological carbon storage which is being intensively researched as a means of utilising "clean coal". However, confidence in the developing technology remains low at this stage.

Hydrogen and distributed energy

In the longer term, the key to sustainability, equity and development, (which are inextricably linked with climate change mitigation [IPCC, 2001]), will be the development of new and affordable small-scale "distributed generation" conversion technologies such as fuel cells, Stirling engines, and micro-turbines as well as internal combustion engines running on landfill gas or biodiesel. If fuelled by these or other biofuels, such as hydrogen, methane and methanol (Hamelinck and Faaij, 2002), then a move towards a decarbonised world based partly on the greater use of biomass will be enhanced.

The move towards the hydrogen economy, from which many OECD countries stand to benefit in the longer term, partly depends on being able to produce the hydrogen using renewable and sustainable resources. This could be from coal or natural gas, but only if the resulting carbon can be captured, transported and physically sequestered underground or in deep saline aquifers. Since the cost for this exercise may be high and the concept is not yet proven, it is perhaps more likely that in the longer term hydrogen will come from sustainably produced biomass or from renewable energy powered electrolysis of water (Lovins, 2003).

Figure 8. Carbon dioxide removal from the atmosphere through the production and use of woody biomass in an energy or hydrogen plant followed by physical sequestration



Source: Author.

Conclusions

The biomass resource is abundant, based on organic waste products and a wide range of energy crops. Many conversion technologies exist and are largely well understood. Currently preventing the bioenergy sector from reaching its full potential, and therefore providing additional revenue for the agricultural community, are the high biomass production costs, the difficulties in securing adequate fuel supplies at an early stage of project development, and the stringent planning constraints, due in part to a lack of understanding by some of the stakeholders. Developing a bioenergy project is therefore usually a challenge. The future prospects for carbon trading, distributed energy systems and hydrogen, multi-product benefits from bio-refining of the biomass feedstock, and the CDM should enable the sector to develop as originally envisaged by policy makers. For this to happen, the biomass industry will have to improve its image, ensure it is using only sustainably produced material, and become more efficient in biomass delivery and bioenergy conversion operations, and less reliant on government incentives.

BIBLIOGRAPHY

Adams, J.F. and R.E.H. Sims (2002), *Methanol production and other liquid fuels from biomass via gasification at both the large and small scale*, Centre for Energy Research, Massey University, Palmerston North, New Zealand.

Askew, M.F. and C.A. Holmes (2001), *The potential for biomass and energy crops in agriculture in Europe in land use, policy and rural economy terms*, Biomass and Energy Crops II, Aspects of Applied Biology, 65, pp. 365-374.

BABFO [British Association for Biofuels and Oils] (2002): www.biodiesel.co.uk.

BDA [Biodiesel Association of Australia] (2002): www.biodiesel.org.au.

Calais, P. and R.E.H. Sims (2000), *A comparison of life-cycle emissions of liquid biofuels and liquid and gaseous fossil fuels in the transport sector*, Proceedings of Solar 2000 conference "From Fossils to Photons", Australian and New Zealand Solar Energy Society, Brisbane, Australia, December.

CEC [Commission of the European Community] (2001), *Proposal for a directive of the European Parliament and Council on the promotion of the use of biofuels for transport*, COM(2001)547, Brussels, Belgium (www.biodiesel.org).

Chisholm, C.J., *et al.* (1994), *Towards a UK research strategy for alternative crops*, ADAS and Silsoe Research Institute, Wrest Park, Silsoe, Bedford, United Kingdom.

Coombes, P. (2002), *Bioenergy projects with the NSW sugar industry*, Proceedings of the Bioenergy Australia Conference, Manly, Sydney, Australia, December (www.users.bigpond.net.au/bioenergyaustralia).

Lindboe, H.H., K.H. Gregersen, S. Tafdrup, O.G. Jacobsen and J. Christensen (1995), *Economy of centralized biogas plants*, Danish Energy Agency, Biomass Section, Copenhagen, Denmark.

Dalta, E.K., T. Feiler, A. Lehmann, A.B. Lovins, K.R. Rabago, J.N. Swisher and K. Wieker (2002), *Small is profitable*, Rocky Mountain Institute, Colorado, United States: www.smallisprofitable.org.

D'Apote, S.L. (1998), *IEA biomass energy analysis and projection* in "Biomass Energy: Data, Analysis and Trends", Proceedings of the OECD/International Energy Agency Conference, 23-24 March, OECD/IEA, Paris, France.

Elam, N., C. Ekstrom and A. Ostman (1994), *Methanol och etanol ur trädråvara*, Huvudrapport, ISSN 1100-5130.

EPRI/DOE [Electric Power Research Institute/US Department of Energy] (1997), *Renewable energy technology characterizations*, Report EPRI TR-109496, Washington, D.C., United States, December.

ETSU [Energy Technology Support Unit] (1996), *Short rotation coppice for energy production*, Good Practice Guidelines, AEA Technology, Harwell, Oxfordshire, United Kingdom.

ETSU (1997), *Anaerobic digestion of farm and food processing residues*, Good Practice Guidelines, AEA Technology, Harwell, Oxfordshire, United Kingdom.

ETSU (1998), *Wood fuel from forestry and arboriculture*, Good Practice Guidelines, AEA Technology, Harwell, Oxfordshire, United Kingdom.

Fischer, G. and G.K. Heilig (1998), *Population momentum and the demand on land and water resources*, International Institute for Applied Systems Analysis, Report IIASA-RR-98-1.

Gapes, R. (2002), *Recent advances in biodiesel production*, Institute of Chemical Engineering, Vienna University of Technology, Austria.

Gigler, J., R.E.H. Sims and J.A. Adams (2001), *Small scale, biomass-fired electricity production systems – present and future*, Massey University, Palmerston North, New Zealand, September.

Grassi (1998), "Modern Bioenergy in the European Union", in *Sustainable Agriculture for Food, Energy and Industry*, N. El Bassam, R.H. Behl and B. Prochnow (eds), James & James Science Publishers, London, United Kingdom, pp. 829-836.

Hall, D.O. and K.K. Rao (1994), *Photosynthesis*, 5th Edition, Cambridge University Press.

Hall, D.O. and F. Rosillo-Calle (1998), *Biomass resources other than wood*, World Energy Council, London.

Hall, D.O. and J.I. Scrase (1998), "Will biomass be the environmentally friendly fuel of the future?" *Biomass and Bioenergy*, Elsevier, No. 15, pp. 357-367.

Hall, P. (2001), *Biomass transport*, Forest logging industry leaflet, Forest Research, Rotorua, New Zealand.

Hamelinck, C.N. and A.P.C. Faaij (2002), *Future prospects for production of methanol and hydrogen from biomass*, Proceedings of the 12th European Conference on "Biomass for Energy, Industry and Climate Protection", 17-21 June, Amsterdam, The Netherlands, ETA, Florence and WIP, Munich, pp. 1 170-1 173.

IEA [International Energy Agency] (2002), *Renewables information*, OECD and IEA joint publication, Paris, France.

IIASA/WEC [International Institute for Applied Systems Analysis/World Energy Council] (1998), *Global energy perspectives*, N. Nakicenovic, A. Grübler and A. McDonald (eds), Cambridge University Press, Cambridge.

IPCC [Intergovernmental Panel on Climate Change] (2001), Third Assessment Report, *Climate Change 2001: Mitigation*, Chapter 3, "Technological and economic potential of GHG emissions reduction", Cambridge University Press, United Kingdom: www.ipcc.ch.

Irving, J. (1999), Personal communication, McNeil power plant manager, Burlington, Vermont.

Korbitz, W. (1998), "Biodiesel – from the field to the fast lane", *Renewable Energy World*, James & James Science Publishers, London, United Kingdom, Vol. 1, No. 3, pp. 32-37.

Larson, E.D. and H. Jin (1999), *A preliminary assessment of biomass conversion to Fischer-Tropsch cooking fuels for rural China*, Proceedings of the 4th Biomass Conference of the Americas, Oakland, Elsevier Science, United Kingdom.

Lovins, A. (2003), *Small is profitable*, Rocky Mountain Institute, Colorado, United States: www.smallisprofitable.com.

Lundberg, H., M. Morris and E. Rensfelt (1998), "Biomass gasification for energy production," *The World Directory of Renewable Energy*, James & James Scientific Publishers, London, United Kingdom, pp. 75-82.

Maniatis, K. (2003), *From where will the hydrogen come? – bioenergy*, International Energy Agency Renewable Energy Working Party Seminar "Towards Hydrogen", Paris, France, March: www.iea.org.

Moomaw, W., A. Serchuk, G. Unruh, J. Sawin and F. Sverrison (1999), *Renewable energy in a carbon limited world*, Advances in Solar Energy 3, D.Y. Goswami (ed.) American Solar Energy Society, Boulder, Colorado, United States, pp. 68-137.

Moore, T. (1998), "Electrification and global sustainability", *EPRI Journal*, January, pp. 43-52.

Moreira, J.R. and J. Goldemberg (1999), "The Alcohol Program", *Energy Policy*, 27, pp. 229-245.

NRC (1999), *Automotive fuel economy*, National Research Council Committee on Fuel Economy of Automobiles and Light Trucks, Energy Engineering Board, National Academy Press, Washington, D.C., United States.

Nuusbaumer, T. (2002), *Combustion and co-combustion of biomass*, Proceedings of the 12th European Conference on "Biomass for Energy, Industry and Climate Protection", 17-21 June, Amsterdam, The Netherlands, ETA, Florence and WIP, Munich, pp. 31-37.

Overend, R. (2000), "Biomass gasification – the enabling technology", *Renewable Energy World*, Vol. 3, No. 3, pp. 42-47.

Overend, R. and R. Costello (1998), *Bioenergy in North America: an overview of liquid biofuels, electricity and heat*, Proceedings of the 10th European Conference on "Biomass for Energy and Industry", Wurzburg, CARMEN, pp. 59-61.

Pachauri, R.K. (2003), *The science and impacts of climate change*, personal communication at two presentations during a brief visit to New Zealand, (9 May), Chair, IPCC.

Pitcher, K., B. Paterson, A. Weekes, J. Neergaard and K. Stahl (2002), *Progress achieved in BIGCC projects and prospects for the future*, Proceedings of the 12th European Biomass Conference "Biomass for Energy, Industry and Climate Protection", ETA, Florence, Italy, and WIP, Munich, Germany, pp. 71-76.

Read, P. (2003), "Linking Bioenergy with Carbon Storage: a Sequential Decision Approach to the Threat of Abrupt Climate Change", paper presented to the OECD Workshop on Biomass and Agriculture, Vienna, Austria, June (see Part I.2 of this publication).

Rexen, F. and U. Blicher-Mathiesen (1998), "Whole crop utilisation – biorefineries", *Sustainable Agriculture for Food, Energy and Industry*, James & James Science Publishers, London, United Kingdom, pp. 825-828.

Rosa, L. P. and S.K. Ribeiro (1998), "Avoiding emissions of carbon dioxide through the use of fuels derived from sugar cane", *Ambio* 27, pp. 465-470.

Saller, G., G. Funk and W. Krumm (1998), *Process chain analysis for production of methanol from wood*, Proceedings of the 10th European Conference on Biomass for Energy and Industry, Wurzburg, CARMEN, pp. 131 –133.

Scharmer, K. (1998), "Biodiesel from set-aside land, Sustainable Agriculture for Food, Energy and Industry", James & James Science Publishers, London, United Kingdom, pp. 844-848.

Schindlbauer, H. (1995), *Standardization and analysis of biodiesel*, Proceedings of the 1st International Conference on Biodiesel, FICHTE/Technical University, Vienna, Austria.

Sims, R.E.H. (2002*a*), *The Brilliance of Bioenergy – in Business and in Practice*, James & James Science Publishers, London, United Kingdom.

Sims, R.E.H. (2002*b*), *The brilliance of bioenergy – environmentally sound technologies or not?* Proceedings, "World Renewable Energy Forum: Policies and Strategies", World Council Renewable Energy, Berlin, June, Eurosolar 65-72.

Sims, R.E.H. (2002*c*), "Bioenergy technologies – environmentally sound or not", *Renewable Energy 2002* (official publication of the World Renewable Energy Network affiliated to UNESCO), pp. 80-85.

Sims, R.E.H. (2003), "The Triple Bottom Line Benefits of Bioenergy for the Community" (see Part I.1 of this publication).

Sims, R.E.H. and D. Culshaw (1998), *Fuel mix supply reliability for biomass-fired heat and power plants*, Proceedings of the 10th European conference "Biomass for Energy and Industry", Wurzburg, CARMEN, June, pp. 188-191.

Sims, R.E.H., K. Senelwa, T. Maiava and B. Bullock (1999), "Eucalyptus species for biomass energy in New Zealand – Part I growth screening trials at first harvest", *Biomass and Bioenergy*, 16, Elsevier, pp. 199-205.

Sims, R.E.H., R.Tungcul, J. Roygard and L. Guo (1997), *Sustainable biomass production using irrigation of waste water - the New Zealand experience*, Proceedings of the international conference on "Sustainable Agriculture for Food, Energy and Industry", Braunschweig, Germany, June, pp. 427-432, James & James Science Publishers, London, United Kingdom.

Sims, R.E.H. and K.M. Richards (2002), *Delivering the bioenergy triple bottom line to the global community*, Proceedings of World Renewable Energy Congress VII, Cologne, Germany, June (CD ROM).

Sims, R.E.H., H.-H. Rogner and K. Gregory (2003), "Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation", *Energy Policy*, 31, pp. 1 315-1 326.

Stahl, K. and M. Neergaard (1998), *Experiences from the biomass fuelled IGCC plant at Varnamo*, Proceedings of the 10th European Conference, Biomass for Energy and Industry, Wurzburg, CARMEN, Germany, pp. 291-294.

Sulilatu, W.F. (1998), *Co-combustion of biofuels*, IEA, Bioenergy Agreement Report T13: combustion:1998:06.

SVEBIO (1998), *Environmental and energy policies in Sweden and the effects on bioenergy development*, Swedish Bioenergy Association: www.svebio.se/environment/env_contents.html.

Tustin, J. (2002), *IEA Bioenergy Annual Report*, International Energy Agency's Bioenergy Implementing Agreement Secretariat, Forest Research, Rotorua, New Zealand.

Ulgiati, S., S. Bastianoni, L. Nobili and E. Tiezzi (1994), *A thermodynamic assessment of biodiesel production from oil seed crops. Energy analysis and environmental loading*, Proceedings of the Dedicated Conferences on: Electric Hybrid and Alternative Fuel Vehicles, 27th International Society of Alternative Transport Authority, ENEA, pp. 477-489.

Van Doorn, J., P. Bruyn and P. Vermeij (1996), *Combined combustion of biomass, municipal sewage sludge and coal in an atmospheric fluidized bed installation*, Proceedings of the 9th European Biomass Conference for Energy and the Environment, Copenhagen, Denmark, pp. 1 007-1 012.

Venendal, R., U. Jorgensen and C. Foster (1997), "European energy crops overview project – synthesis report", *Biomass and Bioenergy*, summer/autumn special issue, Elsevier.

Wilkins, G. (2002), *Technology transfer for renewable energy*, Royal Institute for International Affairs and Earthscan Publications, London, United Kingdom.

World Bank (1996), *Rural energy and development: improving energy supplies for two billion people*, Industry and Energy Department, Report No. 1512 GLB, Washington D.C., United States.

ENERGY FROM BIOMASS: A PROMISING OPTION FOR A FUTURE SUSTAINABLE ENERGY SYSTEM

Josef Spitzer[1]

Abstract

Bioenergy currently covers approximately 11% of the world primary energy demand of 440 EJ/year. Residues from forestry operations, the wood processing industry and from agriculture are the main sources of biofuel today, but biofuel resulting from land use changes in the agricultural sector will also have an important role to play, with the approaching increase in the need for renewable energy. Estimates of this increase range from 35-95 EJ/year by the year 2025. Biofuel utilisation systems operating today range from simple stoves and furnaces to complex plants for combined heat and power production and for liquid biofuels production. Heat systems have been developed to an economically competitive level, while systems for electricity and transportation fuel production operate only as prototypes today, and need further development before they can become competitive in the energy market. Standard emissions from biomass combustion systems have been reduced to an environmentally acceptable level. Bioenergy is considered carbon-neutral and therefore reduces greenhouse gas emissions when substituted for fossil energy. In addition, combining bioenergy schemes with crop management strategies in agriculture can increase above- and below-ground carbon pools and thus contribute to stabilising the carbon dioxide concentration in the atmosphere.

Introduction

Bioenergy is an important source of energy today and will have greater importance in the future. Among the options for increasing the share of renewable energy sources in the energy supply of the European Union, the *White Paper* (European Commission, 1997) identifies bioenergy as the major contributor: of the total projected increase of renewable energy sources of 4.3 EJ (exajoules)/year between 1995 and 2010, bioenergy is expected to contribute 3.5 EJ/year. An additional incentive to increase the use of renewable energy sources may be expected from the Kyoto Protocol (UNFCCC, 1997) once it comes into force in final form. Under the terms of the Protocol, by 2010 the European Union (EU) has to reduce its greenhouse gas (GHG) emissions by 8% compared to 1990, mainly by substituting renewable energy sources for fossil fuels, with bioenergy providing the biggest share. Of the different sources for biofuels feedstock, residues from forestry operations and wood processing are currently the most important. Their use is part of an environmentally sound, closed cycle and can rely on a well-established technology. In the future, an increasing share will have to come from agricultural sources. This also offers opportunities for solving some of the problems OECD countries are facing today in agricultural production. However, besides using traditional agricultural crops and harvesting methods for feedstock production, new options will have to be developed to meet the requirements for converting agricultural biomass to heat, electricity and transport fuels in an environmentally sound way. Technologies for most of these options have yet to be developed to meet market requirements.

1. Joanneum Research, Graz, Austria.

Biofuels and bioenergy potential

Solid, liquid and gaseous fuels derived from biomass are available today for use in energy conversion systems such as furnaces, combustion engines and turbines. Both feedstock collection and fuel production technologies have been developed for feedstock from forestry and wood industry residues in such a way that biofuels have become competitive with fossil fuels in many applications. However, systems using feedstock from agricultural crops require further development in order to become competitive. The global energy potential stored annually in the biosphere through photosynthesis, and the main properties of biomass compared to fossil fuels are shown in Table 1. These numbers indicate that a major part of the fossil fuels used today may be replaced by biofuels and that biomass feedstock for the production of biofuels has only a slightly lower energy content than coal. Typical examples of solid fuels for manual (logs and briquettes) and automatic (chips and pellets) feeding are shown in Figures 1 and 2. These fuels are successfully used to produce heat and power in small and large-scale combustion plants. Opportunities for utilising agricultural crops also exist – crop residues (*e.g.* straw) can be used for pellet production and grain can be directly introduced into in boilers, as fuel. However, the chemical properties of these fuels (ash content, ash melting point) require special provisions in the conversion plants which tend to increase the investment cost.

Table 1. Basic data on bioenergy

Global potential EJ/year		
—	Energy equivalent of carbon stored globally through photosynthesis (60Gt/year)*	2 300
—	World fossil fuel consumption 2001	338
Calorific value (MJ/kg)**		
—	Biomass (0% water)	17-20
—	Biomass (20% water)	13-15
—	Biomass (60% water)	5-7
—	Coal	25-30
—	Lignite	12-15

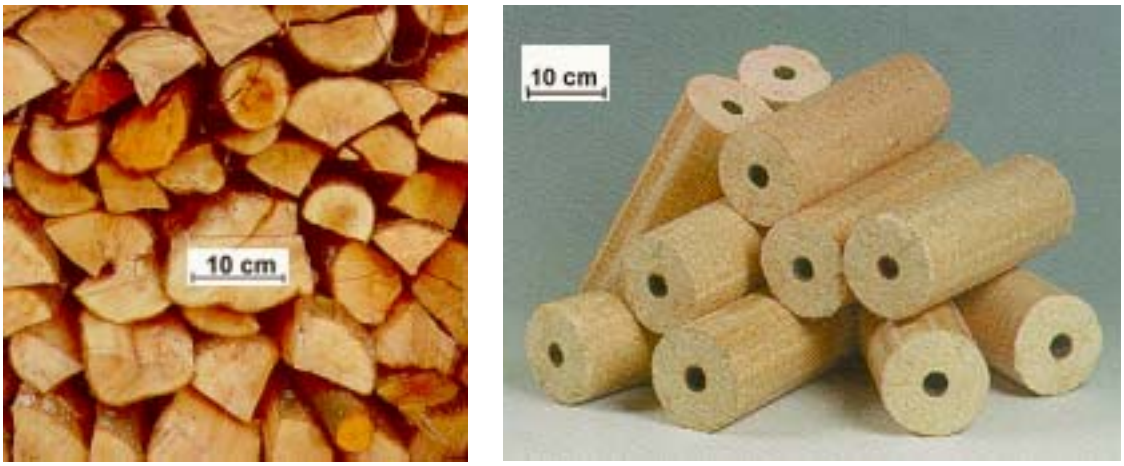
Notes:
* Gt : gigatonnes ; ** MJ : megajoules.
Source: Author.

The processes for the production of liquid and gaseous fuels from biomass are basically known but, as yet, are economical only in certain, specific cases: thermal gasification of solid biomass, anaerobic digestion of liquid waste biomass, production of biodiesel from vegetable oil, and ethanol from grain and sugar-bearing crops. Because of the limited availability of traditional agricultural feedstock (Figure 3) it will be necessary to establish the large-scale production of crops dedicated for energy production. This includes lignocellulosic perennial material (Figure 4). The processes for liquid fuel production from lignocellulosic material (*e.g.* ethanol through fermentation and bio-oil through fast pyrolysis) are basically known but the technologies have to be further developed.

The contribution bioenergy is expected to make towards meeting global energy demand has been estimated by many authors. Table 2 shows examples ranging from 72 EJ/year to 145 EJ/year in the year 2025. The current contribution of bioenergy to total world energy consumption of 440 EJ/year is estimated to be approximately 50 EJ/year (12%). This indicates that a substantial increase of the share

of bioenergy would seem possible: an additional 35-95 EJ/year by 2025, and considerably more thereafter. The main uncertainty of these estimates results from the non-commercial use of firewood in Third World countries. A recent European study identified the potential for an additional use of fuelwood from forests in Austria, Finland, France, Portugal and Sweden (FEEDS, 1998). Table 3 shows the total potential; 1995 use; and the additional use in the year 2020 for a moderate and a high scenario. In all cases a substantial increase is expected, ranging from 50% in France, to more than 100% in Finland and Sweden. The future contribution of agricultural crops depends on the development of global agricultural and trade policies. Limitations on agricultural energy feedstock have to be expected, due to competition with food and feed production and with other fossil or renewable energy sources. While food and feed production requirements naturally have to be met, the chances for additional agricultural biomass in the energy market depend on the price of competing energy sources. Currently, most agricultural feedstock options are not competitive without policy interventions. While the basis for such interventions is undisputed (energy supply security, climate protection, etc.) it will take time to implement the necessary legal framework.

Figure 1. Wood logs and wood briquettes as biofuel



Source: Author.

Figure 2. Wood chips and wood pellets as biofuel



Source: Author.

Figure 3. Traditional agricultural crops for biofuel feedstock



Source: Bundesanstalt fuer Landtechnik Wieselburg, Austria.

Table 2. Current use and future potential of global bioenergy consumption

Future potential (EJ/year):	**Year**		
Scenario and sources:	**2025**	**2050**	**2100**
Shell (1996)	85	200-220	--
IPCC (1996)	72	280	320
Greenpeace (1993)	114	181	--
Johansson *et al.* (1993)	145	206	--
Dessus *et al.* (1992)	135	--	--
Lashof and Tirpak (1991)	130	215	--
Fischer and Schrattenholzer (2001)	--	350-450	--
Current use (2001): 50 EJ/year of 400 EJ/year total world energy consumption			

Source: Author.

Figure 4. Short rotation lignocellulosic crops for biofuel feedstock





Source: IEA Bioenergy, Task 30.

Table 3. Fuel wood resource and consumption in European countries in PJ*/year in 2020 for a moderate and a high scenario

	Austria	Finland	France	Portugal	Sweden
Fuelwood resource	230	350	540	70	470
Consumption 1995	122	94	338	36	177
Additional use in 2020 (moderate/high scenario)	59 / 103	55 / 116	120 / 168	24 / 34	81 / 202

Note:
* PJ : petajoules.

Source: FEEDS, 1998.

Small-scale heat production

Stoves and residential boilers operated with wood chips, wood pellets and wood logs have been optimised in recent years with respect to efficiency and emissions. Figure 5 shows a typical wood log stove (left) and an automatically fed pellet boiler (right). Further improvements regarding fuel handling, automatic control and maintenance requirements are necessary. There is great potential for the application of these systems, particularly in rural areas.

Figure 5. Wood log furnace (left), (Rika/Austria); and automatic wood pellet boiler (right), Herz/Austria)





Source: Company brochures, Rika and Herz.

District heating systems

Municipal district heat plants, operated by farmers' co-operatives or industrial enterprises, (*e.g.* wood processing or the pulp and paper industries), supplying also district heat, typically have a power level ranging from 0.5 MW (megawatts) up to 20 MW. Special boilers for these systems have been developed in recent years. Automatic fuel feeding, control systems and particle filters assure environmentally acceptable operation, and meet the required emission limits. To improve efficiency and further reduce particle emissions, some plants are equipped with flue gas condensing systems. Figure 6 (left) shows the heating station of such a system. The systems applied so far generally use forestry and wood processing residues. In some cases, straw is used as fuel.

Figure 6. Biomass district heat plant at Passail, Austria (left); Steam CHP plant at Reutte, Austria (right)





Source: Landesenergieverein Graz, Austria and VKW Reutte, Austria

Combined heat and power plants

To increase the share of bioenergy in the energy market biofuels have to be introduced into electricity production. Due to the low energy density of solid biofuels, transportation and storage costs are higher than is the case with fossil fuels. To limit these costs biomass power plants generally will be smaller than fossil power plants, typically in the range below 30 MW_{el} (megawatts power electricity). This increases the opportunity to operate them as combined heat and power (CHP) plants, which enables them to cover the district heating demands of small communities. On the other hand, the standard steam cycle technology is not economical in the lower power range. Therefore, R&D efforts are underway to develop special systems for biomass-fuelled CHP plants, through direct combustion of solid fuels, or through gasification and use of the gas produced for power production. As for district heat systems, the conversion plants (combustion and gasification) have been developed for lignocellulosic biomass, but developments are underway to adapt them for straw.

Combustion: Steam cycle plants with turbines or piston engines are available and operate in the power range above 5 MW_{el}. Figure 6 (right) shows a typical steam CHP plant operated by a wood processing company using residues from both manufacturing and nearby logging operations: 6.3 MW process and district heat, 1.3 MW electricity. R&D projects for systems using the combustion gas directly for power production (thus avoiding the high operational cost of steam cycles) have been carried out with some success. An example is a Stirling engine whose heat exchanger is placed in a duct between the furnace and the boiler of a heating plant (Figure 7, left). A number of other concepts are under development, *e.g.* the "hot air gas turbine system"; the application of power units using the organic Rankine cycle; and biomass co-combustion in coal-fired power stations.

Gasification: Two main concepts are under development, one aiming at use of the gas in a combustion engine in the power range up to a few MW_{el}, the other aiming at use in a combined gas turbine and steam turbine system in the higher power range (integrated gasification combined cycle, IGCC). Figure 8 shows a successful IGCC prototype plant with an electrical output of 10 MW. The main challenge in this area is to develop a low-cost gasification process yielding a clean product gas with a high heating value. An overview of international developments in this sphere is presented in (IEA Bioenergy, 1999).

Figure 7.3 kW* stirling engine for biofuel operation at Joanneum Research, Austria (left); flash pyrolysis plant at VTT Energy, Finland (right)



Note:
* kW: kilowatt.

Source: Joanneum Research Graz, Austria and VTT Espoo, Finland.

Figure 8. Integrated biomass gasification combined cycle CHP plant in Värnamo, Sweden



Source: European Commission, 1997.

Liquid fuels for transportation and power production

Liquid fuels may be produced from biomass through biological and thermochemical processes. Biodiesel from rapeseed oil or used cooking oil is used, with minor modifications, in standard diesel vehicles. However, its potential to replace fossil diesel is limited due to the restricted availability of feedstock. Ethanol from sugar and starch plants is widely used where economic incentives are available. Because of the limited resource base for feedstock from agriculture, ethanol from lignocellulosic material (*e.g.* from forestry and wood processing residues) has great potential to replace fossil transportation fuels on a large scale – however, the prototype plants in operation today are in need of further technological development. Bio-oil, the product of fast pyrolysis of biomass (flash pyrolysis), has potential for both heat and power production. While the production technology is basically developed, the properties of the fuel will have to be improved for standard application in boilers or stationary engines for power production. Figure 7 (right) shows a flash pyrolysis prototype plant.

Economy

As indicated above, at present, bioenergy is competitive with fossil energy systems in only a few applications, mainly small-scale heat supply systems and large power plants, where waste wood from forestry operations and wood processing may be used without fuel upgrading. The reason for this lies in both higher fuel production costs and higher end-use conversion costs. Table 4 shows the cost of small-scale heat production with wood log, wood chip and wood pellet heating systems at different power output levels. These costs should be compared to the cost of boilers using fossil oil and gas. Wood log boilers and medium-sized wood chip boilers became competitive at fossil fuel prices as of summer 2002 and, with increasing fossil fuel prices, the more advanced pellet systems will also become competitive.

Table 4. Average cost of heat from biomass and fossil fuels (summer 2002 prices)

Wood log furnaces	**EUR/kWh***
— Chimneys (8 kw**)	0.122 – 0.167
— Wood log boilers (15 kw)	0.065 – 0.085
Wood chip boilers	
— 15 kw	0.082 – 0.132
— 100 kw	0.043 – 0.048
Wood pellet boilers	
— 15 kw	0.136 – 0.154
— 45 kw	0.122 – 0.134
Fossil fuel boilers	
— Fuel oil	0.094 – 0.130
— Natural gas	0.097 – 0.099

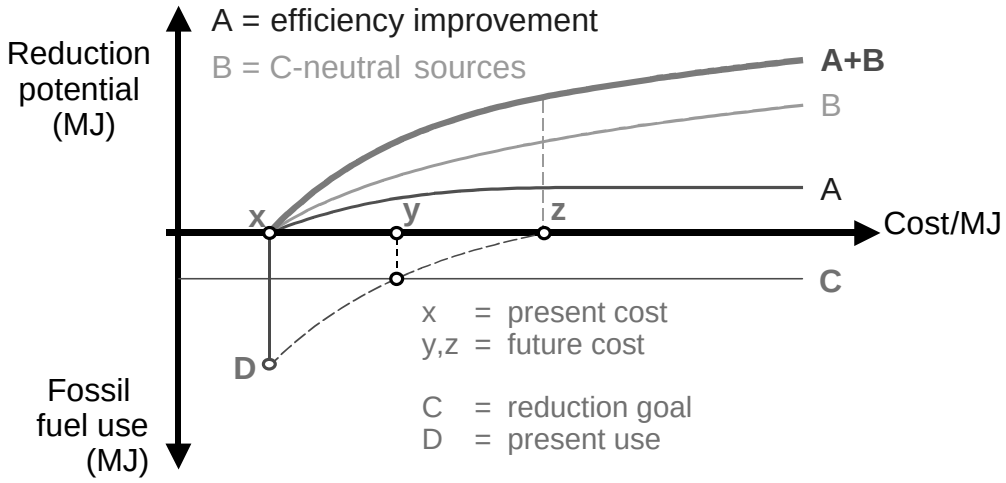
Note:
* – kilowatt-hour; ** – kilowatt

Source: Author.

It cannot be expected, though, that the costs of all bioenergy systems – present and future – will decrease sufficiently so as to achieve full competitiveness. Thus, a breakthrough of bioenergy can only be envisaged if the cost of fossil fuels increases, due either to world market developments, or fiscal measures in individual countries (such as fossil fuel taxes or subsidies for bioenergy systems). Figure 9 (upper part) shows how an increase in energy prices (cost/MJ) will lead to the implementation of both energy efficiency measures and the use of renewable (carbon-neutral) energy sources: with increasing cost, these options become more and more economical, thus covering an increasing fraction of the energy demand.

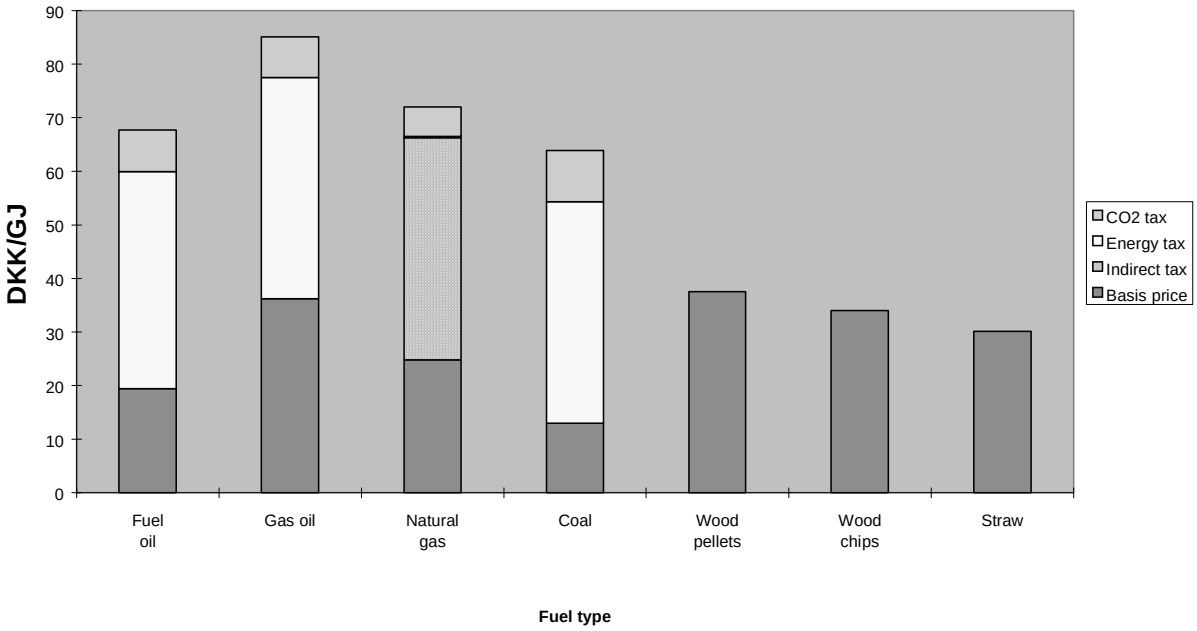
Fiscal measures to increase the cost may be justified through a number of positive secondary effects associated with the use of renewable energy sources, in general, and bioenergy systems, in particular. An analysis of the external effects of fossil fuel utilisation compared to the use of renewable energy sources indicates that an internalisation of external cost would offset the present cost advantage of fossil fuel systems. In the case of bioenergy, a major positive effect is seen in the new opportunities offered to agriculture, in the production of biomass for energy use, and to local enterprises, in the construction and operation of bioenergy systems. However, such analyses contain many uncertainties (particularly in relation to the cost of global warming), so that a convincing basis for the necessary political action is not yet available. An example of a taxation policy is shown in Figure 10, which illustrates the situation in Denmark: fossil fuel prices have been raised through taxation to such an extent that biofuels have become competitive.

Figure 9. Implementation of new energy technologies (energy efficiency, renewable energy sources), as a function of energy cost, and corresponding reduction of fossil fuel use



Source: Author.

Figure 10. Fuel prices in Denmark



Source: dk Technik, Denmark.

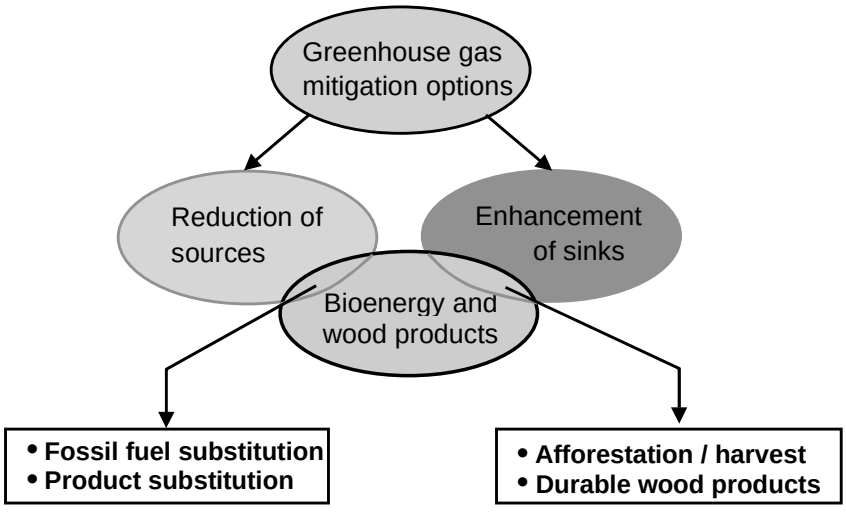
Environment

The utilisation of bioenergy is associated with combustion processes whose emissions, in many cases, are potentially higher than those of natural gas or oil. In particular, the combustion of solid biofuels requires the use of special equipment if emission limits are not to be exceeded. This equipment has been developed in recent years with the result that standard emissions, such as CO, C_xH_y, NO_x and particulates, are now generally kept within the limits.

Regarding GHG emissions, biomass can play a dual role in relation to the objectives of the UNFCCC, *i.e.* as an energy source, acting as a substitute for fossil fuels, and as a carbon store (Figure 11). Modern bioenergy options offer significant, cost-effective and sustainable opportunities towards meeting emission reduction targets, while providing additional ancillary benefits. Moreover, via the sustainable use of the accumulated reserves of carbon, bioenergy has a potential to resolve some of the critical issues surrounding the long-term maintenance of biotic carbon stocks. Finally, wood products can act as substitutes for more energy-intensive products; constitute carbon sinks; and can be used as biofuels at the end of their lifetime (IEA, Bioenergy, 1998).

The relationship between energy cost and the reduction of fossil fuel use through the implementation of energy-efficient technologies and carbon-neutral energy sources is shown in the lower part of Figure 9. A major reduction of the current use of fossil energy sources, (*e.g.* from level D [currently 6.3 GtC {gigatonnes of carbon}/year]) to an acceptable level C (probably less than 2.5 GtC/year)], would be achieved if the energy cost were to rise from level x to level y. However, this would have a substantial impact on the world economy. To initiate the steps necessary in order to make this transition is the main challenge for policy makers today.

Figure 11. Role of biomass in greenhouse gas mitigation



Source: IEA Bioenergy, 1998.

BIBLIOGRAPHY

European Commission (1997), *Energy for the future: Renewable sources of energy; White Paper for a Community Strategy and Action Plan*, European Commission, COM(97)599 final, 26 November.

FEEDS (1998), "Fuelwood in Europe for Environment and Development Strategies (FEEDS)", *Les cahiers du Club d'Ingénierie Prospective Energie et Environment (CLIP)*, No. 8, January.

IEA Bioenergy (1999), *Annual Report 1999 of the Bioenergy Research Network of the International Energy Agency*, Paris, France*:* www.ieabioenergy.com.

IEA Bioenergy (1998), *Annual Report 1998 of the Bioenergy Research Network of the International Energy Agency*, Paris, France*:* www.ieabioenergy.com.

UNFCCC (1997), *The Kyoto Protocol to the Convention on Climate Change*, Climate Change Secretariat and UNEP, June 1998, UNEP/IUC/98/9.

AN OVERVIEW OF BIOMATERIALS

Melvyn F. Askew[1]

Abstract

The potential of biorenewables is about to be rediscovered. However it is essential that true sustainability in the sense of economics, environmental impact and cultural/social acceptability is taken as the yardstick against which biorenewables are developed.

Whilst considerable input has been put into research and development and proof of concept, little has been achieved in terms of industry pull. This issue needs addressing although it has to be recognised that there are a number of reasons why uptake of biorenewables has been limited.

Markets for biorenewables as exemplified by the IENICA (Interactive European Network for Industrial Crops and their Application) project are large and considerably under-exploited. This limits economic, environmental and rural benefits. If uptake of biorenewables is a desired strategic target then definitive strategies confirming this and supporting measures will be essential.

Introduction

Non-food raw materials from agriculture and other land-based industries are not new but in many instances have been pushed to one side by synthetic materials based upon fossil fuels and oil in particular. Frequently the driver for change has been simple economic cost.

Originally most fuels came from trees, for heat or in the form of feed for draught animals. Fibres were all plant-based (cotton and silk have never been supplanted by man-made materials).

Land-based industry has tended to focus almost exclusively upon food production and a limited number of traditional non-food uses of plants or plant materials -- for example, forestry being used as a primary heat source; or, depending upon species, paper pulp or sawn timber. Similarly, wheat has been considered a source of grain and the straw as animal bedding, along with some relatively small tonnage uses in speciality markets. Grassland has been regarded as grazing for livestock and/or an amenity.

Until recently, little has been done in terms of true identification or exploitation of markets and little emphasis paid to co-producting within a given plant or crop to optimise revenue streams.

---

1. Central Science Laboratory (CSL), York, United Kingdom. These are views of the author and not necessarily those of the CSL nor the Government of the United Kingdom.

An ideotype for co-producting may be cannabis (*Cannabis sativa*) where a wide range of products are made from one plant (Figure 1). Similarly, wheat has major potential (Figure 2) and oilseeds, as exemplified by castor bean (*Ricinus communis*), can be used in many different market sectors, although in this latter instance the sole plant product being utilised is the oil (Figure 3).

Occasionally, economic policies such as the Common Agricultural Policy (CAP), along with changes in world markets and improvements in agricultural production, have caused surpluses to be stockpiled, for example in EU Intervention Stores. This has been recognised for about 20 years, and it is surprising that more progress has not been made in reducing them. Rexen and Munck (1984) assessed potential outlets to obviate high levels of cereals building up in EU (the then EEC) stores by 2000.

Their recommendations were:

1. That the EEC stimulates co-operation between agriculture and industry, starting by establishing agricultural refineries as demonstration units in various EEC countries;

2. That the EEC revises its present tariff system regarding cereals and cereal products and changes it to a coherent, simplified set of rules designed to stimulate efficiency in cereal production and in the industrial use of cereals, thus creating the basis for an internationally competitive biotechnology industry in the EEC;

3. That the use of straw as a fibre source should be stimulated by supporting a modernisation of the present industrial process to obtain competitiveness with the wood-based industries;

4. That the production of agricultural commodities in which the EEC is deficient – maize for starch, feed protein, vegetable oil, and cellulose fibres – should be stimulated by quality related premium prices of present commodities and development of new crops;

5. That significant basic research programmes should be established in the industrial manufacture of cereal based products, including genetic engineering of plants and micro-organisms, purification of cereal components and their processing and modification into final products.

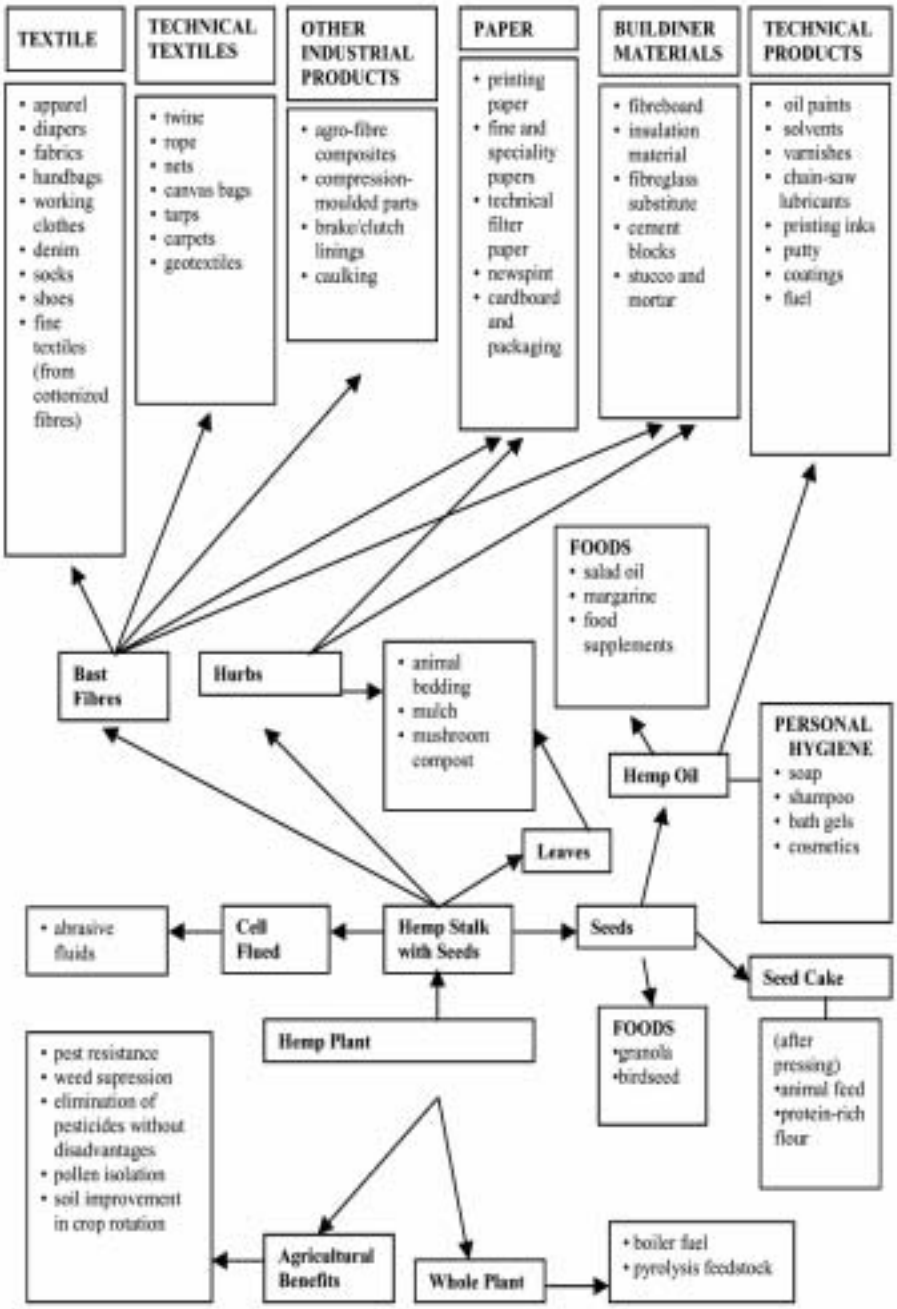
Clearly in this last example the final agreed outcome of the long-term policy perspective for sustainable agriculture could have a major impact upon the exploitation or cultivation of biomass for biorenewables in the EU, although it is perhaps disappointing that the recommendations clearly identified in 1984 have not been addressed.

However, it needs to be borne in mind that the goal of renewability is not in itself sufficient as the only acceptable driver for the development of biorenewables. Certainly *Eucalyptus spp*, in Spain, for example, offer a range of products, albeit in an area where water may be limited, and the depletion of indigenous species not necessarily the best option, environmentally. Similarly, in the UK, when considering projects to plant large areas of *Salix* for use in the combined heat and power (CHP)/electricity sectors it is important to take into account the environmental implications, for example the potential impact upon water reserves in some drier eastern areas.

The key underpinning issue for extension of development of biorenewables is that of sustainability.

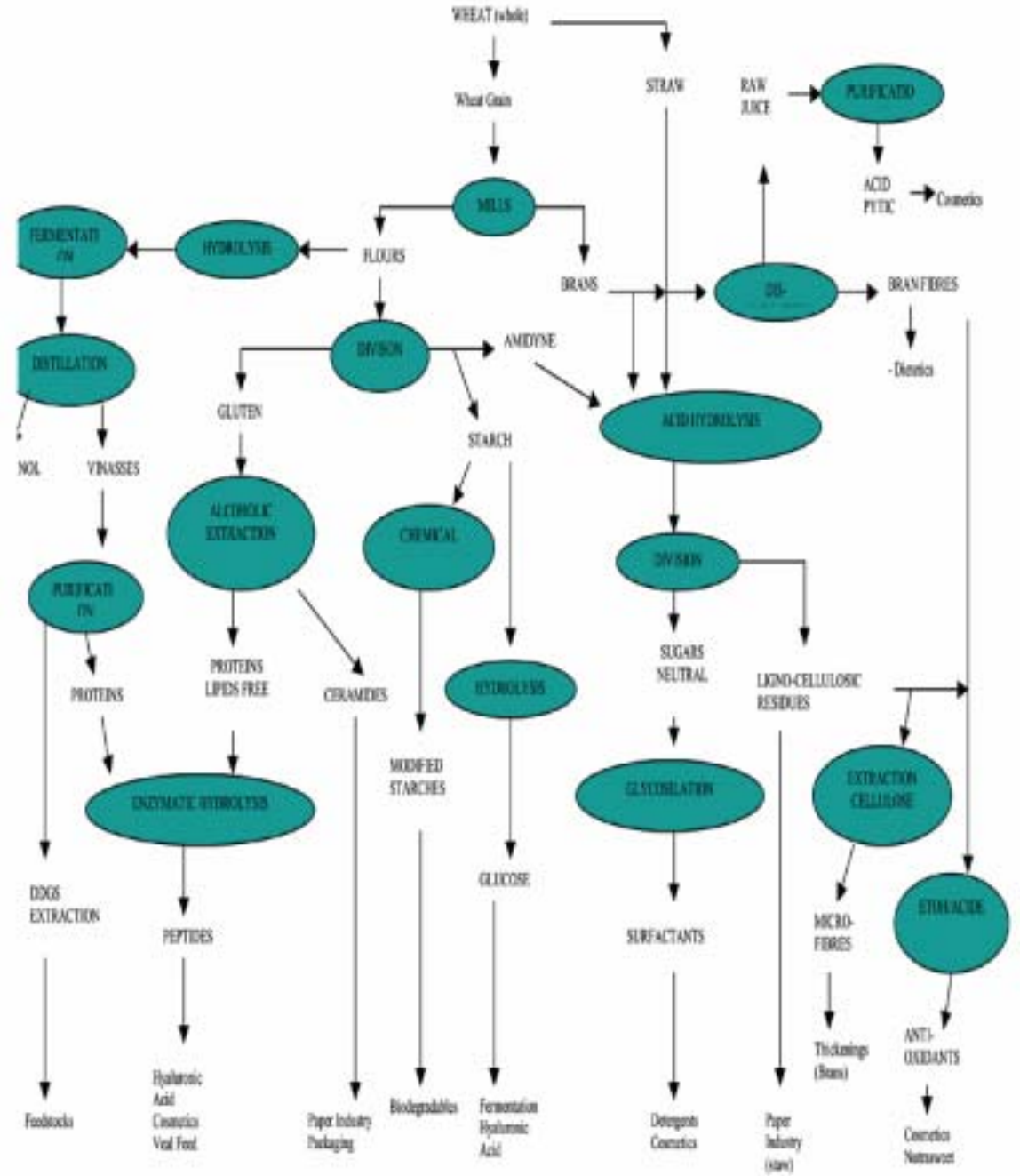
Sustainability = f (economic viability, environmental acceptability, cultural acceptability).

Figure 1. The potential of a fibre plant: an example of co-producting



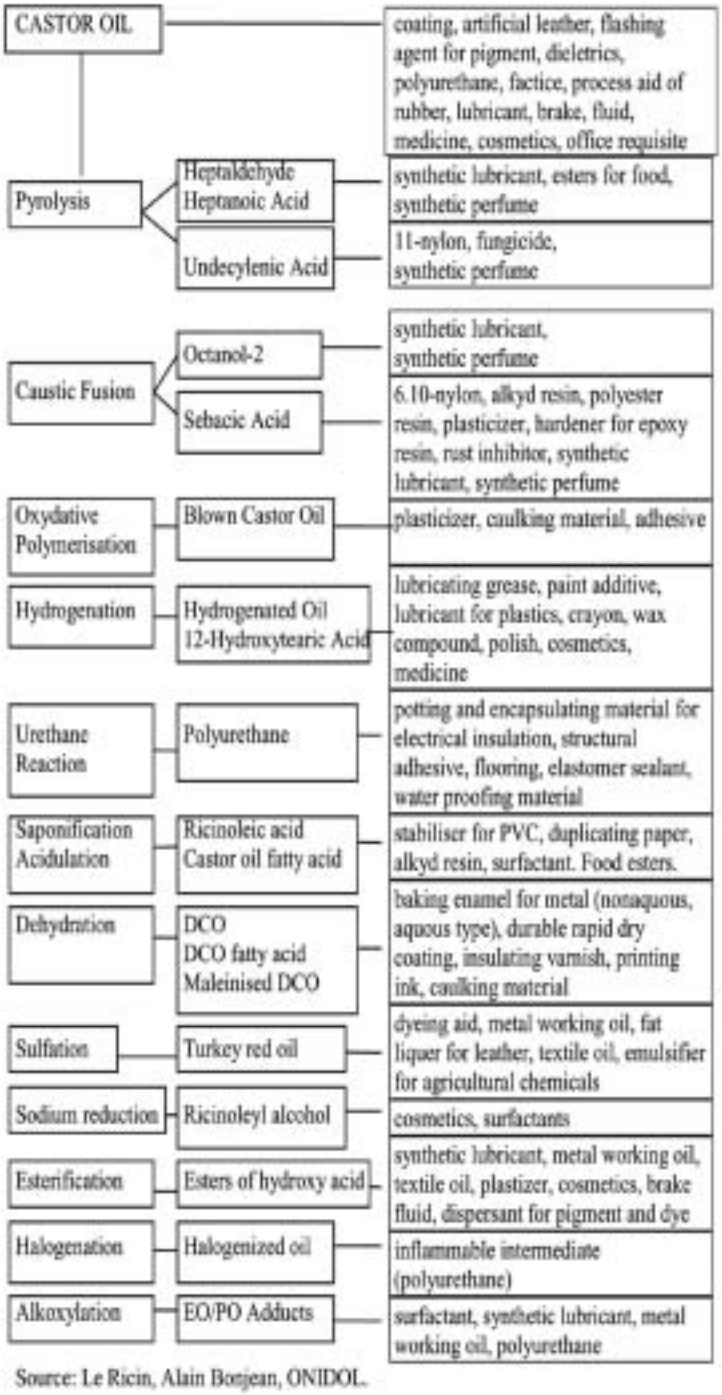
Source: Hemp Horizons: John W. Roulac.

Figure 2. A flow chart indicating products from wheat



Source: IENICA website - www.ienica.net .

Figure 3. Castor oil: an example of the potential of natural lipids



Source: Le Ricin, Alain Bonjean, ONIDOL.

Table 1. Areas of non food crops in EU-15 (1998)

	Hectares
Linseed	314 000
Oilseed (on set-aside for industrial use), of which:	408 000
- Rapeseed	340 000
- Sunflowerseed	68 000
Fibre flax	170 000
Hemp	39 000
Short rotation coppice	19 000
TOTAL	915 000

Source: Mangan, personal communication.

It is to be noted that significant potential contributions can be made to global climate, from non-food crops (Mangan, personal communication) (Table 1).

Whilst there has been little uptake of purpose-grown biorenewables to date, it is untrue to attribute this to a lack of scientific data or knowledge.

As an example, the European Commission (EC) has been particularly active in funding research and development (R&D). Over the past ten years, the Commission has contributed, through the shared cost Framework Programme, research funding to non-food crops and products (excluding bioenergy) amounts in excess of EUR 160 million – which represents 40% of the total expenditure of approximately EUR 360 million. This has been spread over 130 individual projects and networks where the typical project structure is eight partners, ranging from industry to universities and public research institutes, carrying out a defined three-year research project addressing one or more aspects of the complete, integrated production and processing chain. This has been allocated to a wide range of interest areas (Table 2).

Table 2. Non-food EC-funded projects, 1989-97*

Raw material chain	**Number of projects**	**EC contribution** (million EUR)	**Total expenditure** (million EUR)
Bulk chemicals Paints, lubricants, detergents	29	32	62
Plastics Starch, microbes, wastes, etc.	23	31	56
Non-wood fibres New materials, textiles, etc.	23	36	84
Fine chemicals Drugs, dyes, biocides, etc.	67	59	124
Waste treatment	10	6	9
TOTAL	**145**	**228**	**467**

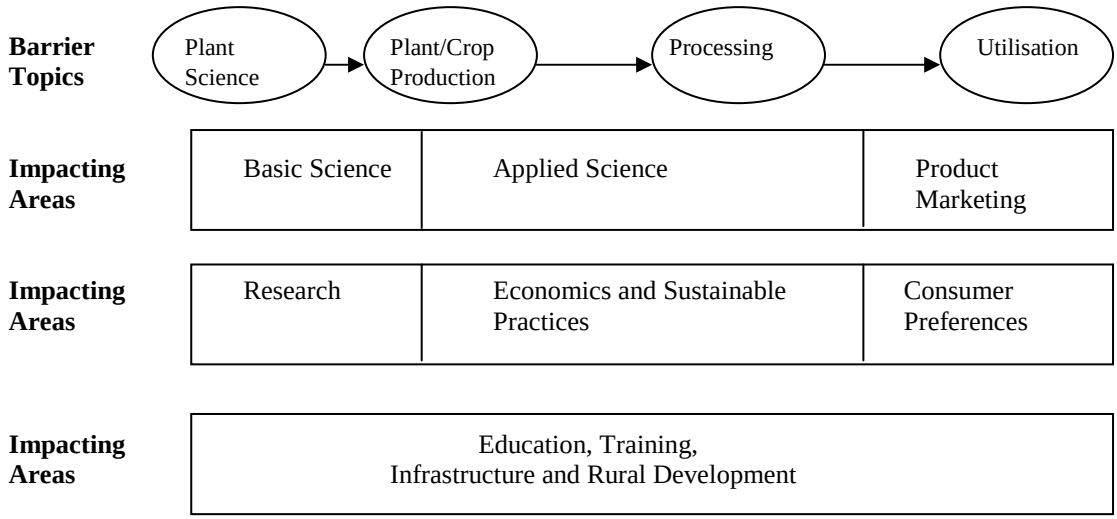
* Excluding bioenergy and wood industry projects.

Source: Mangan, personal communication.

Making progress

In the United States a report by the Vision 2020 Executive Steering Group produced a diagrammatic representation of the pathway for progress of biorenewables (Figure 4).

Figure 4. Pathway for progress and development of non-food crops and products



Source: Vision 2020 Executive Steering Group, United States, 1999.

It seems probable that this pathway concept would be equally applicable to many other countries, if not all, and in the author's opinion it will be the marketing, economics, sustainability and consumer preferences that will be most under-researched or characterised.

The Interactive European Network for Industrial Crops and their Application (IENICA) project was funded by the EC to characterise markets and constraints (other, non-EU states also contribute). The project identified the probable causes for industry's poor uptake of biorenewables:

- Wide lack of awareness of opportunities – by farmers, processors and end users;
- Lack of financial need or incentive to change from existing systems or feedstocks;
- Investment in current technologies and lack of capital to re-tool;
- Lack of clear coherent policy for the development of the non-food renewables market;
- Lack of market organisation and guaranteed supply of primary products;
- Variability/quality in primary produce.

Clearly, any one individual action is unlikely to clear this "logjam", and a co-ordinated overarching and all-embracing response is needed.

Do real markets exist for biorenewables?

Undoubtedly significant markets do exist, as exemplified by Dow-Cargill initiatives with PLA (polyactic acid) polymers, which are at the commercialisation stage and which popular anecdote suggests are already in production at > 80 000 tonnes per annum.

Equally, uptake varies for a given market on a geographical basis. For example, Belgium appears to have made more use of vegetable-based printing inks than Scandinavia, Germany or the UK. Reasons for this are unclear.

Estimates of past and future biorenewables use worldwide (excluding energy) are shown in Tables 3 and 4.

Table 3. Anticipated growth: production of crop-derived products

(million tonnes)

	Global output 1998	Global output 2003	% Growth
Vegetable Oils	12.5	19.8	58
Starch	15.0	22.5	50
Non-Wood Fibres	23.4	28.4	21
TOTAL	**50.9**	**70.7**	**39**

Notes:
Vegetable oils: Projection based on forecast for EU growth (Source: FEDIOL [Fédération des industries Oléagineuses], Brussels).
Starch: Projection based on forecast EU growth (Source: National Starch).
Non- wood fibres: Projection based on Pira global forecast for pulp and paper use combined with EU figures for non- wood fibre production.

Source: IENICA Report, United Kingdom.

Table 4. Production of crop derived raw materials for industrial use

(million tonnes)

	Europe	United States	Global
Vegetable Oils	2.6	3.0	12.5
Starch	2.4	6.5	15.0
Non-Wood Fibres	0.5	3.0	23.4
TOTAL	**5.5**	**12.5**	**50.9**

Notes:
1. Practical Applications
   - Palm Oil / Soap
   - Starches / Paper Industry
   - Fibres / Paper Industry.
2. 1998 figures.

Source: IENICA Report, United Kingdom.

Indications of market size

The examples quoted are primarily EU-15 based and are derived from the IENICA project (data for Central and Eastern European Countries (CEEC); Israel; Canada; Switzerland and Cyprus will be published in late 2003). These data support the hypothesis that major unexploited opportunities exist in the biorenewables sector, excluding the energy sector.

Market opportunities

Oils

Overall usage of vegetable oils and animal fats in the non-food sector of the EU-15 is approximately 3 million tonnes per annum. This excludes biodiesel fuels. Key market sectors are lubricants, paints and surface coatings, surfactants and oleochemicals.

Considerable potential for expansion exists, including import substitution of both vegetable oils and tallow.

- ***Bio-lubricants*** – the potential EU market is approximately 370 000 tonnes per annum but less than 10% of that potential is exploited currently. There are significant environmental benefits in the use of bio-lubricants, where high environmental contamination occurs from the use of fossil fuel lubricants.

- ***Bio-printing inks*** – the EU market is in excess of 120 000 tonnes per annum. Belgium has made considerable progress in using vegetable-based printing inks, but elsewhere, particularly outside Scandinavia, the Netherlands and Germany, usage is very limited. There are no technical reasons for this lag in uptake.

- ***Bio-solvents*** – the EU solvent market is approximately 4 million tonnes per annum of which 1.9 million tonnes/annum are hydrocarbon solvents. Considerable health, environmental and security benefits would accrue from substituting vegetable-derived solvents for current fossil-derived materials. At least 12.5% of the total market could be vegetable-derived, but to date, less than 1.5% has been achieved.

- ***Linoleum*** – the EU demand for linoleum is likely to rise to 56 million m^2 by 2003. This will generate a 64% increase in linseed oil requirement, which could be produced in the EU. Total linseed oil usage in the linoleum market in Europe will therefore be 56 000 tonnes per annum.

- ***Surfactants*** – the EU market is currently in excess of 2 million tonnes per annum and increasing. By 2005, domestic household use of surfactants alone is likely to be 1.5 million tonnes per annum. However, expansion of surfactant production from bio-renewable sources originating in the EU is limited by the EU's inability to produce vegetable-derived short chain fatty acids (*e.g.* lauric acid). Alternative feedstocks for surfactants must therefore be obtained from other EU crop plants, since lauric acid derived from transgenic plants appears uneconomic in cool temperate regions.

- ***Polymers*** – the majority of polymers are derived from petroleum but certain products are based upon, or incorporate, vegetable oil-based derivatives. There appears to be considerable scope for expansion in the use of vegetable oils in polymer production. The most widely used natural polymer is erucamide, derived from High Erucic Acid Rapeseed (HEAR), used as a slip agent in polythene film.

- ***Paints and surface coatings*** – increasing use is being made of bio-solvents by the paint industry as well as the use of alkyl resins and varnishes based on vegetable oils.

Fibres

EU industry uses both domestically produced and imported fibres (*e.g.* jute). There would be considerable benefit to industry, in terms of quality and reliability of supply, if imported fibre would be substituted with domestically produced material.

In terms of specific sectors within the fibres market, clothing textiles form the traditional component, and novel uses (*e.g.* automotive parts), the new and developing component. The total clothing textiles market in Western Europe is projected as 7.9 million tonnes for 2001 with a 10% increase expected by 2006. Of the textiles market, approximately 40% is supplied by natural fibres, of which wool and cotton are dominant. Undoubtedly, small and perhaps valuable niche markets exist for hemp, flax and silk-derived textiles. In the case of the former two crops, progress in development will be enhanced by technological development, although cost and fashion trends will limit potential. It should be noted that small amounts of non-traditional short fibre flax are currently spun with wool. The future of this market requires examination.

The new fibres market sector includes matting-based products (*e.g.* simple filters, growth media, geo-textiles), which tend to be of lower value, and composites (*e.g.* automobile parts, building composites), which tend to be of higher value.

The automotive sector should be considered as a primary market driver for the short to medium-term future within Western Europe, producing about 18 million cars and light vans annually. Proven uses amount to 10 kg fibre per vehicle and potential likely uses in the same vehicles up to 10 kg fibre per vehicle more. A current estimate of the maximum market, based on existing automobile production, is 350 000 tonnes per annum of fibre, amounting to about 1 million tonnes of primary product. This could probably be scaled up three times for world markets.

In insulation products plant fibre is being used to replace glass fibre, giving health, energy and environmental benefits.

While the wood-based panel industry (producing particleboard, medium-density fibreboard etc.) is based on small roundwood and wood residues, there is some potential for substitution with annually cropped fibres. However, these will have to be price-competitive to obtain a market share.

Paper and pulp sectors provide options for utilisation of agricultural wastes (*e.g.* straw) or specially produced crops (*e.g.* reed canary grass, miscanthus). Market potential is virtually infinite but costs, processing scale and market instability limit progress. Similarly, to reduce costs and allow sustainable economic production, scientific and technological developments are essential in terms of cellulose content, impurities and exploitation of secondary metabolites.

Carbohydrates

Starch markets in the EU and elsewhere are well developed and organised.

Estimates of the total EU starch market for the year 2000/2001 were 7.3 million tonnes per annum, of which 3.7 million tonnes is in the non-food sector, 1.4 million tonnes in paper and cardboard manufacture, 1.1 million tonnes in plastics and detergents and 1.2 million tonnes in fermentation and other technical uses. Additionally, smaller markets exist in water purification, cosmetics, toiletries, pharmaceuticals, paints and agrochemicals. Several of these offer high potential for added value, but limited tonnage. The development of biodegradable plastics is currently very limited.

Speciality products

The speciality products sector offers considerable potential for biorenewables, often at high value (*e.g.* personal care products), but at relatively low volume. However the market is volatile, reacting rapidly to supply and demand changes. Specifications are frequently ill defined and processing/formulation details severely restricted because of commercial pressures. Quality control and traceability are becoming key issues for purchasers.

Market segments include:

- Essential oils;
- Pharmaceuticals;
- Popular health products;
- Colourants and dyes;
- Perfumes;
- Personal care/beauty products;
- Novel plant protection products;
- Intermediates for processing.

The essential oils markets worldwide are approximately 45 000 tonnes per annum and rising. However, that estimate includes an uncharacterised tonnage that cannot be produced within the EU. Aromatic plants have a world market in excess of 50 000 tonnes per annum. Estimates of medicinal plant markets are 70 000 tonnes per annum. In Europe, the combined aromatic and medicinal plants market amounts to 20-30 000 tonnes per annum. The market for herbal supplements is valued in excess of EUR 7 billion per annum and demand is increasing.

The global dyes market for textiles is in excess of 700 000 tonnes per annum, with an estimated market value in 2000 in excess of EUR 4.5 billion. It seems unlikely in the extreme that plant-derived dyes can supply anything more than a minor part of this market. However, that minor part could be a valuable niche market.

Where now?

There is a clear opportunity for producers to diversify land use and exploit potential new markets. This could help sustain rural economies, especially in economically developed countries. However, to be successful this will require:

1. Diversifying produce and maximising opportunities offered by cultivated and other plant species through exploitation of co-product streams;

2. Focussing on market needs in terms of tonnage and quality needs

3. Improving market awareness of opportunities as, currently, awareness is poor. This may include novel uses of biorenewables relative to "conventional materials"; economic advantages or legislative drivers allied to health and safety or environment;

4. Providing a clear indication of the political will or need to move to biorenewable feedstocks, where appropriate; and

5. Assessing/projecting the needs and opportunities for non-food products from land-based industry in the longer term, aligned with scientific and technological developments. This means that biotechnological opportunities; classical selection of new species for commercial development; green chemistry and processing, as well as conventional agriculture, all need to be linked into a projected "roadmap" for the medium and long-term future.

BIBLIOGRAPHY

Bonjean, A. (1995) *Le ricin,* Occasional publication, ONIDOL, Paris, France.

IENICA [Interactive European Network for Industrial Crops and their Application], an EC-funded concerted action, references QLK5-CT-2000-00111: FAIR CT96-1495, see the IENICA website at: www.ienica.net.

Rexen, F and L. Munck (1984), *Cereal Crops for Industrial Use in Europe*, EU Commission EUR 9617 EN, Brussels, Belgium.

Part I

BIOMASS AND AGRICULTURE: ECONOMIC, ENVIRONMENTAL AND SOCIAL DIMENSIONS

1. Economic Dimension

Page

The Triple Bottom Line Benefits of Bioenergy for the Community
Ralph E.H. Sims, Massey University, New Zealand *91*

International Energy Agency (IEA) Biofuels Study – Interim Report: Results and Key Messages So Far
Lew Fulton, International Energy Agency (IEA), France *105*

The Brazilian Ethanol Programme – Impacts on World Ethanol and Sugar Markets
Tatsuji Koizumi, Food and Agriculture Organization of the United Nations, Italy *113*

The Possibility of Agricultural Biomass Utilisation in Japan
Yukihiko Matsumura, Hiroshima University, Japan *129*

Energy Crops in Flemish Agriculture: Possibilities and Limits
Frank Nevens, Visi Garcia Cidad, Dirk Reheul and Erik Mathijs, Flemish Policy Research Centre for Sustainable Agriculture, Belgium *139*

THE TRIPLE BOTTOM LINE BENEFITS OF BIOENERGY FOR THE COMMUNITY

Ralph E.H. Sims[1]

Abstract

Sustainable production methods, waste minimisation, reduced vehicle pollution, conservation of native forests, rural employment, and reduction of greenhouse gas emissions are all gaining traction in OECD countries. Modern biomass has a role to play in each of these environmental and social drivers. There will be increasing opportunities in the future for biomass to be used in community-scale, environmentally sound, distributed energy systems. This includes the provision of fuel for micro-turbines, gas engines, co-generation plants and, in the longer term, to provide the hydrogen energy carrier necessary for running fuel cells. In all cases the level of greenhouse gas emissions is low or zero. Whether or not biomass used to provide energy services is economically viable as well as being truly renewable, sustainable and environmentally sound is determined by the source of biomass, land use, alternative treatments of organic wastes, and the type of energy conversion processes involved. The social benefits of bioenergy are not usually clearly presented when new bioenergy projects are proposed or analyses of existing plants are conducted, though they are just as important as the economic and environmental issues. In this paper, the social benefits are outlined with particular emphasis on employment creation in comparison with other renewables and with fossil fuel use. In countries where labour charges are relatively high, this can lead to higher costs for bioenergy; so in such cases high employment can be a barrier to biomass use. In developing countries where labour is abundant, the opposite is true. "Ownership" by stakeholders and local communities at an early stage in the development process is the key to successful project development in order to share the benefits.

Introduction

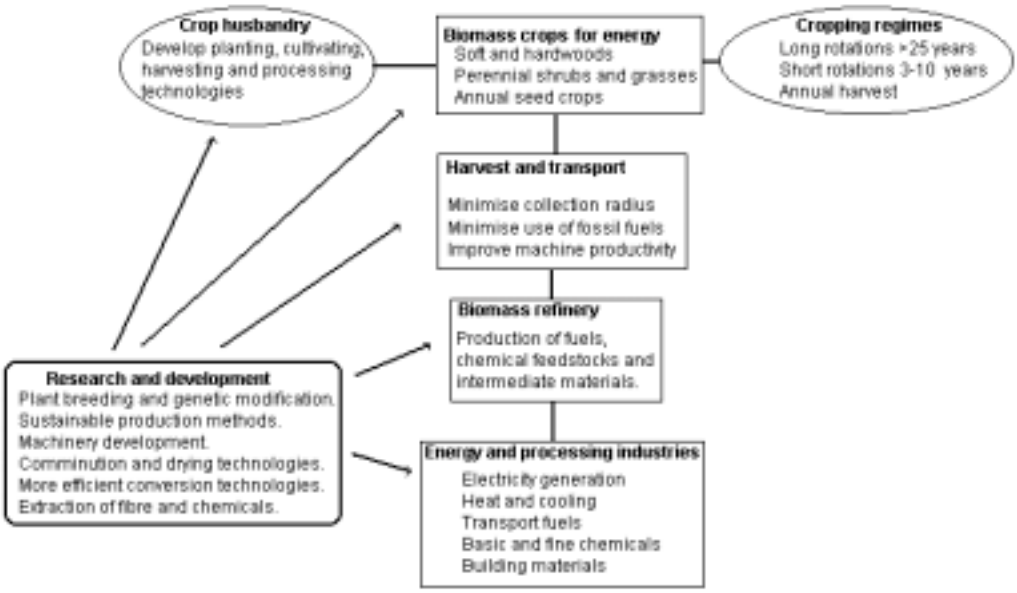
Past assessments of potential energy projects have been based mainly on the economic return on investment. The "triple bottom line" approach now being taken by many energy companies gives greater weighting to social and environmental issues. The triple bottom line potential of growing energy crops or using organic farm wastes to provide a source of biomass is complex. Considerably more research is needed to fully understand the technical and environmental benefits obtained when biomass is used to displace fossil fuels. For example, the integration of energy crop production and processing in order to provide a range of bioenergy services and biomaterial products is variable and Research and Development (R&D) inputs remain valuable to improve the system at all stages, as outlined in Figure 1. What is often lacking is recognition of the social benefits and barriers resulting from bioenergy project developments. The IEA Bioenergy Agreement, Task 29, has been established to improve this situation (IEA, 2003) and the work of that group is acknowledged. This paper attempts to highlight the need for analysing the economic, environmental and social issues when planning a bioenergy project.

1. Massey University, Palmerston North, New Zealand.

The *economic benefits* of biomass use are not always evident when competing with sources of coal, natural gas and oil, which all remain relatively cheap in most OECD countries. Conducting a full life-cycle analysis of a system which supplies agricultural crop residues, plantation forest residues, or energy crops as feedstock to a bioenergy conversion plant is necessary in order to adequately compare the economics with fossil fuel alternatives. This should include key factors such as the appropriate use of land; the methods of crop production; recycling of nutrients (partly through returning the ash from combustion to the land); methods of biomass collection and transport; types of conversion processes involved; and the assessment of any land, water or atmospheric emissions.

In waste-to-energy projects, disposal costs of the organic waste can be avoided by using the material as a biomass resource, thereby placing a negative cost on its disposal. Commercial viability of a bioenergy project can result. Many such examples exist, including numerous landfill gas projects and co-generation plants using bagasse or wood process residues through the combustion/steam cycle. For animal waste-to-energy processes, such as on-farm or rural community-scale biogas production, the treatment used and how it offsets other waste disposal methods are key factors in their implementation. Where the biomass waste product is dispersed, such as cereal straw or forest arisings (left in the forest after sawlog extraction), the cost of collection and transport to a central processing plant can be significant, though many commercial examples exist.

Figure 1. Examples of some research and development inputs that could improve the technical potential of producing a range of bioenergy services and bioproducts from purpose-grown energy crops



Source: Sims, 2002.

For relatively recent developments, such as growing short rotation coppice crops, producing biofuels for vehicles, gasifying woody biomass and implementing small-scale distributed generation bioenergy systems (Gigler and Sims, 2002), some form of government mechanism or subsidy is

usually necessary to encourage implementation of such bioenergy projects in view of the higher commercial risk. This would also be the case should biomass be used as a source of hydrogen once fuel cell development has matured and becomes commercially viable (Lovins *et al.*, 2002).

As with most other types of renewable energy, biomass is in competition with coal, gas and oil. This is often a significant commercial barrier, since externalities such as exploration costs and greenhouse gas emissions are currently excluded when calculating the costs of supply. When international carbon trading begins in earnest, and the carbon emissions from fossil fuels together with the carbon sink and offset values of biomass are fully recognised, then bioenergy will become a more competitive option. In addition, the environmental and social benefits and barriers will need to be fully assessed.

The *environmental benefits* which arise from the utilisation of biomass to provide heat, power, transport fuels, and alternative material feedstocks, thereby mitigating for greenhouse gases and substituting for industrial petro-chemicals and plastics, are reasonably well understood (IPCC, 2001). Where the biomass resource is in the form of an agricultural waste product or crop residue, any adverse environmental impacts from the conventional methods of treatment and disposal (such as dumping animal manures in waterways or burning straw in the field) can be avoided, at least in part, using one of the many possible waste-to-energy conversion routes.

When using any of the wide-ranging sources of biomass to displace fossil fuels, it can be shown, using full life-cycle analyses, that carbon dioxide emissions are largely avoided and the overall system is often carbon neutral or close to it. For example, a life-cycle assessment of the production of electricity in a biomass-fuelled integrated gasification combined cycle (BIGCC) plant showed 95% of carbon delivered was recycled (Mann and Spath, 1997). In addition to such carbon offset benefits, when growing forest energy crops such as short rotation coppice for bioethanol or biomethanol production (Adams and Sims, 2002), then the carbon sink benefits may also be realised, assuming the crops are established into existing pasture or arable land.

Biomass in various forms can also be used to fuel small-scale, environmentally sound, distributed generation systems such as those using Stirling engines, micro-turbines, gas engines, fuel cells, etc. (Gigler and Sims, 2002). In most cases, the level of greenhouse gas emissions would be relatively low or zero. However, where an energy crop is grown specifically and harvested, transported and processed into useful energy carriers or energy products, then the amount of essential fossil fuel-based energy inputs needs to be minimised. Such inputs can include diesel to fuel field machinery and transport vehicles, natural gas to provide heat for the processing operation, and electricity generated from thermal power stations to run the plant. In theory, all of these can be substituted by forms of renewable energy so that the overall system could then be truly carbon dioxide neutral.

The *social benefits* from modern biomass use relate to improved quality of life, lower emissions of human health-harming substances compared with fossil fuel use, local employment opportunities, pride in local community ownership, and social cohesion. For many rural communities, particularly indigenous people from developing countries, biomass has been traditionally used for cooking and heating. Since they are familiar with procuring biomass supplies, though at times in an unsustainable manner, the uptake of improved and more efficient modern biomass conversion technologies should therefore be relatively easy to implement. These include enclosed domestic firewood stoves and small power generating systems. For the many rural communities dependent on imported diesel to run generating sets, and for many others with no access to electricity at all, being able to use local biomass to provide not only electricity but heating, cooling, and even transport fuels will instil a sense of independence and pride.

It is clear that due to the dispersed nature of many renewable energy resources, the increased use of these technologies could bring socio-economic benefits to rural areas in OECD countries. This would serve to provide a stronger sense of "community" once again in agricultural areas that have been in recent decline, often resulting in the closing of local schools, hospitals, shops, public transport, mail deliveries, etc. It may also help to reduce the urban drift of young people that results in a lack of social cohesion within a community. If the community can become more self-sufficient in energy and therefore attract new businesses, there may be attractive reasons to stay (Sims and Richards, 2002).

It is not possible to cover here the specific environmental and social impacts of each of the numerous biomass conversion routes, to identify which of the systems are environmentally sound and which are less so, and to cover the social benefits and barriers for each. The issue is further complicated by the fact that environmental impacts are usually project-specific and therefore difficult to define in general terms. Details and case studies relating to several bioenergy technologies are, however, published elsewhere (Sims, 2002). The objective of this paper is to outline several key generic issues relating to biomass use and the resultant techno-economic, environmental and socio-economic impacts.

Technical and economic issues

Conversion of biomass resources into useful energy services and products can be undertaken using a wide range of technological pathways. Biomass projects can vary in scale from simple combustion in domestic open fires, to municipality-owned bio-fermentation processes for the treatment of organic waste materials, or to fully commercial complex thermo-chemical reactors in the form of 100 MW_e (megawatt power electricity) combined heat and power (CHP) stations. Details of many specific commercial examples of the various conversion technologies can be found in the proceedings of earlier European and world biomass conferences (European Biomass Conference, 2002). Hence this section will be relatively short.

New and improved bioenergy conversion technologies, such as gasification, pyrolysis and the enzymatic hydrolysis of lignocellulose, are being further developed to help solve some of the adverse environmental impacts from inefficient combustion or to overcome the slow and costly batch processing of biofuels. The goal should be to ensure that, once proven, these advanced processes are made available as "leapfrog technologies" for uptake in developing countries at prices they can afford in order to provide a more healthy and enjoyable quality of life. There is an opportunity for such projects to be developed under the Clean Development Mechanism of the Kyoto Protocol once it comes into force to help meet this goal.

Biomass resources and wastes are already widely distributed and people living even in poor rural communities are familiar with their use. However, in future the use of dung or firewood as a biomass resource will need to be managed in a more sustainable manner than at present. The challenge is to encourage the sustainable production of biomass together with the uptake of efficient conversion technologies, ranging from enclosed wood stoves with low smoke production to larger power plants with flue gas emission controls to minimise the production and emission of particulates and dioxins. This will take time, effort, investment and political will to achieve. However, as is clear from the IPCC Third Assessment Report (IPCC, 2001), biomass has a major role to play in meeting the linked global objectives of sustainability, equity and development.

Recent commercial developments of perhaps greater relevance to the forest industry than agriculture include biomass co-generation, co-firing in coal-fired boilers, and BIGCC units. Together with bioethanol production from the hydrolysis of lignocellulosic material, all show good technical and socio-economic potential, with co-firing possibly giving the lowest cost and technical risk. In all cases the capital investment costs continue to decline with project experience. For example, capital investment for a high-pressure, direct gasification combined-cycle plant of 20-30 MW_e-scale, running on woody biomass was estimated to fall from over USD 2 000/kW (kilowatt) five years ago to around USD 1 100/kW by 2030, with operating costs, including fuel supply, also declining from 3.98 US cents/kWh (kilowatt-hour) to 3.12 US cents/kWh (EPRI/DOE, 1997). However, the recent liquidation of the 10 MW_e BIGCC "Project ARBRE" plant in the United Kingdom, prior to completion of its full commissioning, has possibly set back these estimates. It will certainly have created a lack of confidence in the technology by the farmers contracted to grow short rotation willow coppice for 15 years.

Liquid and gaseous transport fuels derived from a range of biomass sources are available commercially in a number of countries. These "biofuels" include methanol, ethanol, di-methyl esters, pyrolytic oil, Fischer-Tropsch gasoline and distillate, and biodiesel from vegetable oil crops or tallow (Sims, 1995). Generally, biofuels can only become commercially competitive with continuing cheap crude oil products (at less than USD 30 per barrel) if significant government support is provided by way of fuel tax exemptions or direct subsidies. Such support in the form of modifying the excise tax laws is evident in Germany for biodiesel and is also currently being investigated by the Biodiesel Association of Australia (BDA, 2002), which points out the anomaly of 100% biodiesel transport fuel being exempt from excise tax whereas, if it is blended with even 1% of diesel, the mixed fuel becomes excised as if it were 100% mineral diesel.

The environmental benefits as compared with using petrol or diesel fuels can include reduced exhaust emissions in terms of carbon dioxide, NO_x and particulates, leading to reduced respiratory complaints for city dwellers and lower health bills. When a true value is placed on these benefits, then the biofuels will become more competitive.

Environmental benefits and barriers

The major environmental benefit from using biomass to displace fossil fuels is the reduction of greenhouse gas emissions (Table 1). Compared with the base case of building a new power station to burn pulverised coal for electricity generation, a bioenergy project can save both dollars and carbon emissions (IPCC, 2001). Other environmental benefits include reducing local emissions, using limited resources better, improving biodiversity, and protecting the natural habitat (including indigenous forests) and landscape. Growing and using short rotation forests can achieve all these benefits if planned and designed carefully. Reducing waste disposal into landfills and waterways; avoiding the noise, maintenance and inconvenience of diesel generating sets; and minimising the need for ugly power lines are other environmental benefits that the uptake of specific bioenergy projects can at times provide.

Conversely, under some circumstances other adverse environmental impacts can result, for example aldehyde emissions from bioethanol use. There are also questions still to be resolved by detailed life-cycle analysis concerning whether a positive energy ratio exists for some projects. Energy balance ratios for each unit of energy input required to produce solid fuels from short rotation forest crops can be up to 1:30 and even higher when crop residues are also utilised (Scholz, 1998). From the energy ratio analysis of a BIGCC plant, one unit of fossil fuel input produced approximately 16 units of carbon-neutral electricity exported to the grid (Mann and Spath, 1997). However, for biodiesel from

vegetable oil crops, a lower positive energy ratio of 1:3.2 (Korbitz, 1998) has been questioned by Ulgiati *et al.* (1994) and, more recently, by Pimental (2001), who showed the energy balance of biomass is not always favourable, especially for biofuels produced from annual energy crops.

Environmental barriers and their mitigation

- There is a lack of information available to potential bioenergy plant investors regarding environmental effects and many rely on their own limited knowledge rather than seek and pay for quality advice. In addition, relatively few senior business managers possess good information about their own processing plant, its energy requirements and the emissions. So there is a need to publish information that will assist investors make appropriate equipment selection.
- Monocultural production of energy crops is deemed unacceptable by many environmental agencies and there could be public rejection due to changing landscape values and lack of biodiversity. Planting a mix of species is sometimes worth considering, not only for landscape benefits, but also for added resistance to the spread of pests and diseases, and to provide a supply of fuel over a longer seasonal period.
- Continuous large-scale production of forest plantations and energy crops could reduce soil fertility levels, impact on downstream water use, and lead to leaching of nutrients and increased use of agri-chemicals. Nutrient recycling through the return of the combustion ash and sustainable crop production methods should be practised.
- For wastes or woody biomass produced from perennial crops the energy output is usually at least 10 to 20 times greater than the energy input. Other systems may have negative energy ratios and detailed analysis should be undertaken.

Table 1. Cost ranges for greenhouse gas reduction technologies compared with a conventional coal-fired power plant, and the relative costs of carbon reduction

Power station type	**Carbon emissions**	**Emission savings**	**Generating costs**	**Carbon avoided**
	(gC/kWh)*	(gC/kWh)	(US cents/kWh)	(USD/tonne)
Pulverised coal – as base case	229		4.9	
Integrated gasification combined cycle (IGCC) – coal	190 – 198	31 – 40	3.6 – 6.0	-10 – 40
Pulverised coal + CO_2 capture	40-50	179-189	7.4-10.6	136 –165
Combined cycle gas turbine (CCGT) – natural gas	103 – 122	107 – 126	4.9 – 6.9	0 – 156
CCGT gas + CO_2 capture	14 – 18	211 – 215	6.4 – 8.4	71 – 165
Hydro	0	229	4.2 – 7.8	-31 – 127
Bioenergy IGCC – wood wastes	0	229	2.8 – 7.6[1]	-92 – 117
Wind – good to medium sites	0	229	3.0 – 8.0	-82 – 135
Solar thermal and solar photovoltaic (PV)	0	229	8.7 – 40.0	175 – 1400

*gC/kWh: grams of carbon released/kWh of electricity generated

Note:

1. Biomass fuels delivered to the power plant range from USD 0/GJ (gigajoules) for on-site waste requiring disposal costs, to USD 4/GJ for purpose- grown energy crops.

Source: Sims *et al.*, 2003.

- The collection and transport of biomass often results in increased use of vehicles, higher exhaust air emissions and greater wear and tear on the road infrastructure. Producing the biomass close to the conversion plant minimises these transport impacts.

- Land requirements for future energy crop and forest plantations will compete with land used for the traditional production of food and fibre products. It could also encourage further land-clearing of indigenous forests which should be avoided at all costs. The land area required will ultimately depend on biomass crop yields as achieved on a sustainable basis, water availability, and the efficiency of the conversion plant. For example, for a steam turbine plant with an overall 20% system efficiency, if fuelled by a miscanthus crop yielding 15 oven dry tonnes (odt)/ha/year, then 360 ha would need to be planted per MW_e of installed capacity if operating the plant for 6 000 hours per year at around 70% capacity factor. If a 40% efficiency gasification plant was built instead and crop yields rose to 20 odt/ha/year, then only 135 ha would be needed per MW_e.

Social benefits and barriers

Whilst the environmental benefits of renewable energy, including bioenergy, are widely accepted, the socio-economic benefits are not so well understood. Investment in renewable energy technologies can usually provide benefits to the whole macro-economy by creating jobs and improving social welfare. From the social perspective there can be little doubt that bioenergy projects protect existing employment, provide new jobs, give learning opportunities, transfer skills, introduce new skills, and provide training and educational opportunities. In addition, the trend towards distributed energy systems and independent power production using smaller-scale plants and embedded generation should result in a decline in urban drift, once rural communities are able to develop and grow using the new sources of bioenergy available to them. This in turn will produce a sense of pride and independence, which is of particular importance to many indigenous or aboriginal communities who are struggling to maintain their cultural identities (IEA, 2003).

Employment opportunities

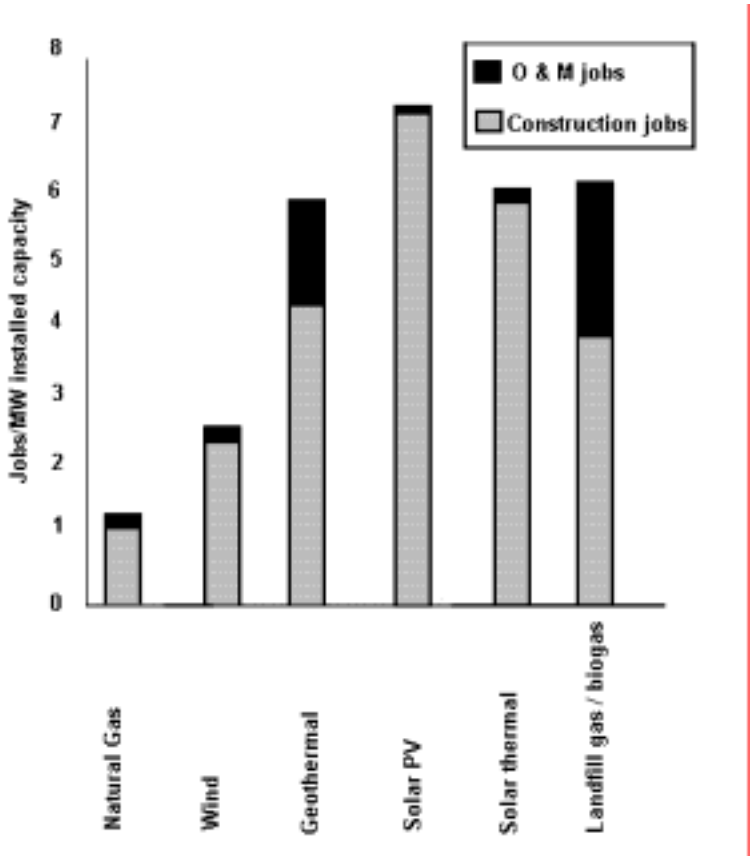
In general, renewable energy systems are more labour intensive than fossil fuel systems and a higher proportion of the jobs are relatively highly skilled. To operate and maintain bioenergy plants and provide the fuel, employment opportunities are often created, particularly in rural areas, bringing a new perspective to rural communities. (The following discussion is partly based on an unpublished IEA report, “Employment benefits of renewable energies”.)

Bioenergy project employment differs from wind, hydro and solar projects where the work activities mainly consist of plant manufacturing, installation and maintenance. Providing the biomass fuel supply and delivering it to the conversion plant is an essential additional component of bioenergy. Therefore the plant construction jobs tend to be in a smaller proportion relative to the on-going operation and maintenance jobs, when compared with other renewables (Figure 2).

In all cases the renewable energy generation plants required more staff for both the construction phase and the operation and maintenance phase than did the natural gas combined cycle plant. This is advantageous in areas where employment is a major political concern, but since labour is often expensive, then it is a major reason why renewable energy projects often find difficulty in competing on an economic basis.

Labour requirements for renewable energy technologies are usually assessed in terms of full-time equivalent (FTE) labour units per MW of installed capacity, or FTE per million dollars of capital investment. However, since the plant capacity factors vary considerably between generation plants such as bioenergy (typically 80%), wind (30-40%) and photovoltaics (20-30%), these metrics have limited value. A recent Australian study undertaken for SEDA (the Sustainable Energy Development Authority of New South Wales) covered labour demand for a range of renewable energy technologies (ACIL, 2002) but concentrated mainly on jobs/MW installed, and therefore had limited application. Also, several of the bioenergy technologies are developing rapidly down their learning or "experience" curves so that future labour demands for operation and maintenance may be significantly lower than at present. Therefore labour requirements would be more usefully measured as "*FTE per MWh generated*" following consideration of the whole life-cycle analysis of a project.

Figure 2. Construction jobs and operation and maintenance jobs per MW of installed power generating capacity for several renewable energy technologies compared with a natural gas plant



Note: O and M: operation and maintenance.
Source: Based on Heavner and Churchill, 2002.

A further anomaly in employment studies occurs when the labour demand for a renewable energy project is compared directly with using traditional fossil fuels to supply the same energy output. Often ignored is the fact that the coal, oil and gas sectors are also striving for cost reductions in order to compete. So they, too, are reducing the job numbers that were previously essential for their businesses.

In addition, a decline in fossil fuel demand in the future will result in further job losses. This has already occurred in the West European coal industry, where direct employment in coal mining decreased from 1.8 million jobs in the 1950s to around 100 000 at present (IEA, 2001). Direct jobs for installation, operation and maintenance of projects, together with indirect jobs for manufacturing the equipment and financing of projects, and local employment resulting from the multiplier effect for shops, cafés, etc., need to be taken into account when comparing labour inputs.

Obtaining employment statistics by sector is very difficult for renewables at present as few countries classify them separately. For example, in the International Standard Industrial Classification (ISIC, 2002) wind turbine manufacturing comes under "engines and turbines" and photovoltaic cell manufacturing under "electronic valves"! In the last century, the advent of motor vehicles, aviation transport and computers created high employment opportunities. If the renewable energy industry continues to grow at the present rapid rate, then it too could warrant separate collection of national employment statistics in this sector.

Claims for employment resulting from bioenergy projects include 4 200 employed in Denmark as a result of the 27 community biogas plants; 6 840 in the French biofuels sector (mainly bioethanol); 26 000 in Finland, working mainly on forest-based bioenergy; 15 000 in Austria, working on the same; and 125 in Sweden per 1PJ (petajoule) of primary woody biomass energy delivered. It is not clear whether these figures all account for the additional work necessary within the forestry and agricultural sectors to produce the biomass.

Other studies (also unpublished) have shown that the FTE staffing needed to operate and maintain conventional gas or coal-fired plants ranges between 1 to 6 per 100 GWh of electricity generated per year (Figure 3). By comparison, wind farms would require 15-20 labour units/ 100 GWh/year; solar PV, 50-54/100 GWh/year; solar thermal, 25-27/100 GWh/year; and small hydro, 8-9/100 GWh/year. Bioenergy projects would need around 42 personnel/100 GWh/year to provide sufficient biomass fuel supplies at the plant if obtained from energy crops; 10 if from collected forest residues, or 36 if from agricultural wastes. A further 22 staff would be needed to run sufficient biogas plants to generate 100 GWh in a year, or 8 if operating combustion/steam turbine plants, or 9 for wood gasification plants, where closer supervision is needed. To produce liquid biofuels would require even higher staff numbers for the same energy output equivalent.

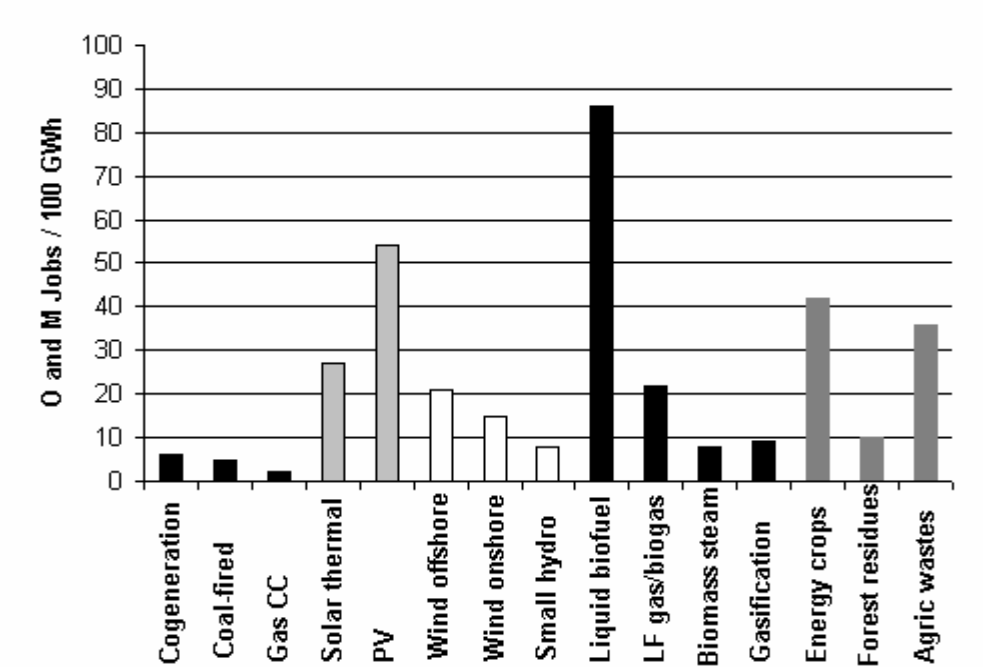
Social barriers and their mitigation

- Health problems, arising from poorly designed bioenergy plants which produce high levels of particulate emissions or from open fires in developing countries, can be overcome by proper installation of clean burning combustors that meet modern air emission standards.

- There may be a future shortage of semi-skilled workers for the harvesting and collection of large volumes of biomass and, to a lesser degree, for maintaining and operating the conversion plants. Although employment opportunities from greater bioenergy uptake are often quoted, finding willing workers for what can be somewhat arduous and repetitive work may not be easy in either developed or developing countries.

- The general public often views biomass plants as dirty, polluting and unhealthy. This is largely based on the image of older, poorly designed burners, poorly managed landfill tips, etc. An education campaign to demonstrate that modern biomass plants are much improved in these regards may be needed in some regions.

Figure 3. Number of FTE labour units needed to operate and maintain a range of power plants per 100 GWh of electricity generated yearly or to produce a similar energy equivalent of liquid biofuels



Note: O and M: operation and maintenance.
Source: Based on IEA unpublished data.

Good practice guidelines

In order to promote the triple bottom line benefits of a newly planned bioenergy plant to a local community, considerable consultation is often required in order to obtain a resource consent to enable the project to proceed. This can be a lengthy and costly exercise, particularly where objections are lodged by local residents, planning authorities or other concerned parties. Once the full benefits of the project have been made clear to all the stakeholders, approval is generally granted, unless there is a good reason not to do so.

To avoid the need to present all the information and repeat the arguments in detail at each resource consent hearing or when undergoing a new series of consultations, the British Biogen Association, in association with the UK's Energy Technology Support Unit of the Department of Trade and Industry (ETSU), developed a series of biomass project guidelines based on a consensus process with all relevant stakeholder groups. These included environmental organisations, equipment manufacturers, project developers, utilities, resource planner associations, transport organisations, landowner associations, etc. Separate guidelines for short rotation coppice, woody biomass and anaerobic digestion were produced (ETSU, 1996). Each took several months of meetings, report drafts, reviews and revisions, until there was full agreement on the content. The logos of all the stakeholders then appeared inside the front cover to show their endorsement of the benefits and impacts as outlined. The technical, environmental, economic and social issues were all covered in each guideline.

This approach takes time and money initially to prepare the material but it can result in considerable savings to the bioenergy industry in the longer term. Once members of a local community take "ownership" of a project due to the benefits that may accrue directly to them, then the planning process becomes easier. The timing of this first consultation is critical in order to avoid unnecessary speculation based on having insufficient information to pass on at the very early stages of development, or to avert the view that the project is a *fait accompli* and the consultation process is just a token gesture. Educating the local stakeholders by providing general guidelines which highlight potential environmental and social benefits, but give a true understanding of the negative issues, would be a good start to the process.

Conclusions

Biomass will continue to supply an increasing demand of consumer energy for heat, electricity, biofuels for transport and bio-materials over the next few decades in many countries, but it is not always produced in an ecologically sustainable manner and it can also have adverse environmental impacts. As the carbon dioxide mitigation benefits of biomass become better understood by investors and international carbon emission trading begins, there is likely to be a significant increase in the total installed capacity of biomass-fuelled plants. Within the wide range of commercial and developing bioenergy technologies are many that, after careful life-cycle analysis, could be classified as environmentally sound. Others create major environmental impacts. The difficulty is that bioenergy projects are very fuel- and site-specific in this regard. Establishing a set of standard project guidelines for use by environmental consenting and project funding agencies to, at least, indicate the key points that need to be considered for each of a range of bioenergy technologies could be a useful approach.

The social benefits resulting from greater bioenergy use will become apparent as distributed energy systems become more widely accepted as reliable and safe sources of providing energy services. Rural communities currently in a mode of decay, following the general decline in commodity values for the global agricultural sector, could well be revitalised due to the employment prospects that renewable energy systems, particularly bioenergy, could bring.

For bioenergy projects to be successful in the longer term, their full value in terms of environmental, economic and social benefits needs to be included in any comparative assessment with fossil fuel alternatives.

BIBLIOGRAPHY

ACIL (2002), *Employment indicators for Australia's renewable energy industries,* ACIL Consulting Pty. Ltd., Canberra, Australia: www.seda.gov.au/pdf/employmentindicators.pdf.

Adams, J.F. and R.E.H. Sims (2002), *Methanol production and other liquid fuels from biomass via gasification at both the large and small scale,* Internal report, Centre for Energy Research, Massey University, Palmerston North, New Zealand.

BDA [Biodiesel Association of Australia] (2002): www.biodiesel.org.au.

EPRI/DOE [Electric Power Research Institute/US Department of Energy] (1997), *Renewable energy technology characterizations*, Report EPRI TR-109496, Washington, D.C., United States, December.

ETSU [Energy Technology Support Unit (now Future Energy Solutions)] (1997), Good Practice Guidelines, *A Series on Anaerobic Digestion, Short Rotation Coppice and Forest Residues*, Department of Trade and Industry, Harwell, Oxfordshire, United Kingdom.

European Biomass Conference (2002), *Biomass for Energy, Industry and Climate Protection*, 12th European Conference, Amsterdam, the Netherlands, June, ETA, Florence, Italy and WIP, Munich, Germany.

Gigler, J. and R.E.H. Sims (2002), "The brilliance of bioenergy – small projects using biomass", *Renewable Energy World*, James & James Science Publishers, London, United Kingdom, Vol. 5, No. 1, pp. 56-63.

Heavner, B. and S. Churchill (2002), *Renewables work - job growth from renewable energy development in California*, Californian Public Interest Research Group (CALPIRG), Los Angeles, United States, June: www.calpirg.org/reports/renewableswork.pdf.

IEA [International Energy Agency] (2001), *Experiences from coal industry restructuring*, Paris, France: www.iea-coal.org.uk/pdffiles/pf01-05.pdf.

IEA (2003), *Socio-economic aspects of bioenergy systems* IEA Bioenergy Agreement, Activity 29, IEA, Paris, France: www.eihp.hr/task29.htm.

IPCC [Intergovernmental Panel on Climate Change] (2001), Third Assessment Report, *Climate Change 2001: Mitigation*, Cambridge University Press, United Kingdom: www.ipcc.ch.

ISIC [International Standard Industrial Classification] (2002): www.unstats.un.org/unsd/cr/registry/regcst.asp?Cl=17.

Korbitz, W. (1998), "Biodiesel – from the field to the fast lane", *Renewable Energy World*, Vol. 1, No. 3, pp. 32-37, James & James Scientific Publishers, London, United Kingdom.

Lovins, A. *et al.* (2002), *Small is profitable*, Rocky Mountain Institute, Colorado, United States: www.smallisprofitable.org.

Mann, M.K. and P.L. Spath (1997), *Life cycle assessment of a biomass gasification combined-cycle system*, National Renewable Energy Laboratory, Report NREL/TP-430-23076 for the US Department of Energy: www.eren.doe.gov/biopower/life_cycle.html.

Pimental, D. (2001), *Biomass utilization, limits of*, Encyclopaedia of Physical Sciences and Technology, Third Edition, Vol. 2, Academic Press.

Scholz, V. (1998), "Energy balance of solid biofuels", *Sustainable Agriculture for Food, Energy and Industry*, James & James Science Publishers, London, United Kingdom, pp. 861-866.

Sims, R.E.H. (1995), *The biodiesel research programme of New Zealand*, Proceedings of the 2nd Biomass Conference of the Americas, Oregon, pp. 849-858, National Renewable Energy Laboratory, Golden Colorado.

Sims, R.E.H. (2002), *The brilliance of bioenergy – in business and in practice,* James & James Science Publishers, London, United Kingdom.

Sims, R.E.H. and K.M. Richards (2002), *Delivering the bioenergy triple bottom line to the global community*, Proceedings of the World Renewable Energy Congress, Cologne, July.

Sims, R.E.H., H.-H. Rogner and K. Gregory (2003), "Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation", *Energy Policy* 31, pp. 1 315-1 326.

Ulgiati, S., S. Bastianoni, L. Nobili and E. Tiezzi (1994), *A thermodynamic assessment of biodiesel production from oil seed crops. Energy analysis and environmental loading*, Proceedings of the Dedicated Conferences on: Electric Hybrid and Alternative Fuel Vehicles and Supercars, 27th International Society of Alternative Transport Authority, ENEA, pp. 477-489.

INTERNATIONAL ENERGY AGENCY (IEA) BIOFUELS STUDY – INTERIM REPORT: RESULTS AND KEY MESSAGES SO FAR

Lew Fulton[1]

Abstract

At present, it can be concluded that given current commercial technologies available for producing biofuels, and given the costs of growing the feedstocks in North America and the European Union, increased production of biofuels will likely provide a variety of private and social benefits. Whether these benefits will exceed the fairly high costs of biofuels production, however, is not clear. If technology improvement and cost-reduction goals can be achieved – in particular those technologies designed to efficiently convert cellulosic materials to alcohol – then the effective resource base for biofuels would increase substantially and the net benefits of increased production of biofuels in the future could become strongly positive. If, in addition, the resource base for biofuel feedstocks were expanded beyond the borders of the United States, Canada, and the European Union (for example, by drawing on feedstock production potential from developing countries), then the costs of biofuels could drop substantially and their total potential for oil displacement could increase substantially. This latter point is not explored in detail, but will be addressed during the next phase of analysis undertaken as part of this project.

Interim report on IEA Biofuels Study

This paper provides an interim report on IEA's on-going study of liquid biofuels for transport. It summarizes work so far, which has focused primarily on ethanol and biodiesel as transportation fuels in North America and the European Union (EU). It focuses in particular on the availability, cost, and potential energy and greenhouse-gas impacts of increased use of these fuels. Currently, the production of biofuels is quite small in nearly every country studied. The largest production, by far, is of ethanol in the United States (the US and Brazil produce similar amounts of ethanol, many times more than any other country), but the EU, the US and Canada are all giving serious consideration to adopting policies that would require, or strongly encourage, dramatic increases in production and use of biofuels over the next 5-10 years. This paper summarizes the findings in terms of availability, cost, and potential benefits of liquid biofuels in this context. IEA (2004, forthcoming) can be consulted for fuller details of our analysis.

The principal findings and conclusions, so far, are outlined below in point form.

- **Biofuels use is growing rapidly**. Although biofuels still account for only a small percentage of motor fuels in both North America and the EU (no more than 1% on an energy-basis in any country in these regions), their use is growing rapidly and could increase dramatically over the coming decade. This growth is driven by a number of factors, not least by pending

1. International Energy Agency, Paris, France.

legislation in both the US and EU that could require much greater use. (Note that comparisons of biofuels and conventional transport fuels on an "energy basis" will generally be used throughout this report, except where otherwise indicated. Since ethanol has only about ⅔ as much energy per litre as gasoline, an energy equivalent litre is 50% more ethanol than gasoline on a volume basis. Biodiesel has about 12% less energy per litre than diesel.)

- **There are several driving forces for biofuels use**. In both the US and EU, there are similar driving forces for increased use of liquid biofuels in transport. Among these are the need for gasoline octane enhancement (and restrictions on some alternative lower-cost octane boosters) to meet vehicle requirements; the need for oxygenates to help meet emission control requirements in some areas; a desire to lower dependence on imported petroleum; a desire to reduce the overall ("well-to-wheels") greenhouse gas (GHG) emissions associated with motor vehicles; and a desire to expand the markets for domestic agricultural products like grains and oilseed crops.

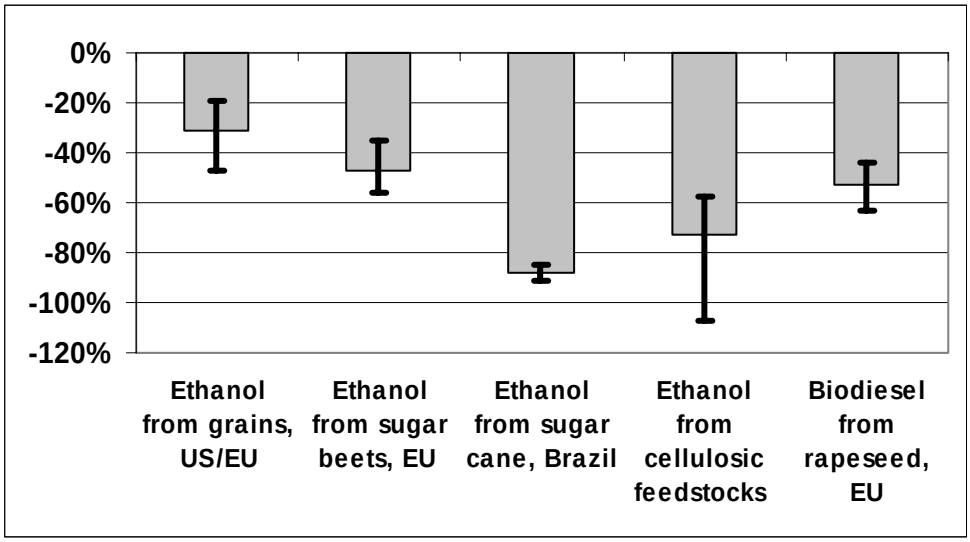
- **Conventional biofuels can provide a number of benefits**. Ethanol and biodiesel derived from common grain and oilseed crops (respectively), using conventional production and conversion techniques, provide significant benefits in the following areas:

  - **Reductions in oil use**. Production of ethanol and biodiesel generally yield net energy increases (*i.e.* more energy embodied in the biofuel than in the fossil energy required to produce it). Studies vary on the amount of fossil energy required to produce one litre of ethanol and biodiesel, but most studies of current processes in North America and the EU estimate that there is a significant net energy gain. More importantly, most process energy is not petroleum-derived (it is natural gas and electricity) and thus the displacement of petroleum per litre of produced biofuels is substantial. On average, it appears that five litres of ethanol displaces about four litres of oil (*i.e.* that about one litre of oil goes into making five litres of ethanol, for crop fertilizer, tractor fuel, feedstock transport, etc.).

  - **Reductions in greenhouse gas emissions**. Ethanol and biodiesel provide significant reductions in greenhouse gas emissions compared to gasoline and diesel fuel, on a "well-to-wheels" basis (Figure 1). While a range of estimates exists, Figure 1 shows that most studies reviewed find significant net reductions in CO_2-equivalent emissions for both types of biofuels. More recent studies tend to make estimates toward the higher-reduction end of the range, reflecting efficiency improvements over time in both crop production and ethanol conversion. Few studies exist for sugarcane-to-ethanol, and the variation reported in these studies is small.

  - **Air quality and waste reduction benefits.** In addition to their oil displacement and greenhouse gas reduction benefits, biofuels also can provide air quality benefits when blended with petroleum fuels. Benefits from ethanol blending include lower emissions of carbon monoxide (CO), hydrocarbons (HC), sulphur dioxide (SO) and particulate matter. Benefits from biodiesel include all these plus lower particulate emissions. Biofuels are generally less toxic than conventional petroleum fuels and in some cases they feature the benefit of reducing waste through recycling – in particular waste oils and grease which can be converted to biodiesel. However, the use of biofuels can also lead to increases in some emissions, such as increased aldehyde emissions from use of ethanol.

Figure 1. Range of estimated greenhouse gas reductions from biofuels



Note:
Relative well-to-wheels CO_2-equivalent GHG emissions per kilometre from vehicles with various biofuel/feedstock combinations, compared to similar conventional-fuelled vehicles.
Source: Author literature review.

- **Vehicle performance benefits**. Ethanol has a very high octane number and can be used to increase the octane of gasoline. It has not traditionally been the first choice for octane enhancement due to its relatively high cost, but other options such increasingly out of favour (lead is banned and methyl tertiary butyl ether [MTBE] is being discouraged or banned in an increasing number of countries) and demand for ethanol for this purpose (and as an oxygenate) is on the rise in places such as California. In Europe, ethanol is typically converted to ethyl tertiary butyl ether (ETBE) before being blended with gasoline. ETBE provides high octane with lower volatility than ethanol.

- **Agricultural benefits**. Production of biofuels from crops such as corn and wheat (for ethanol) and soyabeans and rapeseed (for biodiesel) provides a new product market for farmers and can increase farming revenues substantially. Production of biofuels tends to draw crops away from other purposes (such as animal feed) and increase their price, which also can lead to higher farm incomes. On the other hand, higher crop and feed prices can translate into higher food prices for consumers. Whether the net benefit to farmers is greater than the costs to consumers (and taking into account other factors, such as balance-of-payments impacts) is a complicated and controversial question. No consensus exists on the answer.

Table 1. Estimates of crop and land requirements to achieve near-term biofuels production targets

SCENARIO	UNITED STATES				EUROPEAN UNION			
	Ethanol / Gasoline		Biodiesel / Diesel		Ethanol / Gasoline		Biodiesel / Diesel	
	2005	2010	2005	2010	2005	2010	2005	2010
	Triple current ethanol production by 2005; assume similar to EU for 2010 for comparison; assume similar shares for biodiesel in diesel				*Proposed EU targets for ethanol; assume similar shares for biodiesel in diesel*			
Biofuel share of relevant road transport fuel (energy basis)	2.4%	5.8%	2.4%	5.8%	2.0%	5.8%	2.0%	5.8%
Biofuel share (volume basis)	3.5%	8.6%	2.7%	6.7%	3.0%	8.5%	2.3%	6.6%
Gasoline/diesel displacement under scenario (billion litres)	12.5	33.4	4.1	11.5	2.9	8.2	3.2	10.0
Required biofuel production under scenario (billion litres)	18.5	49.4	4.7	13.2	4.3	12.1	3.6	11.5
Percentage of current biofuels crops needed to produce biofuels in scenario	17.6%	42.8%	27.1%	70.8%	7.4%	20.0%	68.9%	200.5%
Percentage of total cropland area needed to produce biofuels crops in scenario	5.5%	13.4%	7.9%	21.0%	4.6%	12.3%	6.5%	21.2%

Note:
See 2004, forthcoming IEA book, *Biofuels for Transport: and International Perspective*, for more details. Target displacements chosen to relate to recent policy proposals in the US (for 2005) and EU (for 2005 and 2010). Assumes growth in demand for gasoline and diesel fuel.
Source: IEA analysis; agricultural data mainly from USDA and EU-DG-Agriculture.

- **Estimating the net benefits from biofuels is difficult**. Even taking into account all of the benefits described above, it is unclear whether, at present, expansion in the use of biofuels will provide net benefits to a country. This is mainly because both ethanol and biodiesel are quite expensive. Whether their high cost is more than offset by their benefits depends in part on how the various benefits are valued. In particular, the monetary value of oil displacement, greenhouse gas reductions, and air quality benefits are all uncertain and controversial. Another area of uncertainty and complexity is the macroeconomic impacts of biofuels use; for example, the net effects of their higher costs to consumers – but increased revenues for farmers – on the economy as a whole. Some studies have concluded that increased production of biofuels will likely result in net benefits, others estimate that there will be net costs.

- **Near-term ethanol production targets appear achievable from a land-availability perspective**. Taking into account the current and expected future production of crops currently used as feedstocks for ethanol (corn in North America and corn, wheat, barley and sugarbeet in the EU), and given current and expected near term production and conversion technologies, it appears possible to displace 5% of gasoline fuel with ethanol over the next 10 years without major disruptions to domestic crop markets or food supplies, although crop prices may increase. As shown in Table 1, it is estimated that in North America about 17% of the expected corn crop, or about 6% of total cropland, would be needed in 2005 to allow a tripling of ethanol production (with a displacement of about 2% of gasoline in that year). These percentages would need to increase by about 2.5 times in order to reach 5% gasoline displacement by 2010. In the EU, displacing 2% of gasoline by 2005 would take about 7% of cropland; reaching 5.75% (as per the targets mentioned in the EU draft directive) in 2010 would require about 20%. In both cases, it is very likely that additional land would be brought under cultivation of biofuels crops, or that new crops (such as wheat in the US) would begin to be grown for biofuels production. In any case, the net impact on total production of different crops, and on the prices of these crops, is difficult to predict.

- **Aggressive production targets for biodiesel may be more problematic**. For biodiesel, the required crop requirements to meet similar targets would be greater for several reasons: First, the yield of biodiesel per hectare of land used to grow feedstock (especially soy) is typically much lower than for ethanol with ethanol crops. Second, diesel demand, particularly in the EU, is expected to grow rapidly over the next ten years. Finally, again particularly for the EU, the land area allocated to producing potential biodiesel feedstocks (such as soyabeans and rapeseed) is currently quite limited. The EU has begun to use set-aside land for the production of rapeseed for biodiesel; if all set-aside land were used this way, about 2% of EU motor diesel could be displaced with biodiesel. In both the EU and the US, it would take about 21% of total cropland area to produce enough biodiesel to displace 5% of diesel fuel in 2010, compared to 12-13% of cropland to produce enough ethanol to displace 5% of gasoline. Biodiesel can also be produced with waste oils, though it appears unlikely that enough waste oil will be available to displace more than 1-2% of diesel fuel in the US or the EU.

- **Biofuels' blendability is an important advantage compared to most other alternative fuels**. Both ethanol and biodiesel can be blended with their conventional fuel counterparts (gasoline and diesel fuel, respectively) and used in today's vehicles. Few other alternative fuels offer that convenience. Biodiesel is typically blended with conventional diesel up to 20%, but can be blended up to 100% without problem (and is in some places). Ethanol can be blended with gasoline up to at least 10% in conventional vehicles, and to much higher levels in vehicles that have had minor modifications to the engine and refuelling systems. Indeed, it is somewhat unclear why most manufacturers do not warrant their conventional

vehicles for ethanol blends above 10% by volume, or why governments are not pushing harder for this (since, for example, it may be cheaper to hit certain consumption targets by increasing the blend above 10% in focused areas rather than go to 10% blends in wider areas). A number of studies suggest that conventional vehicles may experience few problems on ethanol blends up to 20% or even 30%. More testing work is needed in this area.

- **Domestically-produced biofuels in IEA countries are still relatively expensive**. Using today's technology, and produced in the US, Canada or the EU, conventional (grain) ethanol and biodiesel are still quite expensive relative to gasoline, on the order of two-to-three times the delivered cost of gasoline and diesel. However, biofuel production costs have dropped somewhat over the past decade and probably will continue to drop, albeit slowly, in the future. It is unlikely, however, that the production cost of these fuels will drop below the cost of gasoline and diesel unless there are large increases in world oil prices because the technologies are mature and not much additional reduction in production costs can be expected. Future technologies or changes in where biofuels crops are grown (or where biofuels are produced) could change this.

- **Advanced ethanol feedstocks and conversion processes hold promise**. Ethanol from new types of feedstocks, namely lignocellulosic (grasses and woody plants) produced by using new conversion technologies, appears capable of much greater reductions in well-to-wheel greenhouse gases than does conventional ethanol. Reductions of more than 100% appear possible (taking into account credits for co-production of electricity and other products). There also may be a much larger potential land-base for growing cellulosic crops than there is for grain and oilseed crops.

- **A key research goal: fully developing cellulosic conversion technologies.** Research efforts are underway to develop methods to convert cellulosic materials, such as grasses and woody crops, to ethanol (by first breaking the cellulose down into sugars). These efforts hold great promise for several reasons. First, there are far greater potential resources of cellulosic biomass than of grains and sugars, both because grains and sugar crops also contain substantial amounts of cellulose (that currently are not used) and because many types of land that are not suitable for grain and sugar crops can be used to grow cellulosic crops. Second, using cellulosic crops to produce fuels would not compete directly with their use for food and feed production. Third, the advanced production and conversion process under development for cellulose can provide far greater fossil energy displacement and greenhouse gas reductions than can grains under current practice. Finally, if research targets can be met, reductions in conversion cost for cellulosic ethanol could eventually make it much cheaper to produce than grain ethanol, at least in North America and the EU.

- **New directions in cellulosic research are being pursued**. Throughout the 1990s the targeted cost reductions for cellulosic ethanol were slow to materialise, and it now appears unlikely that significant production of ethanol from cellulosic feedstock will occur before 2010. While it is unclear to what extent this is due to under-funding of research, to more time needed for development, or to inherent limitations in technology (or to cost reductions of technology), emphasis in the US biofuels research programme has shifted since 2000. Recent work has focused on developing test production facilities that produce a variety of outputs (sometimes called "bio-refineries"), including co-generated electricity and other productions besides liquid biofuels, from primarily cellulosic inputs in order to improve conversion efficiencies and the value of outputs for a given input. This appears to be a promising new avenue for development. Greater emphasis is also being placed on developing genetically modified crops as well as new enzymes that can provide better conversion efficiency.

- **More research is also needed in several other areas**. While there has been, and continues to be, considerable research into the production of biofuels and their use in transport, there are a number of areas where key questions remain. A principal concern is the impact of increased use of biofuels from conventional (grain and oilseed) crops on agriculture and food markets (and prices). Another is the long-term impact of shifts in crop production on the environment and how this might depend on the types of crops grown (*e.g.* grains *v.* cellulosic crops). Work needs to continue into achieving the full potential for cost reductions and optimising biofuels production efficiency, even for conventional approaches. Finally, there is almost no research on biofuels from a global perspective; for example, the potential for oil displacement from biofuels worldwide. More discussion of this point is provided below.

Policy implications

- **Currently biofuels policy is largely agriculture-driven**. Policies related to biofuels in both the US and EU are driven largely by agricultural concerns, perhaps more than by energy concerns. Agricultural policy (and industry) in the developed world is very complex and serves multiple policy objectives. Major producer support schemes exist in both North America and Europe. As this industry provides the fuel for biofuels, agricultural priorities and support schemes will likely continue to play a key role in biofuels policy in the future. Some studies have shown that the cost of subsidising increased biofuels production will be at least partly offset by resulting reductions in other agricultural subsidies.

- **A better understanding of ethanol benefits is needed and of how to maximize their net benefits**. As mentioned above, the use of biofuels can provide substantial benefits in a number of areas, but the value to the US, Canada, and to EU countries of these benefits is unclear. From a GHG point of view, the cost-per-tonne of CO_2 emissions reductions using biofuels, given current feedstocks and technology, appears high. However, if this is combined with other benefits, such as improvements in the balance of trade, energy security benefits, octane enhancement and air quality benefits, the cost:benefit ratio may be more attractive. A key aspect is the value that countries place on reducing dependence on imported oil. In addition, shifting to lower GHG-emitting biofuels such as ethanol from cellulose could dramatically reduce the cost-per-tonne for CO_2 emissions reductions – even if the cost of ethanol remains high – since it will provide much greater well-to-wheels CO_2 reduction per litre used. In any case, given the high cost of biofuels, it is important for governments to better estimate the value of their benefits. Unless societies make an effort to place a value on the key benefits, decisions about whether to produce biofuels, and how much to produce, will likely be dictated more by political expedience than by an effort to maximise net societal benefits.

- **Increased use of biofuels will require government intervention, at least in the near term**. Given the relatively high cost of biofuels compared to petroleum fuels, it is unlikely that widespread use of biofuels will occur without strong policy intervention, particularly price supports. But given existing high gasoline and diesel taxes in Europe, and current ethanol subsidies in North America, only relatively minor "tweaks" in policy may be needed to spur the market for biofuels to higher levels. For example, the existing subsidy in North America (of about USD 0.14/litre) is sufficient to encourage substantial production and sales of corn-derived ethanol as a fuel. An adjustment to this subsidy to vary payments according to the oil displacement and/or GHG reduction of the process could provide a strong incentive for changes in production practices that would increase these benefits.

- **A better understanding of impacts on crops and food markets is needed**. As mentioned above, while the impact of increased biofuels production for farmers is expected to be mainly positive (due to increases in crop sales and possibly crop prices), the net effects on all groups from the full set of market impacts is much less clear. For example, the impact on consumers could be negative if crop (and food) prices rise due to lower availability of non-biofuels crops. Few economic studies of these effects appear to be available, and those that are (mainly by the US Department of Agriculture) estimate that increased production of ethanol could lead to price increases not only of ethanol crops (like corn) but also of other crops, as their production declines due to increased production of crops for ethanol (resulting from competition for cropland). This area deserves much greater attention than it has received to date.

- **The development of international markets for biofuels could change the picture**. Nearly all analysis (and policy initiatives) to date have focused on domestic production and use of biofuels. However, there are fairly wide ranges of biofuels production costs across different countries and regions which could create opportunities for biofuels trade. This could substantially lower the cost of using biofuels and increase biofuels supply for certain countries. The IEA intends to explore this question in the next round of analysis on this topic. It will undertake an assessment of biofuels production potential, cost and recent initiatives in various parts of the world, and develop a general picture of the potential for international trade to help countries meet production and use targets at a lower cost than if all fuel were produced domestically.

- **What is the global potential for biofuels production and displacement of petroleum?** Apart from the potential for biofuels trade, the more general question of just how much biofuels could be produced around the world, under various assumptions regarding land availability and other factors, is worthy of study. Since both GHG emissions and oil use are essentially global problems, it makes sense to look at these problems globally. For example, it may make sense for the US and EU to invest in biofuels production in countries that can produce them more cheaply if the benefits in terms of oil use and GHG emissions reductions are similar to what could be achieved domestically. In the next phase of this project, the IEA is undertaking a more global analysis of biofuels cost, benefits, and potential production. This will be presented in a forthcoming IEA book on the topic, due for publication in 2004.

BIBLIOGRAPHY

This paper represents a preliminary version of the executive summary contained in the 2004 International Energy Agency publication, Biofuels for Transport: An International Perspective. A full bibliography is included in this book.

THE BRAZILIAN ETHANOL PROGRAMME: IMPACTS ON WORLD ETHANOL AND SUGAR MARKETS

Tatsuji Koizumi[1]

Abstract

The sugar market in Brazil has a strong relationship with the ethanol market. The Brazilian government has now abolished all sugar market intervention measures except for the control on the ethanol-gasoline blend ratio. In this study, the implications for the sugar markets of a change in blend ratio, particularly in its production resource use, are investigated by applying a newly developed ethanol-sugar market projection model. The model simulation result shows a moderately sized impact on the world ethanol and sugar markets.

Introduction

The world sugar market operates under an extensive range of governmental interventions. Its production, trade and even consumption levels are subject to governmental controls in many countries. Strong governmental policy influencing sugar market activities has been deepening since the middle of the 1970s. The world sugar market now operates under governmental programmes in three broad categories: agriculture, energy and environment. Pollution issues concerning air and ground water in the United States are one example of the links between environmental and energy policies, while the energy policy decisions in Brazil and India are other examples of the links between agriculture and energy programmes.

World sugar and ethanol markets have strong mutual influences because most sugarcane goes to ethanol production. At present, less than half of the sugarcane (between 35-47.2%, Ministry of Mines and Energy of Brazil, 2000), goes to sugar production, while the rest goes to the ethanol market. Among the major sugar-producing countries, Brazil is the world's largest producer of sugarcane and sugarcane-based ethanol. Hence, development in Brazil may have considerable implications for the world sugar and ethanol markets.

Over the last three decades, the government of Brazil has intervened heavily on the sugar market through its ethanol programme, but this changed in the late 1990s. With the de-regulation of its ethanol programme, which was implemented over the 1998-99 period, the government now no longer exercises direct control over sugar production and exports. Within the remaining range of permitted controls, the government can only set the ethanol-to-fuel blend ratio. The most likely foreseeable decision will be that on the planned compulsory usage of ethanol-blend diesel fuel.

1. Food and Agriculture Organization of the United Nations, Rome, Italy.

This study reports the evaluated results of the implications of imposing the use of ethanol-blend diesel fuel on the world sugar and ethanol markets. The present analysis is based on world sugar-ethanol market modelling work. The link between the agricultural (sugarcane and sugar) and energy (ethanol) markets was analysed and translated into the econometrically estimated structural equations of the model. The paper is organised as follows. In the next section a brief overview of the Brazilian ethanol programme is presented, followed by an explanation of the world sugar-ethanol model that is applied in evaluating the Brazilian programme. Baseline projection figures are discussed in the fourth section; the fifth section reports the market situations when the programme comes into force; and the last section summarises the findings.

A brief history of the Brazilian ethanol programme

The government of Brazil inaugurated the national ethanol programme (PROALCOOL) in 1975 (Table 1). The major target of the programme was to reduce the oil import bill because, in the mid-1970s, Brazil was strongly dependent on imported oil. An important direct effect of the programme was the creation of a huge domestic demand for sugarcane. The creation of PROALCOOL provided a much-needed solution to the problems of the sugar producers, who were frequently faced with excess production and huge price fluctuations. With the second oil-shock in 1979, the government decided to enlarge the programme by providing enhanced support to large-scale, hydrated ethanol producers to supply the undiluted and cheaper fuel. Two institutes played vital roles in implementing the national ethanol programme. The Institute of Sugar and Alcohol (IAA) controlled sugar and ethanol production and exports by implementing a production quota, and fixed the purchasing price for ethanol. Petrobas, a monopolistic state oil company, controlled domestic ethanol sales and distribution. The government set the sugarcane price for independent growers. A wide range of governmental investment support programmes were implemented in the 1980s and national ethanol production capacity expanded to produce over 16 billion litres of ethanol per year.

Table 1. Brazilian ethanol and sugar programmes

	Ethanol	Sugar
1975-98	Creation of the Brazilian National Alcohol Programme (PROALCOOL) • IAA: responsible for sugar and ethanol production and exports, through production quotas and a fixed purchasing price of ethanol • Petrobas: controls domestic ethanol sales and distribution as a monopolistic agent • Subsidies to ethanol-blend gasoline producers • Tax incentives to ethanol-blend gasoline car owners	• Credit and subsidies for distillers' production facilities investments • Set sugarcane price to independent growers
1998-99	• Abolition of the monopolistic distributional arrangement given to Petrobas • Liberalisation of ethanol prices • Reduced subsidies on ethanol-blend gasoline producers	• Removal of government-set sugarcane producer price
1999-present	• Blend ratio of anhydrous ethanol-gasoline between 19-26%	

Source: Ministry of Mines and Energy, Brazil, 2000.

Despite this achievement, the programme has faced criticism since the middle of the 1980s. Changes in the macroeconomic conditions were the first source of discontent. The 1982 Brazilian debt crisis dried up the sources of finance, and international oil prices began to decline in 1986. Inadequate ethanol supply and demand management raised serious market disruptions in the early 1990s and resulted in a loss of consumer confidence regarding ethanol fuel. The production of ethanol-powered cars has been in decline ever since. Today, only 1% of cars are ethanol-powered. To forestall this trend, the government set the anhydrous-ethanol blend to gasoline between 20-25% of the product, with a variation of + or -1%, as a means of balancing the relationship between supply and demand of sugar and ethanol. The government put radical reform programmes in place over the 1997-99 period. In 1997, the price of hydrated ethanol was liberalised, followed by the 1999 price liberalisation decision on anhydrous-ethanol and the abolition of the distribution monopoly given to Petrobas, and the reduction of subsidies to the ethanol-blend gasoline producers. Currently, there are no restrictions on ethanol production, and the only tool left to the government is setting the anhydrous blend ratio to gasoline. The actual percentage of the blend ratio is determined by the Ministry of Agriculture as a means of balancing the relationship between supply and demand of sugar and ethanol. A blend ratio of 26% is set as the legal maximum blend ratio level. As of April 2003, the blend ratio was set at 20% and it was increased back to 25% from July 2003.

The World Ethanol and Sugar Model

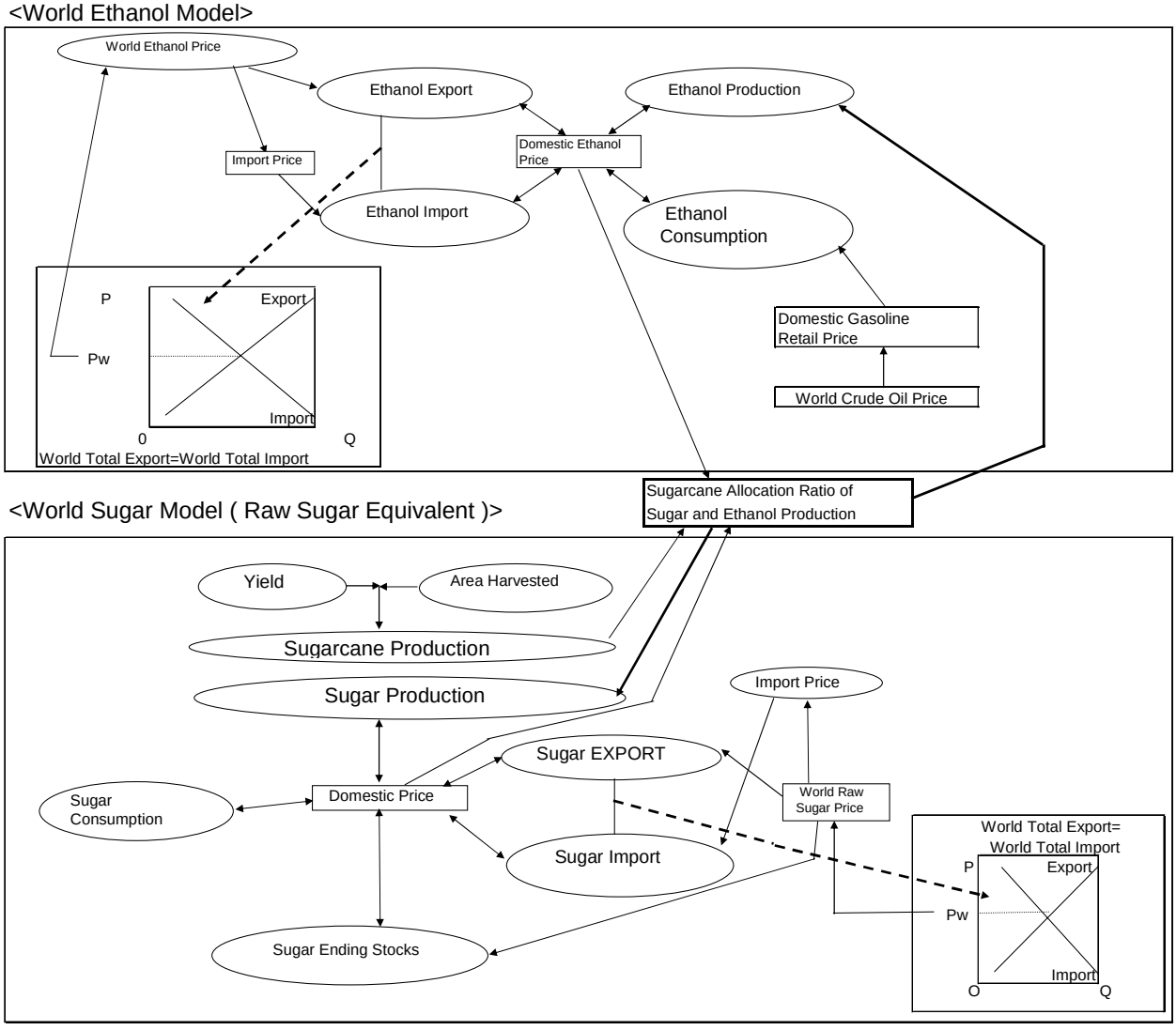
A World Ethanol and Sugar and Model has been developed in order to analyse how an ethanol, energy or environmental policy in major producing countries will affect not only the ethanol market, but also the domestic and world sugar markets (Figure 1). The model has been developed as a dynamic partial equilibrium model. The world sugar market consists of 14 major producing countries, while there are 11 major country markets for the world ethanol market. In the model, two markets are linked together through the Brazilian sugar and ethanol markets. In the Brazilian market, a “sugarcane allocation ratio variable” is defined. This allocation ratio of sugarcane determines what portion of sugarcane goes to ethanol production and what goes to sugar production. In recent years, mills have become more flexible, producing both sugar and ethanol. The main driving factor that determines the level of sugar and ethanol production is the relationship between domestic sugar and ethanol prices. The reaction of producers to a change in market price is replicated in the model through the introduced allocation ratio variable to allow the instantaneous ethanol and sugar production adjustment to change the relative sugar:ethanol price ratio.

Each country market consists of the production, consumption, export, import and ending stock activities (Annex). The sugar market activities are defined on a raw sugar equivalent basis. Because several country markets are operated under strong governmental intervention, country market clearing prices are solved from the country market clearing identities, while the trade market price is found as a trade market clearing price. Among the 14 sugar country markets, 2 country and regional markets prices are almost perfectly isolated from the trade market price movements. The exogenously specified market intervention prices guide the market supply and consumption activities while trade takes place to fill the resulting supply-consumption gaps in these cases. Among the EU’s sugar production and trade programmes, the model takes into account the sugar production quotas, intervention prices, export subsidies and preferential treatments for specified countries.

Sugarcane is not the only source of ethanol. United States ethanol production, for example, is based mostly on maize. Ideally, the model specification should be extended to cover related agricultural commodity markets. However, at this stage of model development, relevant markets are approximated by the exogenously provided market prices. Ethanol consumption is specified as the

sum of transportation use and other uses. Transportation use is defined as a function of ethanol and gasoline prices, which is further explained by the exogenously provided crude oil price, and the number of vehicles. Data for the sugar and ethanol markets are taken from FAOSTAT. Brazilian ethanol and automobile data have been collected from publications from the government of Brazil.

Figure 1. The concept of the World Ethanol and Sugar Model



Source: Author.

Market perspectives

Assumptions

The baseline simulation is grounded in a series of assumptions about the general economy, agricultural policies and technological changes in exporting and importing countries for the projection period. The exogenous assumptions on the projected demand for gasoline and diesel in Brazil and India are taken from *World Energy Outlook 2002* (International Energy Agency, 2002). Another set of exogenous assumptions, the projected United States ethanol consumption and crude oil price are derived from the *Annual Energy Outlook 2003* (United States Department of Energy [USDOE], 2003). In this USDOE baseline scenario, the world crude oil price will decrease by 1.5% per year from 2000 to 2010. Gasoline consumption data in four major Indian cities are derived from the government of India. Macro data are mainly based on the assumption of World Food Model (MFN) of the Food and Agriculture Organization of the United Nations.

It is generally assumed that current agricultural policy will be continued in all countries over the projection period in accordance with the baseline market situations. Normal weather and historical rates of technological innovation are assumed in this projection. New World Trade Organization (WTO) agricultural agreements are not taken into account in the models. Reduction commitments for market access and export subsidies will be frozen at levels prevailing in the year 2000 for developed countries, and 2004 for developing countries. Regional free trade areas are not assumed to expand. The entry of China and Taiwan Province into the WTO is taken into account in calibrating the baseline estimates. The Russian Federation is not assumed to be a member of WTO. Brazil will maintain PROALCOOL, and the ethanol-blend ratio is assumed to remain, with a maximum level of 25% throughout the projection period. The government of India is implementing its E-5 programme (5% ethanol, 95% unleaded gasoline) from 2003 in four major cities (Delhi, Calcutta, Mumbai and Bangalore).

World and Brazilian ethanol market perspectives to the year 2010

World ethanol consumption is projected to increase by 3% per annum from 2000-10 (Table 2). As a result of the change-over from methyl tertiary butyl ether (MTBE) to ethanol in the United States fuel market, United States ethanol consumption is projected to show a step-shaped increase. The projected world ethanol price is reported on the basis of an artificially created price index (2000=1). The world ethanol price is predicted to increase in a fluctuating manner during the 2000-10 projected period and is estimated to reach 1.05 in 2010. Most ethanol-producing countries are expected to give priority to domestic markets in supplying their products, hence the world ethanol trade share to production and consumption is not projected to expand. The trade share to production will remain at 9.9% in 2010. World ethanol exports are projected to increase by 1.1% per annum during this period. Since the relatively high domestic and international prices of ethanol stimulate its production, world ethanol production is projected to grow by 3% per year.

Brazil's ethanol consumption is projected to increase by 2.3% per annum, and its ethanol consumption is predicted to dominate 51.5% of world ethanol demand in 2010 with the assumed anhydrous-ethanol blend ratio of 25% (Table 2). Since gasoline demand in Brazil is predicted to increase by 2.7% per year, ethanol consumption of anhydrous ethanol is predicted to increase proportionately, while hydrated ethanol and anhydrous-ethanol for other uses are estimated to decrease by 0.9% per annum. Ethanol production in Brazil is projected to increase by 2.3% up to 2010. It is assumed that, as the purpose of PROALCOOL is to reduce the cost of oil imports, the government of Brazil will give priority to meeting domestic demand rather than joining international markets. Brazil's ethanol exports are predicted to increase by 3.9% per annum during this period.

As noted above, the E-5 programme will be promoted in four major cities in India. Ethanol consumption and production in India are projected to increase by 1.9% per annum during the projection period (Table 2). In the US, the use of MTBE is expected to be regulated in 14 states which have passed the relevant legislation (these are Arizona, California, Colorado, Connecticut, Indiana, Iowa, Illinois, Kansas, Michigan, Minnesota, Nebraska, New York, South Dakota and Washington). However, in the baseline projection it is assumed that the federal ban will not be adopted. As a consequence of the regulations on MTBE, it is expected that, in those states, MTBE will be replaced by ethanol. United States ethanol consumption is projected to expand by 5.7% per annum over the projection period. Owing to the estimated higher ethanol demand, the domestic ethanol producer price is projected to increase from 140.0 to 147.2 (Index: 1982=100) during this period. United States ethanol production is projected to increase by 5.7% by annum, and its ethanol export to decrease by 3%. Total ethanol consumption by OECD countries is projected to increase by 4.7% per annum, and production to increase by 5% per annum (in this paper, the OECD total is calculated as the sum of the US, Mexico, EU-15, Australia, Japan and the Republic of Korea). Market developments in the United States greatly influence the market situation of OECD countries.

World and Brazilian sugar market perspectives to the year 2010

World sugar production (in raw sugar equivalent) is projected to expand by 1.7% per annum from 2000-10 (Table 3). The country which contributes most to the increase in world sugar production is Brazil. World sugar consumption is projected to expand by 1.9% during this period. The country which contributes most to the increase in world sugar consumption is India. World sugar exports (raw sugar equivalent) are projected to increase by 1.5% per annum and world sugar imports are projected to expand by 2.6% per annum during this period. The world raw sugar price (in terms of the International Sugar Agreement average price) was 8.18 US cents/lb in 2000 and is projected to observe the cyclic fluctuations in the world sugar market price during the projection period because of the biologically required time-lag in sugarcane production. Because of this, the world price in the year 2010 is estimated at 6.96 US cents/lb.

Brazil's sugarcane production is predicted to increase by 3.2% over the 2000-10 period, supported by the projected steady growth in area harvested and yield (Figures 2 and 5). Brazilian sugarcane area harvested is projected to increase by 1.4%. The sugarcane area harvested in Brazil amounts to about 10.6% of the total crop area harvested. Sugarcane yield is predicted to increase by 1.8%.

The sugarcane allocation ratio of sugar production over ethanol production is determined by the relative price ratio between domestic sugar and ethanol prices. The sugar:ethanol price ratio is the crucial factor in deciding the allocation ratio (this price ratio is calculated as: [domestic crystal sugar price]/[domestic anhydrous ethanol price]). From 2009-10, domestic crystal sugar price is projected to decrease from 1.074 to 1.064 (Index; 2000=N, domestic crystal sugar price is projected to decrease from BRL 22.74 to 22.53/50 kg [Figure 4]) and domestic anhydrous-ethanol price to decrease from 1.137 to 1.104 (the domestic anhydrous-ethanol price is projected to decrease from BRL 646.75 to 628.23/1 000 litres [Figure 3]). The price ratio, which is calculated as a ratio of normalised sugar price over normalised ethanol price, is projected to increase from 0.944 to 0.963. It means that there is expected to be an incentive for sugar production. With this change in the producer price ratio, the sugarcane allocation ratio for sugar is projected to increase from 50.77 to 51.19 in 2010.

Brazil's sugar production is predicted to increase by 3.8% per annum during this period. Exports are predicted to grow by 5.8%. In 2010, Brazil is expected to be the largest sugar exporter in the world.

Table 2. World Ethanol Markets (Baseline-Projection)

World Ethanol Production

<Thousand Metric tonnes, %>

Region	1990	1995	2000	2006	2010	Growth Rate 1990/2000	Growth Rate 2000/2010
World Total	**18,391**	**19,418**	**19,284**	**25,192**	**26,768**	**0.4%**	**3.0%**
Brazil	12,028	12,700	10,900	14,268	14,017	-0.9%	2.3%
OECD Countries Total	3,487	3,789	5,129	7,214	8,790	3.6%	5.0%
USA	2,216	2,540	3,999	5,905	7,359	5.5%	5.7%
EU15	1,144	1,121	1,002	1,174	1,293	-1.2%	2.3%
Mexico	126	128	128	135	137	0.1%	0.7%
India	1,175	1,434	1,985	2,290	2,434	4.9%	1.9%
China, Mainland	43	125	200	212	220	15.1%	0.9%
ACP Countries	14	18	21	24	26	3.8%	1.8%
Thailand	77	86	90	94	97	1.4%	0.7%
Former USSR	191	393	263	286	302	2.9%	1.3%
Rest of World	1,377	873	697	803	881	-6.0%	2.2%

Source; FAOSTAT (1990,1995,2000)

World Ethanol Consumption

<Thousand Metric tonnes, %>

Region	1990	1995	2000	2006	2010	Growth Rate 1990/2000	Growth Rate 2000/2010
World Total	**18,509**	**19,873**	**19,269**	**25,192**	**26,768**	**0.4%**	**3.0%**
Brazil	12,676	13,575	10,769	14,083	13,779	-1.5%	2.3%
OECD Countries Total	3,311	3,968	5,923	8,160	9,851	5.4%	4.7%
USA	1,974	2,269	4,211	6,300	7,857	7.1%	5.8%
EU15	814	1,009	879	969	1,032	0.7%	1.5%
Mexico	134	146	255	266	285	6.0%	1.0%
JAPAN	320	418	420	440	470	2.5%	1.0%
Korea Republic	69	127	158	186	207	7.8%	2.5%
India	1,152	1,434	1,916	2,219	2,360	4.7%	1.9%
China, Mainland	22	101	48	51	53	7.4%	0.9%
ACP Countries	18	14	46	53	58	8.9%	2.1%
Thailand	40	27	12	13	13	-10.1%	0.6%
Former USSR	61	187	227	249	264	12.6%	1.4%
Rest of World	1,229	567	327	363	389	-11.3%	1.6%

Source; FAOSTAT (1990,1995,2000)

World Ethanol Export

<Thousand Metric tonnes, %>

Region	1990	1995	2000	2006	2010	Growth Rate 1990/2000	Growth Rate 2000/2010
World Total	**1,990**	**3,211**	**2,343**	**2,509**	**2,649**	**1.5%**	**1.1%**
Brazil	30	256	182	229	277	17.9%	3.9%
OECD Countries Total	1,369	1,813	1,155	1,181	1,209	-1.5%	0.4%
USA	648	909	414	333	295	-4.0%	-3.0%
EU15	719	862	738	835	901	0.2%	1.8%
Mexico	0.1	35	0	10	10	-	-
JAPAN	0.1	1	-	-	-	-	-
Korea Republic	1	6	3	3	3	5.5%	-0.1%
India	23	2	69	71	74	10.4%	0.7%
China, Mainland	21	33	152	162	168	19.9%	0.9%
ACP Countries	0.17	8	29	32	35	59.4%	1.8%
Thailand	37	60	80	85	88	7.3%	0.9%
Former USSR	130	516	40	42	44	-10.2%	0.8%
Rest of World	381	523	637	707	754	4.8%	1.6%

Source; FAOSTAT (1990,1995,2000)

World Ethanol Import

<Thousand Metric tonnes, %>

Region	1990	1995	2000	2006	2010	Growth Rate 1990/2000	Growth Rate 2000/2010
World Total	**2,108**	**3,666**	**2,328**	**2,509**	**2,649**	**0.9%**	**1.2%**
Brazil	678	1,131	51	44	38	-20.9%	-2.6%
OECD Countries Total	1,194	1,992	1,949	2,127	2,270	4.6%	1.4%
USA	406	638	627	728	793	4.0%	2.2%
EU15	389	750	615	630	641	4.3%	0.4%
Mexico	8	53	127	140	158	28.5%	2.0%
JAPAN	320	418	420	440	470	2.5%	1.0%
Korea Republic	70	133	160	189	209	7.8%	2.5%
India	0.0	2	0.1	0.1	0.1	10.7%	1.2%
China, Mainland	0.2	9	1	1	1	11.7%	3.2%
ACP Countries	4.0	4.5	53	61	67	26.4%	2.1%
Thailand	0.02	1	3	4	5	56.4%	4.2%
Former USSR	-	310	5	5	6	-	2.0%
Rest of World	232	217	267	267	262	1.3%	-0.2%

Source; FAOSTAT (1990,1995,2000)

Table 3. World Sugar Market (Baseline-Projection)

World Sugar Production (Raw Sugar Equivalent)

<Million Metric tonnes, %>

Region	1990	1995	2000	2006	2010	Growth Rate 1990/2000	Growth Rate 2000/2010
World Total	**110.51**	**117.92**	**130.76**	**147.05**	**156.69**	**1.5%**	**1.7%**
Brazil	7.94	13.59	17.04	23.31	25.57	7.2%	3.8%
OECD countries Total	32.21	33.46	36.40	37.39	38.79	1.1%	0.6%
USA	6.34	6.69	7.88	8.02	8.34	2.0%	0.5%
EU15	17.98	16.53	17.64	17.85	18.54	-0.2%	0.5%
Australia	3.68	5.06	5.45	5.38	5.77	3.6%	0.5%
Mexico	3.28	4.27	4.70	5.33	5.32	3.3%	1.1%
Japan	0.93	0.91	0.73	0.82	0.83	-2.2%	1.2%
Korea Republic	0	0	0	0	0	-	-
India	11.76	16.41	20.22	21.50	22.46	5.1%	1.0%
China, Mainland	6.88	6.77	6.74	8.25	8.99	-0.2%	2.7%
Cuba	8.04	3.26	4.06	4.01	4.08	-6.0%	0.0%
ACP Countries	5.86	6.03	6.73	7.62	8.14	1.3%	1.7%
South Africa	2.03	1.67	2.66	2.82	3.18	2.5%	1.6%
Thailand	3.51	5.20	6.45	7.74	8.03	5.7%	2.0%
Fomer USSR	9.43	6.61	4.15	4.81	5.07	-7.2%	1.8%
Rest of World	22.86	24.92	26.33	29.58	32.37	1.3%	1.9%

Source; FAOSTAT (1990, 1995, 2000)

World Sugar Consumption (Raw Sugar Equivalent)

<Million Metric tonnes, %>

Region	1990	1995	2000	2006	2010	Growth Rate 1990/2000	Growth Rate 2000/2010
World Total	**109.35**	**113.17**	**127.89**	**146.16**	**156.94**	**1.4%**	**1.9%**
Brazil	6.95	8.25	9.59	11.45	12.93	3.0%	2.8%
OECD countries Total	29.82	31.10	32.06	33.95	35.58	0.7%	1.0%
USA	7.90	8.47	9.36	9.99	10.34	1.5%	0.9%
EU15	12.94	13.65	13.85	14.37	15.11	0.6%	0.8%
Australia	0.96	1.00	1.09	1.17	1.26	1.2%	1.3%
Mexico	4.43	4.46	4.48	4.85	5.05	0.1%	1.1%
Japan	2.78	2.54	2.23	2.38	2.50	-2.0%	1.0%
Korea Republic	0.82	0.99	1.04	1.19	1.32	2.2%	2.2%
India	10.99	13.33	17.23	21.12	22.24	4.2%	2.3%
China, Mainland	7.95	7.60	6.89	8.53	9.22	-1.3%	2.7%
Cuba	0.77	0.56	0.69	0.77	0.83	-1.0%	1.6%
ACP Countries	4.54	5.83	7.12	7.30	7.35	4.2%	0.3%
South Africa	1.35	1.36	1.55	1.57	1.56	1.3%	0.05%
Thailand	1.06	1.58	1.83	2.02	2.17	5.1%	1.6%
Fomer USSR	12.11	9.27	11.65	13.31	14.46	-0.4%	2.0%
Rest of World	33.80	34.29	39.28	46.14	50.60	1.4%	2.3%

Source; FAOSTAT (1990, 1995, 2000)

World Sugar Export (Raw Sugar Equivalent)

<Million Metric tonnes, %>

Region	1990	1995	2000	2006	2010	Growth Rate 1990/2000	Growth Rate 2000/2010
World Total	**30.54**	**36.88**	**41.94**	**46.57**	**49.18**	**2.9%**	**1.5%**
Brazil	1.63	6.42	6.78	11.71	12.58	13.8%	5.8%
OECD countries Total	11.42	13.78	14.81	13.82	14.21	2.4%	-0.4%
USA	0.52	0.46	0.15	0.14	0.15	-10.4%	-0.5%
EU15	7.70	8.42	9.63	8.55	8.73	2.1%	-0.9%
Australia	2.86	4.04	4.19	4.16	4.55	3.5%	0.7%
Mexico	0.01	0.55	0.41	0.55	0.37	39.2%	-0.8%
Japan	0.01	0.002	0.003	0.003	0.003	-8.8%	0.2%
Korea Republic	0.33	0.31	0.41	0.40	0.41	2.1%	-0.1%
India	0.03	0.40	0.35	0.28	0.25	26.3%	-3.1%
China, Mainland	0.64	0.56	0.52	0.62	0.74	-1.8%	3.2%
Cuba	7.16	2.60	3.42	3.23	3.26	-6.5%	-0.4%
ACP Countries	2.79	2.54	3.40	3.49	4.03	1.8%	1.6%
South Africa	0.98	0.40	1.51	1.24	1.65	4.0%	0.8%
Thailand	2.43	3.88	4.29	5.64	5.86	5.3%	2.9%
Fomer USSR	0.15	2.57	0.68	0.65	0.66	14.9%	-0.3%
Rest of World	3.32	3.75	6.19	5.89	5.95	5.8%	-0.37%

Source; FAOSTAT (1990, 1995, 2000)

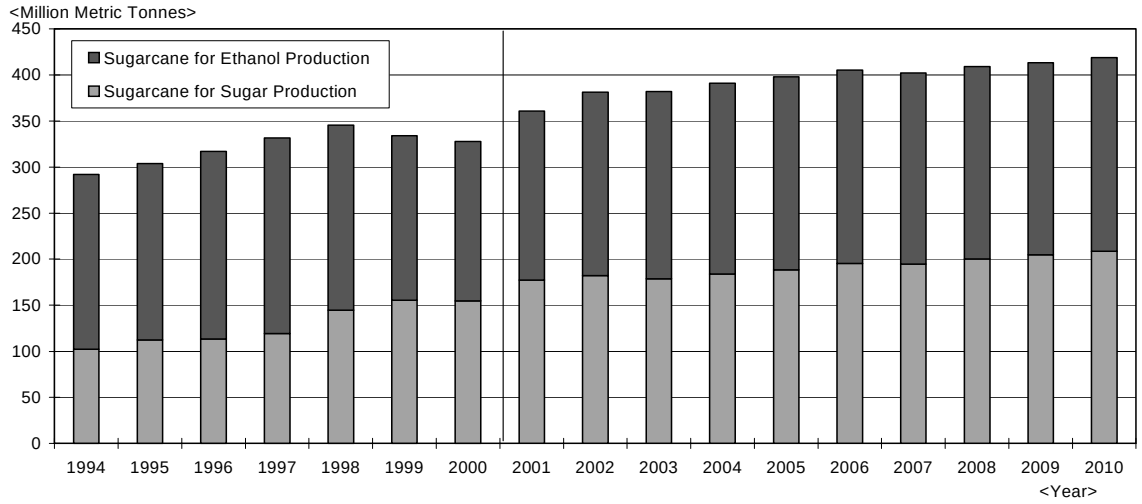
World Sugar Import (Raw Sugar Equivalent)

<Million Metric tonnes, %>

Region	1990	1995	2000	2006	2010	Growth Rate 1990/2000	Growth Rate 2000/2010
World Total	**29.64**	**33.49**	**37.18**	**46.57**	**49.18**	**2.1%**	**2.6%**
Brazil	0.00	0.05	0.01	0.02	0.02	18.7%	0.5%
OECD countries Total	10.91	8.89	9.13	10.49	10.90	-1.6%	1.6%
USA	1.91	1.76	1.58	2.15	2.19	-1.7%	3.0%
EU15	4.22	3.98	4.43	5.08	5.22	0.4%	1.5%
Australia	0.02	0.02	0.02	0.03	0.03	1.2%	2.3%
Mexico	1.93	0.06	0.05	0.06	0.06	-27.7%	0.2%
Japan	1.72	1.75	1.57	1.57	1.68	-0.8%	0.6%
Korea Republic	1.10	1.32	1.48	1.61	1.73	2.7%	1.4%
India	0.01	0.16	0.03	0.04	0.04	9.0%	1.5%
China, Mainland	1.16	3.02	0.68	0.99	1.00	-4.8%	3.6%
Cuba	0	0	0	0	0	-	-
ACP Countries	1.51	2.56	2.99	3.24	3.22	6.4%	0.7%
South Africa	0.04	0.03	0.02	0.03	0.03	-4.2%	1.0%
Thailand	0.0001	0.002	0.004	0.005	0.005	35.6%	2.5%
Fomer USSR	4.10	5.09	7.06	9.16	9.98	5.1%	3.2%
Rest of World	11.92	13.69	17.24	22.60	23.99	3.4%	3.0%

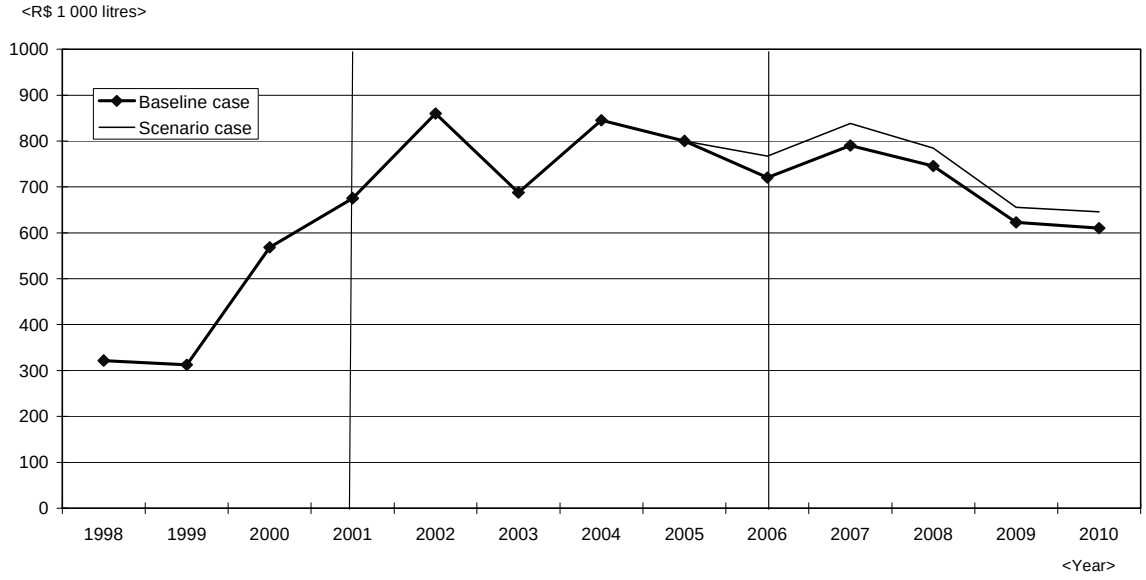
Source; FAOSTAT (1990, 1995, 2000)

Figure 2. Brazilian sugarcane production (baseline case)



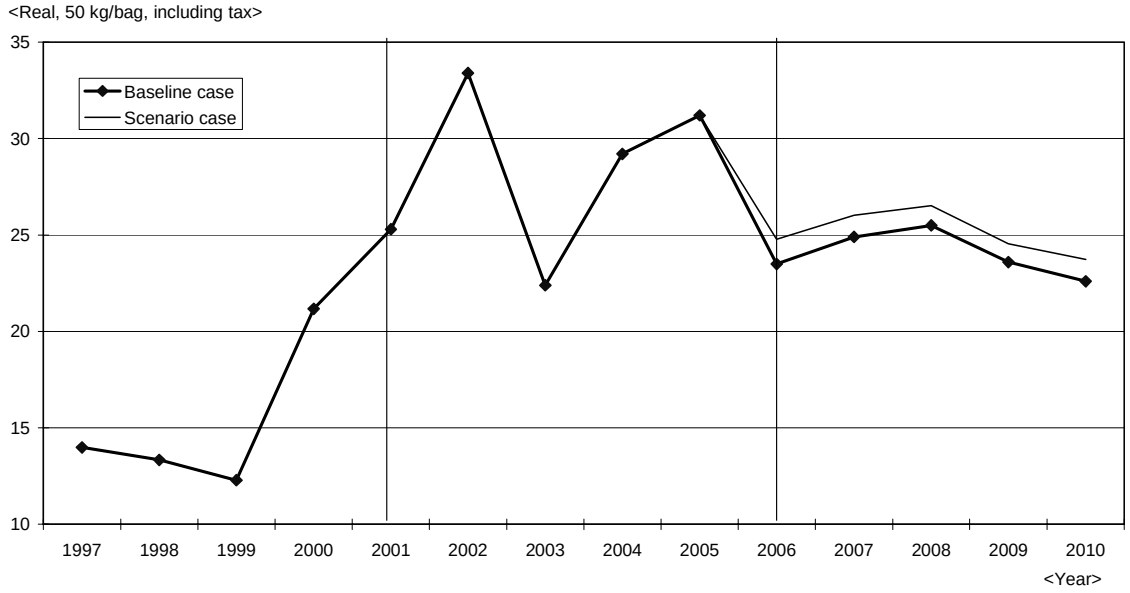
Source: FAO, FAOSTAT, Ministry of Mines and Energy, Federative Republic of Brazil, "Brazilian Energy Balance 2000" (from 1994-2000).

Figure 3. Brazil fuel anhydrous ethanol price (State of São Paolo)



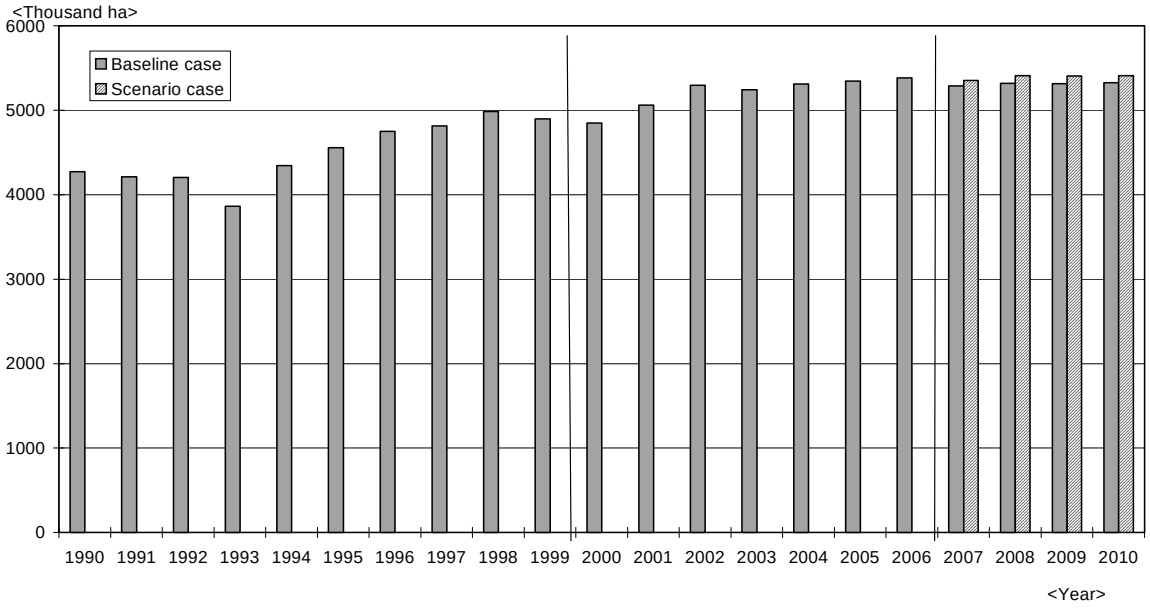
Source: USDA, 2003.

Figure 4. Brazil crystal sugar price on the domestic market



Source: USDA, 2003.

Figure 5. Brazil sugarcane, area harvested



Source: FAO, FAOSTAT (1990-2000).

Sugar production in the EU-15 is derived from sugarbeet and sugarcane. Production is projected to increase by 0.5% per annum. Exports are projected to decrease by 0.9% per annum during the projection period. Total OECD sugar production is projected to increase by 0.6% and exports to decrease by 0.4% per annum during this period.

Impacts of the diesel fuel blend ratio control

Scenario-imposition

Since the end of the 1970s, the hypothesis of substituting diesel with ethanol in diesel cycle engines has been considered. At the experimental level, anhydrous-ethanol is blended with diesel at a level of 8%. The same experiment has been conducted in Sweden and the United States (both countries adopted the blend rate at 15%). The repercussive effects of increasing ethanol demand are vast, but the government has not adopted the anhydrous-ethanol blend to diesel oil. Because the upper limit of the anhydrous-ethanol blend ratio is set at 26%, there seems to be little room to expand anhydrous-ethanol within the current ethanol policy. To increase domestic ethanol consumption and control the sugar market more effectively, setting the anhydrous-ethanol blend ratio to domestic diesel oil seems to be required.

As an alternative scenario to this study, it is assumed that the government imposes a further restriction on setting the anhydrous-ethanol blend ratio to domestic diesel oil, after the technology for practical use is completed. This programme is assumed to begin in 2006 and the blend ratio will be set at a level of 8%.

Impacts on ethanol markets

Diesel oil consumption is projected to increase by 2.7% per annum from 2000-10. In 2006, consumption is projected to be 26.2 million tonnes. Owing to setting the anhydrous-ethanol blend ratio to domestic diesel oil as from 2006, Brazil's ethanol consumption in 2006 is predicted to increase by 15.3% (Table 4). In 2010, its consumption is predicted to dominate 55.5% of world ethanol consumption. Because of the high consumption, the domestic anhydrous-ethanol price in 2006 is predicted to increase by 6.49%. Ethanol production can be switched flexibly from sugarcane for sugar production without a time-lag. As a business practice, it was assumed that producers can adjust their ethanol-sugar production-mix by allocating 22% of total sugarcane as adjustable input for a change in the sugar:ethanol price ratio. Brazil's ethanol production is predicted to increase by 14.98% in 2006. Similar to other ethanol-producing countries, Brazil is expected to give priority to higher domestic ethanol prices than the international ethanol price. Brazil's ethanol exports are predicted to decrease by 4.23% in 2006.

The world ethanol market can be heavily influenced by Brazil's ethanol markets. World ethanol consumption and production are predicted to increase by 8.51-9.22% from 2006-10 (Table 4). The volume of world ethanol trade is predicted to decrease by 0.10-0.12%. The world ethanol price is predicted to increase by 0.91-1.14% (Table 4).

Table 4. Impacts on world ethanol markets

World Ethanol Production (Scenario/Baseline)

	Maximum	Minimum
World Total	**9.22%**	**8.51%**
Brazil	17.26%	14.98%
OECD countries Total	0.09%	0.07%

World Ethanol Consumption (Scenario/Baseline)

	Maximum	Minimum
World Total	**9.22%**	**8.51%**
Brazil	17.61%	15.25%
OECD countries Total	-0.03%	-0.02%

World Ethanol Export (Scenario/Baseline)

	Maximum	Minimum
World Total	**-0.12%**	**-0.10%**
Brazil	-4.23%	-3.28%
OECD countries Total	0.42%	0.33%

World Ethanol Import (Scenario/Baseline)

	Maximum	Minimum
World Total	**-0.12%**	**-0.10%**
Brazil	3.38%	2.60%
OECD countries Total	-0.21%	-0.16%

Ethanol Prices (Baseline/Scenario)

	Maximum	Minimum
World	**1.14%**	**0.91%**
Brazil Fuel Anhydrous Ethanol (State of São Paulo)	6.49%	5.27%

Source: Author.

Table 5. Impacts on world sugar markets

World Sugar Production (Scenario/Baseline)

	Maximum	Minimum
World Total	**-0.2%**	**0.0%**
Brazil	-2.5%	-0.3%
OECD countries Total	0.2%	0.0%
EU15	0.3%	0.0%
ACP Countries	0.7%	0.0%
Thailand	0.6%	0.0%
Australia	0.6%	0.0%

World Sugar Consumption (Scenario/Baseline)

	Maximum	Minimum
World Total	**-0.2%**	**0.0%**
Brazil	-1.3%	-0.9%
OECD countries Total	-0.2%	0.0%
EU15	-0.3%	-0.1%

World Sugar Export (Scenario/Baseline)

	Maximum	Minimum
World Total	**-0.3%**	**0.0%**
Brazil	-2.9%	-0.7%
OECD countries Total	0.9%	0.2%
EU15	0.9%	0.2%
ACP Countries	1.3%	0.1%
Thailand	0.7%	0.2%
Australia	0.6%	0.2%

World Sugar Import (Scenario/Baseline)

	Maximum	Minimum
World	**-0.3%**	**0.0%**
Brazil	1.4%	0.5%
OECD countries Total	-0.1%	0.0%
EU15	-0.1%	0.0%

Raw Sugar Prices (Scenario/Baseline)

	Maximum	Minimum
World (I.S.A Average Price)	**2.23%**	**0.34%**
Brazilian Crsystal Sugar	5.44%	3.82%

Source: Author.

Impacts on sugar markets

As a result of a high domestic ethanol price, Brazilian sugar production is predicted to shift from sugar to ethanol production. In 2006, the domestic anhydrous-ethanol price is predicted to be much higher than the crystal sugar price. The price ratio is predicted to be 0.687, although the ratio is projected to be 0.839 in the baseline-case. For this reason, the allocation ratio for sugar production is predicted to decrease from 48.46 to 45.12% in 2006. The price ratio is predicted to diminish from 2006-10. The allocation ratio for sugarcane is predicted to be 47.92% in 2010, although the ratio is projected to be 51.19% in the baseline-case. As a result of the shift, Brazil's sugar production is predicted to decrease by 0.3-2.5% during this period, with exports predicted to decrease by 0.7-2.9% (Table 5). Brazil's domestic crystal sugar price is predicted to increase by 3.82-5.44% (Figure 4). On account of the country's diminishing sugar production, world sugar production is predicted to decrease by 0.0-0.2%, compared with the baseline-case, and world sugar exports are predicted to decrease by 0.0-0.3%. As a result, the world raw sugar price is predicted to increase by 0.34-2.23% (Table 5).

Concerning sugarcane production, the area harvested for sugarcane is predicted to increase by 1.2-1.7%, compared with the baseline-case. In the scenario-case, the area harvested for sugarcane is predicted to reach 5.69 million ha in 2010 (Figure 5). In Brazil, more than 80% of sugarcane is harvested by hand, and the dry leaves are burned off before cutting. Due to the expansion of the sugarcane area harvested, the practice of burning before cutting could have a negative impact on the environment.

Conclusion

As a result of the Brazilian energy programme's imposition of a further 8% anhydrous-ethanol blend diesel oil from 2006, world ethanol and sugar prices are predicted to increase. The estimated results indicate that the magnitude of world price hikes of both sugar and ethanol are moderate, but will persist for years.

Although Brazil's sugar exports are predicted to decrease, world sugar exports are predicted to remain at the baseline predicted level because the higher world sugar price will stimulate major exporting countries to increase their exports from 2006. An increased raw sugar trade price will benefit sugar-exporting countries. The EU-15, which stands to benefit from the diminishing price differences between the domestic market price and the world price, is predicted to increase its sugar export level by 0.9%. The benefits to other sugarcane-based sugar exporters are expected to materialise with a two-year time-lag, because of the biological condition of sugarcane production. The exports of African, Caribbean and Pacific (ACP) countries are predicted to increase by 1.3% (the ACP includes 70 countries, excluding South Africa). Because most of the ACP countries' economies depend heavily on their sugar exports, the higher world sugar price could benefit their economies. The exports of Thailand and Australia are predicted to increase by 0.7% and 0.6%, respectively.

The country which will benefit most from the programme is Brazil itself. The government of Brazil can control not only domestic sugar and ethanol markets, but also the world sugar and ethanol price. The government of Brazil abolished most of the regulations for domestic sugar and ethanol markets in the 1990s. There is no regulation of their markets, except for setting the anhydrous-ethanol blend ratio. The policy change of PROALCOOL can control sugar output and exports and lead to the world sugar price being heavily influenced. Setting a further anhydrous-ethanol blend ratio can be an effective policy tool to control domestic and world sugar markets and, moreover, the programme will contribute to expanding domestic ethanol markets, which will have the effect of reducing oil imports (23.2-25.8 million metric tonnes of oilimports are predicted to be saved). It will also lead to expanding job opportunities and to reducing air pollution.

ANNEX

Model Equations

Production

$\Delta Ah_{is,t} = f(\Delta PP_{is,t-1}, \Delta PP_{ia,t-1}, \Delta Q_{is,t-1})$ or $\Delta Ah_{is,t} = f(\Delta PP_{is,t-2}, \Delta PP_{ia,t-2}, \Delta Q_{is,t-2})$

$\Delta Y_{is,t} = f(\Delta G_{is,t})$ -

$QP_{is,t} = AH_{isc,t} * Y_{isc,t} * SUAL_t * ER_{isb,t} + AH_{isb,t} * Y_{isb,t} * ER_{isb,t}$

$SUAL_t = f((DP_{is,t}/DP_{is,t0})/(DP_{ie,t}/DP_{ie,t0}))$

$\Delta QP_{ie,t} = f(\Delta PP_{ie,t}, \Delta G_{ie,t})$ or $\Delta QP_{ie,t} = f(\Delta PP_{ie,t}, \Delta PP_{im,t}, \Delta G_{ie,t})$

Consumption

$QC_{i,t} = PQC_{i,t} * POP_{r,t}$

$\Delta PQC_{i,t} = f(\Delta DP_{i,t}, \Delta DP_{ia,t}, \Delta I_{r,t})$

Export

$\Delta EX_{i,t} = f(\Delta WP_{i,t}, \Delta DP_{i,t})$ or $EX_{i,t} = QP_{i,t} + IM_{i,t} - QC_{i,t} - (SS_{i,t} - SS_{i,t-1})$

Import

$\Delta IM_{i,t} = f(\Delta MP_{i,t}, \Delta DP_{i,t}, \Delta I_{r,t})$ or $IM_t^s = EX^s + QC_t^s + (SS_t^s - SS_{t-1}^s) - QP_t^s$

Ending Stocks

$SS_{i,t} = f(\Delta QP_{i,t}, \Delta DP_{i,t})$ or $SS_{i,t} = f(\Delta QC_{i,t}, \Delta DP_{i,t})$

Market Equilibrium

$\sum_r EX_{i,r,t} = \sum_r IM_{i,r,t}$

Variable Definition

Ah	=	area harvested,
Q	=	production quota
Y	=	yield
G	=	exogenous growth rate
QP	=	production
ER	=	extraction rate
SUAL	=	sugarcane allocation ratio for sugar production
QC	=	consumption
PQC	=	per capita consumption
EX	=	export
IM	=	import
SS	=	ending stocks
I	=	per capita income
POP	=	population
DP	=	domestic price
PP	=	producer price
MP	=	import price
WP	=	world price

Index

i	=	all commodities
is	=	sugar
isc	=	sugarcane
isb	=	sugarbeet
ie	=	ethanol
ia	=	alternative commodities
im	=	input for ethanol production
r	=	countries/ country groups
t	=	time

BIBLIOGRAPHY

Arnaldo, Walter (2002), *Notes on Large Scale Production of Wood, Charcoal and Ethanol: the Brazilian Experience and Perspectives for International Trade*, position paper of the Biotrade Workshop.

Arnaldo, Walter and Luis Cortez (1999), *An Historical Overview of the Brazilian Bioethanol Program*, Stockholm Environment Institute Publications, Sweden.

Audinet, Pierre (1995), *A Note on Public Policy and Innovation in the Biomass-based Industrial sector: lessons from the sugarcane industry in Brazil and India*, United Nations Environment Programme [UNEP] Publications.

Bolling, Christine and Nydia R. Suarez (2001), "The Brazilian Sugar Industry: Recent Developments" *Sugar and Sweetener Situation & Outlook*, Economic Research Service, United States Department of Agriculture Publications, Washington, D.C., United States.

Food and Agriculture Organization of the United Nations [FAO] (2003), *World Food Model*, FAO Publications and the Secretariat for Energy, Ministry of Mines and Energy of the Federative Republic of Brazil (2002), *Brazilian Energy Balance 2000* Federative Republic of Brazil Ministry of Mines and Energy, Secretariat for Energy Publications.

FAO, FAOSTAT (2002), FAO Publications, Rome, Italy.

FAO, FAOSTAT (1990-2000) FAO Publications, Rome, Italy.

International Energy Agency [IEA] (2002), *World Energy Outlook 2002*, IEA, Paris, France.

IEA (2002), *Energy Statistics of OECD Countries 1999-2000* IEA, Paris, France.

IEA (2002), *Energy Statistics of Non-OECD Countries 1999-2000*, IEA, Paris, France.

IEA (2002), *Energy Prices and Taxes*, IEA, Paris, France.

International Sugar Organization (2002), *Statistical Bulletin*, International Sugar Organization Publications: www.sugaronline.com.

Ministry of Mines and Energy, Brazil (2000), *Brazilian Energy Balance 2000.*

Schmitz, Troy G., James L. Seale Jr. and Peter J. Buzzanell, *Brazil's Domination of the World Sugar Market*, www.east.asu.edu/msabr/research/workingpapers/msabr0207_brazilsugar.pdf.

United States Department of Agriculture [USDA], 2003, *Brazil Sugar Semi Annual*, Washington, D.C, United States.

United States Department of Energy [USDOE] (2003), *Annual Energy Outlook 2003*, USDOE Publications, Washington, D.C., United States.

Verdonk, Ron and Sergio Barros (2003), *Brazil Sugar Semi-Annual* Foreign Agricultural Service, USDA, Washington, D.C, United States.

THE POSSIBILITY OF AGRICULTURAL BIOMASS UTILISATION IN JAPAN

Yukihiko Matsumura[1]

Abstract

This paper discusses the situation of Japan regarding agricultural biomass generation, collection, conversion and utilisation. For Japanese agriculture, the main problems posed by the utilisation of biomass from farms are: 1) the small scale of farming, which generates correspondingly small amounts of biomass; 2) nitrification of the environment; and 3) the high cost for agriculture. The present situation and details of these problems are introduced, and possible approaches and policies for effective the utilisation of biomass are discussed.

Introduction

In Japan, the government demonstrated its positive attitude towards the active introduction of biomass as materials and energy resources by approving the "Biomass Nippon Strategy" in December 2002. The Strategy analyses current biomass resources in Japan, and sets targets for the future introduction of biomass (biomass from agriculture is also included as a potential source). Cattle manure is considered as waste biomass, and its increased utilisation is expected to be achieved relatively quickly. Agro-residue is regarded as one of the presently unused sources of biomass. However, utilising agricultural biomass in Japan poses particular challenges. In this paper, the situation of Japan regarding agricultural biomass generation, collection, conversion and utilisation, is discussed. The main problems of Japanese agriculture in terms of utilisation of biomass from farms are: 1) the small scale of farming, that leads to the small scale of biomass generation; 2) nitrification of the environment; and 3) the high cost of agriculture.

Situation of agricultural biomass in Japan

The amount of biomass resources in Japan has been reported by several researchers. The share from agriculture is shown in Tables 1 and 2. Table 1 shows the maximum potential amount of biomass supply, and Table 2 shows the useable potential amount. The latter is estimated by the researchers' judgment of which part of the biomass can be utilised, and thus the numbers are variable. Japan imports more than 50% of food in calorific value, as well as most of its cattlefeed. This is due to the fact that the cost of agricultural products in Japan is higher than abroad. It would also imply that energy production from agriculture, as practised in Brazil and the United States, is not possible in Japan. Roughly speaking, the price of energy is one-tenth of the price of food or feed – therefore if Japanese agricultural products are expensive, even as food or feed, utilising them as energy resources is economically extremely difficult. Thus, the discussion here will exclude plantation biomass and will be limited to the utilisation of cattle manure and agro-residue.

1. Hiroshima University, Hiroshima, Japan.

Table 1. Maximum potential of biomass from agriculture in Japan

PJ/annum[1]

	New Energy Foundation (2001)	**Yamaji *et al.*** (2000)	**Biomass Waste Recycling Research Team** (1999)	**Ministry of Public Welfare, Japan** (2000)	**Saka** (2001)
Fiscal year	2010	1990	1995-1996	1997	1997-2000
Feedlot manure	348	128	290	289	277
Agro-residue	141	183	160	N/A	222

Notes:
* PJ: petajoules. 1. Values were obtained by converting original values in t/yr by multiplying by 3.1 MJ (megajoules)/wet-kg for feedlot manure and 11.4 MJ/kg for agro-residue, respectively, except Yamaji *et al.* (2000), where they provided values in PJ/yr.
Source: see Table.

Table 2. Useable potential of biomass from agriculture in Japan

PJ/annum[1]

	New Energy Foundation (2001)	**Yamaji *et al.*** (2000)	**Biomass Waste Recycling Research Team** (1999)	**Ministry of Public Welfare, Japan** (2000)	**Saka** (2001)
Fiscal year	2010	1990	1995-1996	1997	1997-2000
Feedlot manure	N/A	32	N/A	N/A	>2
Agro-residue	13	47	18	N/A	16[2]

Notes:
1. Values were obtained by converting original values in t/yr by multiplying by 3.1 MJ/wet-kg for feedlot manure and 11.4 MJ/kg for agro-residue, respectively, except Yamaji *et al.* (2000), where they provided values in PJ/yr.
2. Does not include residue other than rice straw, rice husk, and barley straw, whose value was not specified.
Source: see Table.

Cattle manure production in Japan has been studied in detail by Fujino *et al.* (2002), Japan Institute of Energy, in a survey commissioned by the Agency of Natural Resources and Energy, Ministry of Economy, Trade, and Industry (METI), Japan. Table 3 shows the results of this survey. The amount of energy potential is almost identical for dairy cattle, beef cattle, pigs and chickens, including broilers. The amount in total is 183 PJ/yr, which is almost 0.8% of Japanese primary energy production.

Since most food and feed is imported in Japan, the amount of residue produced by food and feed production is limited. The volume of biomass residue, together with the food and feed materials produced by domestic agricultural activity, has been reported by Matsumura *et al.* (2002). Rice straw and husk form by far the largest category of agricultural residue in Japan (Table 4).

Table 3. Feedlot manure production in Japan (1990)

PJ/annum

	Production	Manure production		Moisture content	Heating value	Energy potential
	('000)	(wet-kg/day/head)[1]	(Tg*/year)	(-)	(MJ/dry-kg)	(PJ/year)
Dairy cattle	2 058	33.5	25.2	0.862	14.8	51.7
Beef cattle	2 702	18.6	18.3	0.862	14.8	37.5
Pigs	11 817	2.23	9.6	0.705	17.2	48.7
Chicken for eggs	187 412	0.12	8.2	0.775	13.0	23.9
Broilers	150 445	0.13	7.1	0.775	13.0	20.9
TOTAL	352 376	-	68.4	-	-	182.7

Note:
1. This table is a condensed version reproduced by the author. For reproduction, values in this column, not directly shown in the original paper, were recalculated by the author.
Source: Fujino *et al.*, 2002.

Table 4. Agro-residue production in Japan (2000)

PJ/annum

	Production	Residue ratio[1]	Residue production	Moisture content	Ash content	Energy potential
	(tonnes/ annum)	(-)	(Gg/yr)	(-)	(-)	(PJ/yr)
Rice	9 472 000	1.43	13 500	0.2	0.22	157.2
Wheat	688 200	2.53	1 740	0.28	0.14	20.1
Barley	192 200	2.5	481	0.09	0.15	6.9
Sweet potato	1 008 000	1.14	1 150	0.89	0.1	2.1
Potato	2 844 000	1.14	3 240	0.89	0.1	6.0
Soyabeans	235 000	2.14	503	0.6	0.15	3.2
Sugarcane	1 395 000	0.52	725	0.8	0.16	2.3
Corn	5 287 000	1.1	5 820	0.47	0.1	51.6
Sorghum	1 625 000	1.57	2 550	0.6	0.16	15.9

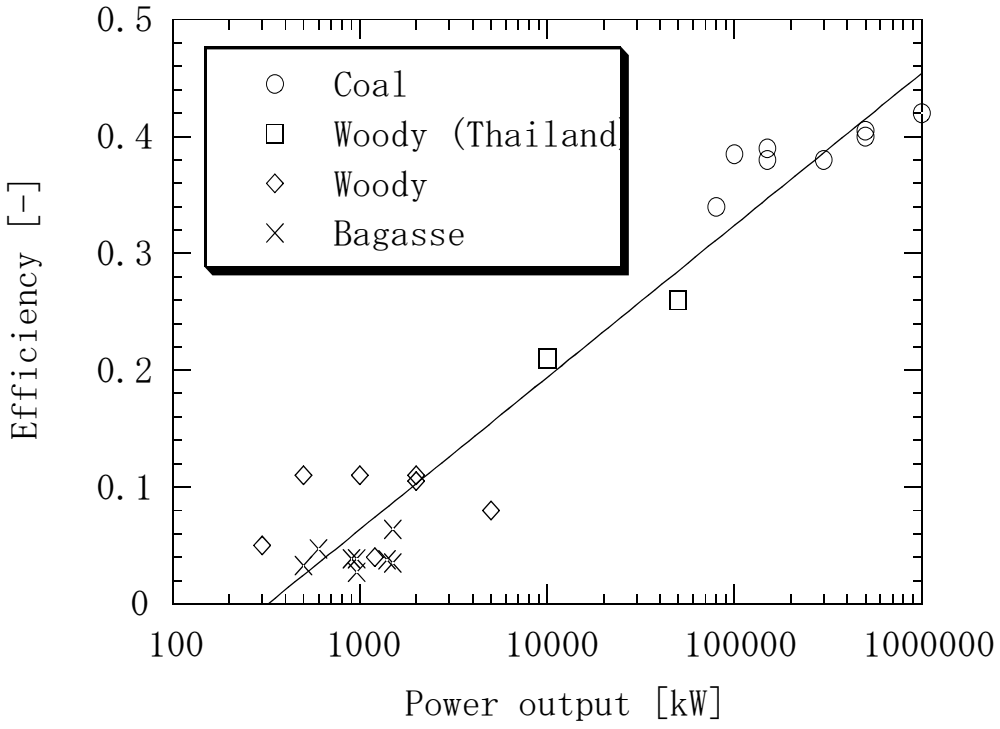
Note:
1. A heating value for residues of 18.6 MJ/dry-kg is assumed regardless of the commodity. The values of residue ratio, moisture content, and ash content depended on Klass (1998).
Source: Matsumura *et al.*, 2002.

Problems in the utilisation of biomass resources

The small scale of farming

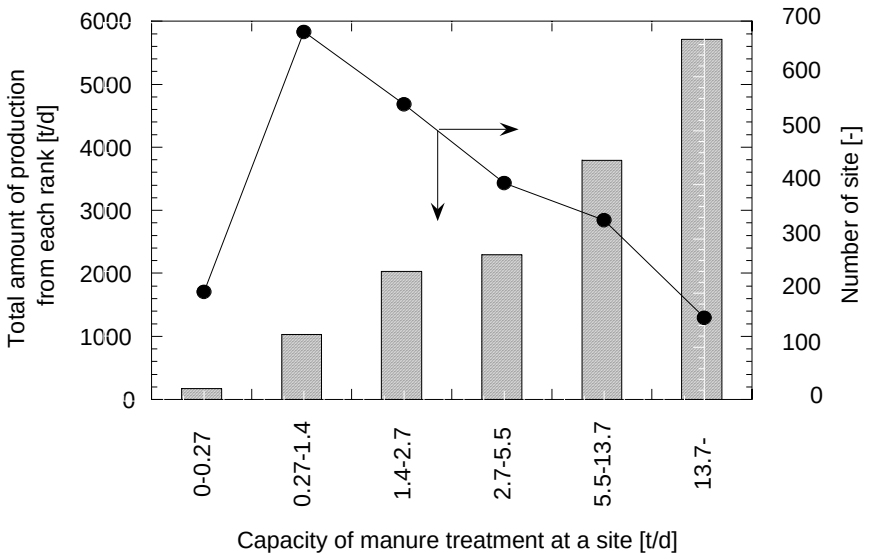
One of the problems in Japanese agriculture is its small scale, which poses a considerable problem in terms of energy utilisation of biomass from agriculture. The scale of the energy plant is directly related to the efficiency of the energy conversion plant. Figure 1 shows the relationship between the scale of the plant and its efficiency for power generation by direct combustion of fuels, including biomass. As is clearly shown, the larger the plant scale, the higher the efficiency of power generation. One of the reasons for the low efficiency observed for small-scale plant is heat loss. Another reason is the cheaper cost per unit of energy produced. Generally speaking, the cost of the plant increases in proportion to the scale of the plant to the power of 0.7, which means that for the energy conversion process, the initial cost per unit of energy production decreases in proportion to the scale of the plant by the power of -0.3. The larger the plant, the cheaper the initial cost per unit of energy produced. The issue of subsidies for additional equipment to improve energy efficiency then arises. These subsidies are not available for small-scale plants, thus operation at low energy efficiency results.

Figure 1. Relationship between power output and efficiency



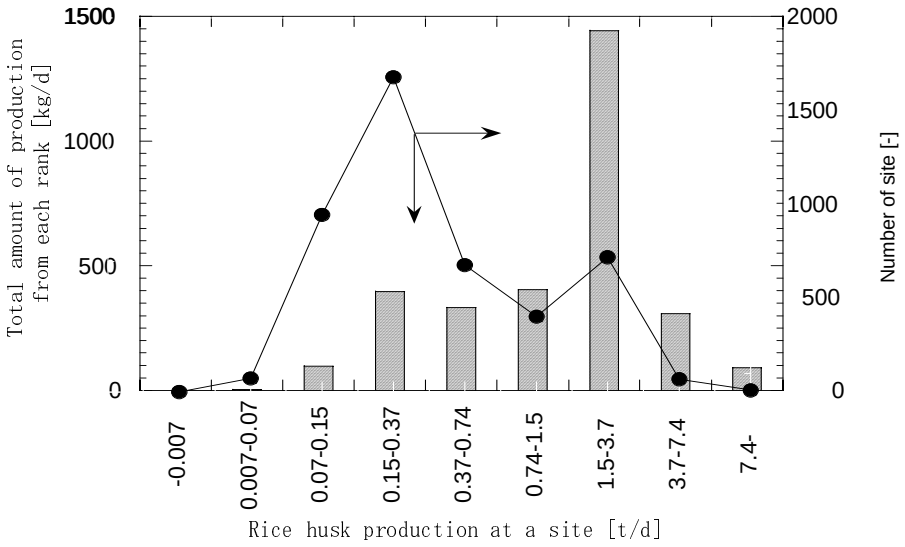
Source: Japan Institute of Energy, 2001.

Figure 2. Size distribution of manure treatment facilities in Japan



Source: Japan Institute of Energy, 2001.

Figure 3. Size distribution of rice husk production at a site



Source: Japan Institute of Energy, 2001.

On the other hand, the scale of production of Japanese biomass from agriculture is small. The scale of biomass production is the subject of a survey by the Japan Institute of Energy (2001). Data on feedlot manure and rice production residue are shown in Figures 2 and 3. For feedlot manure, the size of manure storage was taken as an indication of the scale of biomass production. For rice production residue, the scale of rice milling centres was employed as the basis of calculation. It should be noted that rice husks (which are derived from rice milling) have been chosen. When using certain means of harvesting, rice straw is also collected together with the rice, and the total amount of rice residue will be 5 times greater than is shown in Figure 3. In either case, whether feedlot manure or rice husk, the most frequent scale is around 1 dry tonne/day and, compared, with the scale and efficiency relationship in Figure 1, the efficiency available for the case of direct combustion is less than 0.1.

Nitrification of the environment

Nitrification of the environment presents another difficulty in using biomass from agriculture in Japan. For feedlot manure utilisation, bio-methanation is the conventional technology. Since bio-methanation cannot convert all organic compounds into methane, it is necessary that fermentation sludge and its liquid content undergo correct treatment. The cheapest and easiest way of doing this is to turn the fermentation sludge into compost, and the liquid into liquid fertiliser. However, the nitrogen content of the compost and fertiliser from feedlot manure is high and, when returned to the field, nitrification of the environment takes place.

This is due to the net amounts of nitrogen imported into the country. (As mentioned above, Japan imports most of its cattlefeed.) Most of the nitrogen contained in the feed is transferred in feedlot manure and, through methane fermentation, it accumulates in the sludge and liquid. As Japan does not export this nitrogen in any way, it accumulates within the country and is eventually released into the environment. When released into water, it increases the nitrogen concentration in the lake, river and the adjoining seas and cause eutrophication. Environmental destruction due to eutrophication produces red tides in Japan, and is to be prevented.

The best solution would appear to be converting the nitrogen into fertiliser and using it for domestic food and feed production in Japan. In order to bring this about, the fertiliser currently obtained from the oil industry will have to be replaced by the fertiliser obtained from cattle manure. However, the low cost of the synthesised fertiliser from the oil industry, together with limited production and the instability of the composition of fertiliser obtained from feedlot manure treatments make its utilisation difficult.

High cost of agriculture

The cost of agricultural production is high in Japan – this is the third obstacle to using biomass from agriculture. Japan has developed its agricultural technology so that the yield per unit area is maximised. The result is intensive methods of agriculture, which involve high inputs of fertiliser and energy. In Japan, the energy input for agriculture is larger than the heating value of the agricultural product. This leads to the high cost associated with agriculture. The high cost of electricity and fertiliser coupled with high labour costs in Japan result in the high cost of the agricultural product. Table 5 (Fujino, 2002) compares the cost of agricultural products on the domestic market in Japan with the United States' export price. There is sometimes a difference of 10 times between the two.

Table 5. Comparison of biomass prices (JPY/t)

(cost in Japanese market and exporting price from US)

Product	US export price	Japanese domestic price	Ratio
Rice	35 269	234 500	6.6
Wheat	12 556	164 283	13.1
Corn	9 506	153 600	16.2
Soyabeans	20 834	230 833	11.1

Notes:
Export price is f.o.b. price. Domestic price is from the Ministry of Agriculture, Forestry and Fisheries, Japan.
Source: Fujino, 2002.

Geological conditions in Japan also contribute to the high cost of agriculture. In Japan, whose restricted land surface of 370 000 km^2 is densely populated, with 125 million people, agriculture is conducted on a much smaller scale compared to the United States (and even compared to most European countries). Large-scale agriculture is not practical and the law prohibiting private companies from running agricultural concerns is an obstacle to economies of scale.

This high cost of agriculture in Japan even poses problems for residue utilisation. To make the product competitive, the farmer needs to cut unnecessary costs as much as possible, and sell by-products at the highest price possible. For example, most rice straw is returned to the soil simply because it is the cheapest form of soil improvement. In Japan, combine harvesters usually cut the rice straw into small pieces, and scatter them on the surface of the field. If maximum use is to be made of the combine harvester, it must be equipped with a knotter. Considering the cost associated with this modification, efficient collection of rice straw will be difficult to bring about without some subsidies or legal regulations.

Proposals

To circumvent the problems in Japan, – the small scale of farming, environmental eutrophication and the high cost – both technological and political initiatives are needed. From a technical viewpoint, it is necessary to develop energy conversion technology that allows high energy efficiency on a small scale, and also the complete treatment of nitrogen. From the political viewpoint, an economically feasible framework is needed that will promote the collection and utilisation of agricultural biomass.

When developing a technology to utilise small-scale biomass in Japan, the concept of compact plant is effective. As with Japanese compact cars, higher efficiency in limited conditions should be developed. Following the oil embargo, compact cars were developed to achieve high efficiency in on narrow roads, with frequent stopping and slowing down, and strict pollution controls. The same level of experience and technology should be applied to biomass conversion processes.

As technologies to be employed, gasification power generation is suitable for dry biomass species, including rice straw. Gasification technology itself is an established, old technology that is used even in developing countries. The advantage is that, once gasified, bioenergy can be converted into other forms of energy with high efficiency, even on a small scale. For power generation, gas engines, micro gas turbines and fuel cells are available to convert fuel gas into electricity at a conversion efficiency of at least 0.25, even on as small a scale as 30 kW (kilowatts). For heating facilities, fuel gas is easily distributed to individual households, enabling utilisation of conventional cooking equipment, following minor modifications.

For wet biomass, including feedlot manure, the development of a technology to convert whole organic compounds into gas is needed. At the moment, methane fermentation or anaerobic digestion is the only technology applicable to this kind of biomass feedstock, due to its high moisture content. Trials for improving this technology include pre-treatment and multistage fermentation, but treatment by biological activity has limitations. Thermochemical conversion is one solution. Conventional thermochemical processes cannot not be applied to wet biomass with a moisture content higher than 0.7, due to the difficulty in the recovery of heat needed as latent heat for the evaporation of contained water. Technologies that enable improved heat recovery, such as supercritical water gasification, will be effective.

Unfortunately, the economic situation in Japan does not allow the intensive development of this kind of technology by the private sector. It is therefore recommended that the government subsidise the technology.

Another important aspect in terms of the utilisation of biomass from agriculture is the method of collection. Biomass produced from the rice field or feedlot should be transported to the energy conversion facilities. Feedlot manure is collected for compost production and the transportation cost is usually covered by the income generated by selling the compost, although this kind of facility is often economically supported by the municipal government. For rice-milling centres, rice husks are automatically collected on-site, but in order to collect rice straw, combine harvesters have to be modified, and transportation fees will arise. When biomass is to be utilised, the transportation cost has to be covered by the income associated with the biomass utilisation. This leads to the higher cost of biomass energy, since in Japan labour, as well as transportation, is expensive. To reduce transport costs, the existing transportation network must be efficiently utilised. For example, in Japan several delivery services operate, including the government-administered postal service. There are also private transportation companies. Another possibility is the utilisation of the waste collection/management companies. Thus, the initial costs of developing a delivery system can be avoided.

From the political position, economical support is essential. The cost of biomass utilisation from agriculture is higher than the cost of fossil fuel utilisation. The Japan Institute of Energy (2002) estimated the price of power generated from feedlot manure at 64.9 JPY/kWh (kilowatt-hour), even on a scale of 200 t/d. Matsumura *et al.* (2002) estimated the cost of power production from rice straw at 25 JPY/kWh (excluding the supply cost). Considering that the price of Japanese electricity is around 10 JPY/kWh (excluding the supply cost), it is evident that the introduction of biomass energy needs some economic assistance.

It is desirable that this economic aid should be based on the understanding that the utilisation of biomass energy is advantageous for the reduction of greenhouse gas emissions in Japan. Thus, a system to evaluate the utilisation of biomass from agriculture at market value is needed. A Renewable Portfolio Standard is one possibility, but more flexible and global mechanisms are required. The Renewable Portfolio Standard that Japan has at present is restricted in amount and options. The number of electricity producers is limited – as is the amount they can accept as the obligation for electricity production from renewable energy. If the utilisation of biomass from agriculture receives cheap and proper certification, and is related to CO_2 emission credit for international trading, future producers and users of biomass from agriculture will have the advantage of many more options than is the case today.

The above proposal should apply not only to Japan, but also to European countries and to any situation where agriculture is conducted on a small scale.

Conclusion

The utilisation of biomass from agriculture is desirable from the viewpoint of reducing Japanese greenhouse gas emissions. The three main problems for utilising this biomass in Japan are the small scale of biomass production; eutrophication of the adjacent water system; and the high cost of agriculture. This paper has proposed the development of compact plant technologies to commercialise gasification technology on a small scale. For biomass collection, conventional delivery networks should be utilised. Economic incentives should be put in place, and mechanisms to include the biomass from agriculture in the emission trade of CO_2 should be developed.

BIBLIOGRAPHY

Biomass Waste Recycling Research Team (1999), *Present Situation and Problems of Recycling Biomass Waste,* Report prepared by the Ministry of Agriculture, Forestry, and Fisheries, Tokyo, Japan.

Fujino, Junichi, Hiromi Yamamoto and Kenji Yamaji (2002), "Comparative Investigation of Bio-energy Supply Potential in Japan", Proceedings of the 18th Conference on Energy Systems, Economy, and Environment.

Fujino, Junichi (2002), "Economical evaluation of bioenergy", in Japan Institute of Energy, *Biomass Handbook*, Tokyo, Japan, Ohm-sha.

Japan Institute of Energy (2002), *Report on Fundamental Investigation for Promoting Introduction of New Energy etc. FY2001 – Investigation on Biomass Energy Utilization and Propagation Policy*, Tokyo, Report submitted to the Ministry of Economy, Trade and Industry, Tokyo, Japan, p. 283.

Japan Institute of Energy (2001), *Report on Fundamental Investigation for Promoting Introduction of New Energy etc. FY2001 – Investigation on Biomass Energy Conversion Technology with a High Efficiency*, Report submitted to the Ministry of Economy, Trade and Industry, Tokyo, Japan.

Klass, Donald L. (1998), *Biomass for Renewable Energy, Fuels, and Chemicals*, Academic Press, San Diego, United States of America.

Matsumura, Yukihiko, Tomoaki Minowa and Hiromi Yamamoto (2002), "Amount, Availability, and Possibility of Utilization of Rice Straw (Agricultural Residue) Biomass as an Energy Resource in Japan", *Journal of the Japan Institute of Energy*, Vol. 81, No. 901, pp. 290-296.

Ministry of Public Welfare (2000), *Report on Situation of Industrial Waste Emission and Treatment*, Report prepared by the Ministry of Public Welfare, Tokyo, Japan.

New Energy Foundation (2001), *Fundamental Research on Promotion of New Energy Introduction – Fundamental Research on Actual Situation of Bioenergy*, Report submitted to the Ministry of International Trade and Industry, Tokyo, Japan.

Saka, Shiro (2001), *Biomass, Energy, Environment*, Industrial Publishing & Consulting, Tokyo, Japan.

Yamaji, Kenji, Hiromi Yamamoto and Junichi Fujino (2000), *Bioenergy*, Myosin Shuppan, Tokyo, Japan.

ENERGY CROPS IN FLEMISH AGRICULTURE: POSSIBILITIES AND LIMITS

Frank Nevens, Visi Garcia Cidad, Marijke Meul, Dirk Reheul and Erik Mathijs[1]

Abstract

To determine if and how energy crops can be an appropriate track to produce green energy in Flanders, we studied the energy yields and energy efficiency (output: input ratio) of potential crops in Flemish circumstances.

Provided that heat is recovered to a considerable extent, combustion of wood from short rotation coppices provides most green energy at the highest efficiency. However, i) covering the requirement for green electricity (6% of annual use) by these crops would take half of our currently utilised agricultural area; and ii) from a farm economical point of view, the best option resulted in a financial yield that was EUR 300 below the current actual yields in arable rotations.

Growing crops for biofuels is less efficient and provides less energy per ha. Winter rape was the most interesting crop but i) it can hardly be fitted into the currently applied arable rotations (with sugarbeet) and ii) even without imposing taxes, the resulting biofuel is not competitive with fossil fuels.

We conclude that in the small region of Flanders, where open space is rather scarce, energy crops are not the obvious track towards the use of green energy. Other possibilities, such as wind or solar energy, along with importing fuel (*e.g.* biodiesel) from countries with scale advantages seem appropriate.

Introduction

Also in Flanders (which has a surface area of 13 106 km²) there is much concern as to the best way of covering some part of its future energy needs with energy from renewable sources. Growing energy crops is one possibility which would have the additional advantage of promoting a more multifunctional, sustainable agricultural sector.

In order to direct and justify the appropriate future policy concerning energy crops, the Flemish Minister of Environment and Agriculture commissioned the Policy Research Centre for Sustainable Agriculture to examine the possibilities and the limits of such crops in Flanders.

1. Flemish Policy Research Centre for Sustainable Agriculture ("Stedula"), Belgium. Stedula is connected to Ghent University and the Catholic University of Leuven.

In the present study, we review potential energy crops and conversion techniques for possible development in Flanders. As our focus is on energy production and energy use in a region where open space is rather limited, we concentrated on those crops and processes that combined high energetic efficiency (output/input) and high net energy production per hectare.

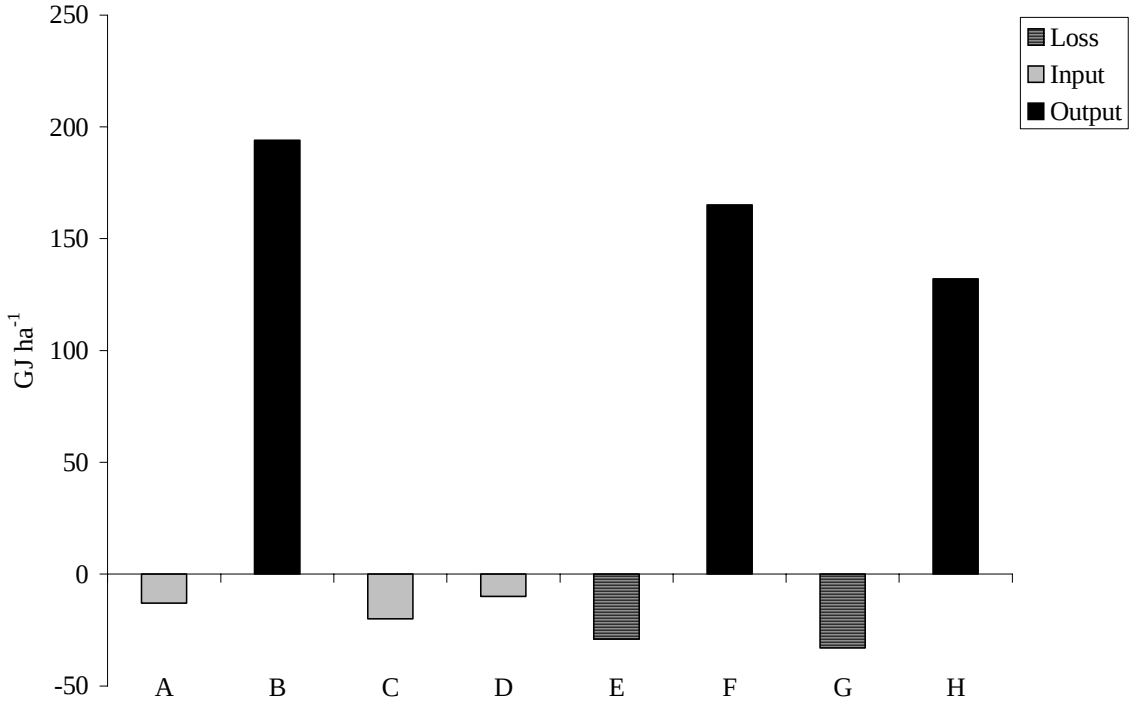
Materials and methods

Concerning the technical aspects of growing and processing energy crops, we collected existing scientific and practical knowledge and data on crops and techniques. Important data were gross energy yield potentials of various energy crops in Flanders. We considered classical arable crops (wheat, sugarbeet, potatoes, maize and rapeseed), new crops, such as elephant grass (miscanthus) and bamboo, and short rotation coppices of poplar or willow.

We distinguished two main groups of energy crops, according to the nature of the usable energy they result in: i) solid fuels, burned and transformed into electricity and heat, or ii) liquid fuels burned in engines.

To study the energetic aspects of energy production for each of the crops and conversion processes, we collected data on the crop energy yields, the energy inputs in production and processing and the energy losses during conversion for each of the possible conversion techniques. These data were summarised in an energetic life-cycle analysis (Figure 1).

Figure 1. Energy input, output and losses during the life cycle of an energy crop
(example case: combustion of short rotation willow, chopped at harvest and dried subsequently)



Notes:
A = crop production; B = crop gross energy yield; C = input for transport to conversion plant; D = input conversion process; E = losses during conversion; F = usable energy following conversion; G = losses during actual use; H = useful energy.
Source: Stedula, 2003.

A: Energy input for crop production

This input was calculated as the sum of all direct and indirect energy inputs during crop production. Direct energy comprised the use of fuel and lubricants for the soil and plant treatments. Indirect energy comprised the energy necessary to produce the used seeds, pesticides, fertilisers and machines. Data on soil and plant treatments, pesticide and fertiliser use were collected from local experts. Appropriate coefficients of energy use for treatments or inputs were retrieved from Dalgaard *et al.* (2001).

B: Crop gross energy yield

Combining crop yields (NIS, 2002, Moens *et al.*, 1995; Lettens *et al.*, 2003; Lewandowski *et al.*, 1995; Macpherson, 1995; Ministerie van Middenstand en Landbouw, 2001; Ampère commissie, 2000; IPA, 2002; Novem, 1992) and crop gross energy contents (Novem, 1992) resulted in the gross energy yields.

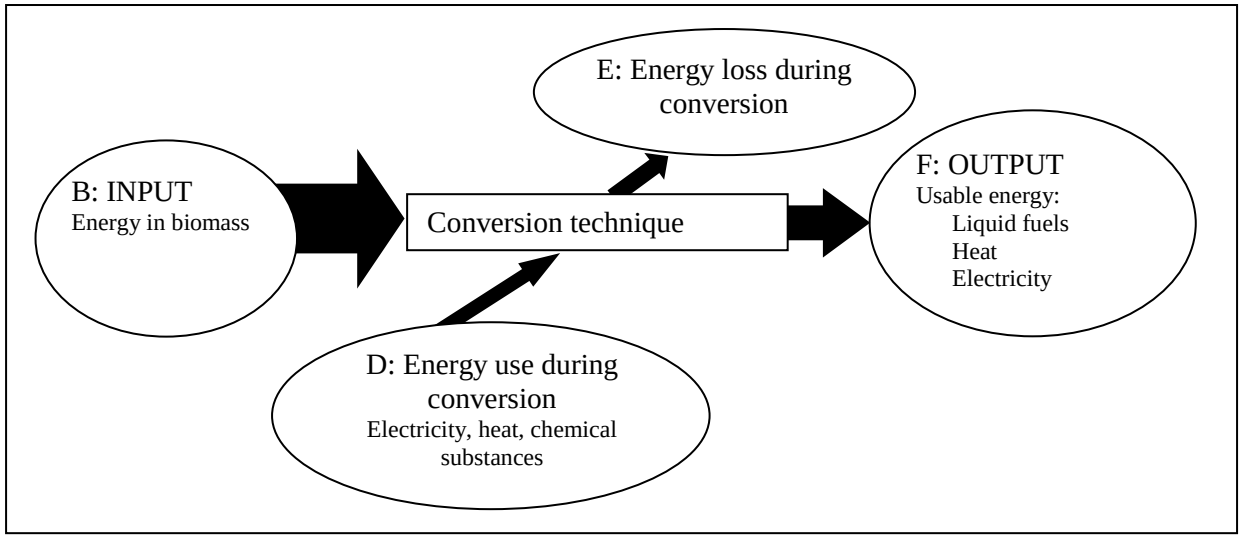
C: Energy use for transport to conversion plant

Based on conversion plant capacities; the amount of utilised agricultural area (UAA) in Flanders; and assuming a 10% share of energy crops in the total UAA, a transport radius was calculated and the energy use was calculated, based on an energy need of 0.8 MJ/tonne/km (Biewinga and van der Bijl, 1996). We are aware of the substantial assumptions resulting in the calculated transport radius but we observed that, relatively, the energy cost of transport was a minor factor in most of the energy cycles.

D and E: Energy use and energy loss during conversion, respectively

Literature data resulted in conversion performances summarised in Figure 2 and Table 1.

Figure 2. Elements of the conversion performance



Source: Stedula (2003).

Table 1. Conversion techniques and their energetic performance

Technique (plant capacity)	Conversion performance (gross efficiency) F/B	Net efficiency (F-D)/B
	(%)	(%)
Co-combustion (>100 MW_e)	$37_e + 50_t$ [h *]	$34_e + 46_t$ [h]
Combustion (5 MW_e)	$16_e + 69_t$ [a]	$15_e + 65_t$ [h]
Gasification (0.15-1.5 MW_e)	$27_e + 53_t$ [g]	$25_e + 50_t$ [g]
Anaerobic fermentation	$30_e + 50_t$ [c]	$17_e + 28_t$ [b]
Cold pressing	41 [d, e]	39 [i]
Chemical extraction	57 [e, f]	49 [j]
Chemical extraction + trans-esterification	57 [f]	35 [j]
Alcoholic fermentation	50-42-78 [f]	24-17-37 [j]

Notes:
* e = electric; t = thermic
Sources: a. Hauben *et al.*, 2000; b. Verstraete *et al.*, 1981; c. Novak-Zdravkovic en De Ruyck, 2002; d. Boerenbond, 2002; e. Janssen, 2002; f. Boerenbond, 2001; g. Xylowatt, 2002; h. Van den Spiegel en Roose, 2001; i. Badger *et al.*, 1999; j. Martin en Vanhemelryck, 1992.

F: Usable energy

In the case of solid fuels this is the amount of electricity and heat leaving the power station. In the case of liquid fuel this is the energy comprised in the fuels.

G: Energy losses during final use and H: final useful energy

We assumed that the efficiency of conversion of electrical energy in an electrical motor is about 80% (US Department of energy, 1996). For liquid fuels, efficiencies are 25–30% for benzine, 30-35% for gas oil (Van den Schoor, 2002; Persoons, 2002) and 40% for adapted motors, working on pure oil (Fortech, 2002).

Actual goals concerning the use of green energy are expressed in usable energy: 6% of the use of electricity should be green in 2010; 2% of the use of fuels should be green in 2005. Therefore, to compare the relative position of each of the energy crops and to estimate their potential contribution to actual goals on green energy production, we compared the different crops and systems at the level of usable energy (F).

We positioned the multiple combinations of energy crop + conversion technique in a two-dimensional graph: the x-axis indicating the net amount of usable energy per hectare (F – A – C – D), the y-axis indicating the energetic efficiency calculated as (F – A – C – D) / (A + C +D). This efficiency is the amount of usable energy that is produced in surplus of the invested amount of energy. The amount of usable energy comprises electricity and heat in the case of solid fuels, the energetic value of the fuel in the case of liquid fuels.

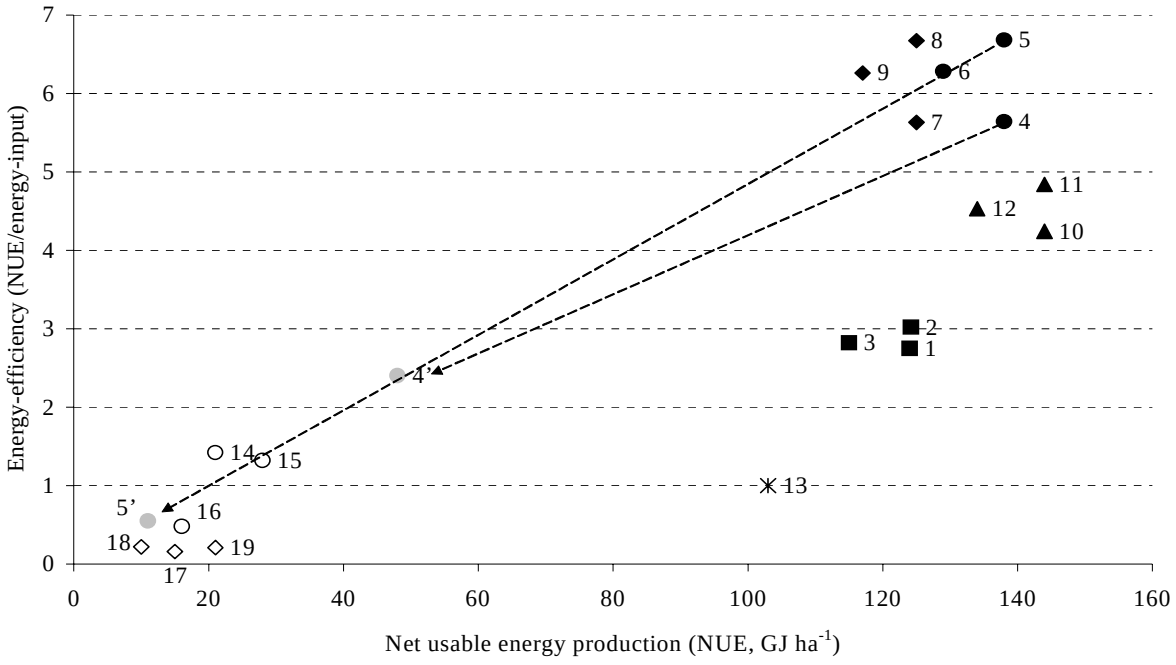
Beyond the purely technical and energy aspects, we also studied the economic perspectives for the introduction of energy crops into agricultural practice. For biofuels, we calculated the price of one litre of fuel, if the farmer were to receive the same rate of compensation as he currently does for growing the crop in question in the usual way(wheat, sugarbeet, potatoes), or the compensation he would like to receive when substituting, for example, winter wheat for rapeseed. Transport costs and conversion costs were also included in the cost price. We assumed biofuels to be levy-free. Subsequently, we compared the found total cost price with the actual price of the energetic equivalent in fossil fuels.

For green electricity, we assumed that the power station is prepared to pay a maximum price based on the penalty for non-produced green electricity: EUR 0.12 per kWh (Vlaamse Regering, 2001). After extracting transport and conversion costs, a price for the farmer was calculated. This price was compared with the actual financial margin on arable land in Flanders: EUR 1 091/ha (CLE-CEA, 2002).

Results and discussion

Figure 3 represents the net yields of usable energy per hectare (F – A – C – D), as well as the ratio of this amount to the invested energy (F – A – C – D) / (A + C + D). A first general observation is that energy crops for solid fuels (particularly short rotation coppices) are superior in the combination of energy yield and efficiency. However, when only electrical energy is considered (*i.e.* the released heat is not utilised), this relative advantage decreases significantly (Figure 3, arrows 5 -> 5' and 4 -> 4').

Figure 3. Energy production and efficiency of energy production for combinations of energy crops and conversion techniques



(For notes, see following page)

Notes to Figure 3:

1 = Willow or poplar (harvested with chopper and dried subsequently), co-combustion.
2 = Willow or poplar (harvested with chopper and dried subsequently), combustion.
3 = Willow or poplar (harvested with chopper and dried subsequently), gasification.
4 = Willow (harvested as stems, dried in the field), co-combustion.
4' = Willow (harvested as stems, dried in the field), co-combustion. Considering only electricity output.
5 = Willow (harvested as stems, dried in the field), combustion.
5 ' = Willow (harvested as stems, dried in the field), combustion. Considering only electricity output.
6 = Willow (harvested as stems, dried in the field), gasification.
7 = Poplar (harvested as stems, dried in the field), co-combustion.
8 = Poplar (harvested as stems, dried in the field), combustion.
9 = Poplar (harvested as stems, dried in the field), gasification.
10 = Elephant grass, co-combustion.
11 = Elephant grass, combustion.
12 = Elephant grass, gasification.
13 = Maize, anaerobic fermentation.
14 = Rapeseed, cold pressing.
15 = Rapeseed, chemical extraction.
16 = Rapeseed, esterification.
17 = Sugarbeet, alcoholic fermentation.
18 = Wheat, alcoholic fermentation.
19 = Potato, alcoholic fermentation.

Source: Stedula (2003).

From an energetic point of view, the option of liquid fuels is less productive and less efficient. If liquid fuel production is nevertheless considered, rapeseed oil is the best alternative. Biodiesel from rapeseed is less efficient owing to the extra energy input required for the esterification process.

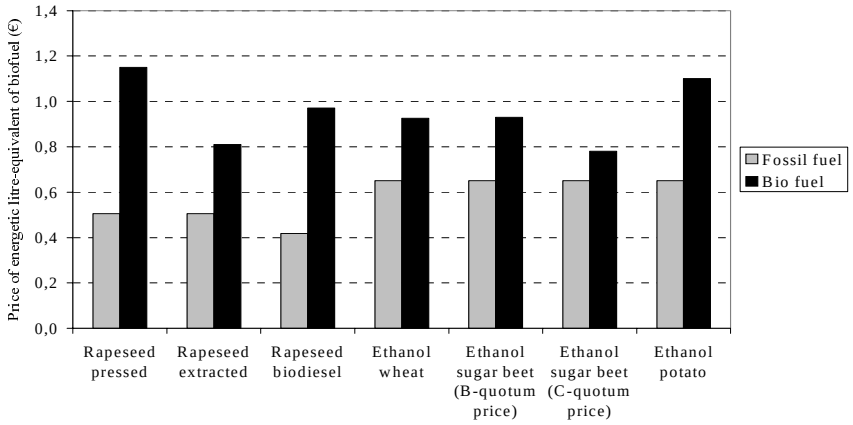
If we adopt the policy goal that by 2010 6% of the Flemish consumption of electricity should originate from renewable sources, this would mean that about $16.2\ 10^{15}$ J should be produced in a "green" way. If the energy crops on agricultural land would be the track and if we assume a maximum electricity production of 50 GJ ha^{-1} from energy crops (4' in Figure 3), attaining half of this goal would take 162 000 ha (= 25% of the total Flemish UAA): attaining the entire 6% would require half of the Flemish UAA (324 000 ha). If we consider using exclusively the current area of fallow land (about 8 300 ha), only 2.6/100 of the 6% goal would be attained.

It is obvious that to produce a significant amount of energy with energy crops, the surface area required is extensive, particularly in the densely populated Flemish region where open space is relatively scarce and is used for numerous other purposes (nature conservation, recreation, etc.). We calculate that, in the current situation in Flanders, to produce equal amounts of electricity, one windmill is equivalent to 250 ha of short rotation coppices: 100 m² of photovoltaic cells on buildings are equivalent to 7 200 m² of short rotation coppices.

Another policy goal is that by 2010 2% of fuel consumption should be "green" (corresponding with $4\ 10^{15}$ J). Were this fuel to come from energy crops, Flanders would need 34 000 ha of potatoes, 36 000 ha of sugarbeet or 68 000 ha of winter wheat – each of these figures corresponds roughly with the area currently used for these crops.

Using rapeseed to produce the 2% of green fuel would require about 90 000 ha. Considering the practical preconditions – that rapeseed is not adapted to sandy soils, that the profitable sugarbeet will not be banned from arable rotations, that rapeseed and sugarbeet do not grow in one crop rotation and that rapeseed should be grown in a 1 : 4 crop rotation – leaves a realistic maximum of actual available area for rapeseed of only ± 10 000 ha.

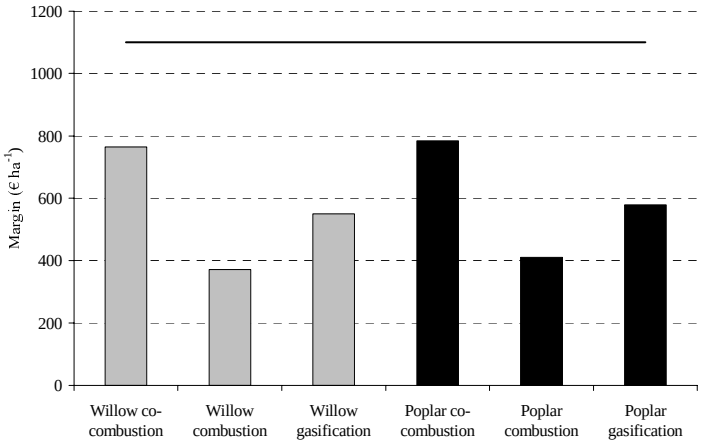
Figure 4. Calculated prices of 1 litre of biofuel and the prices of the energetically corresponding amount of fossil fuel
(biofuels considered levy-free)



Source: Stedula, 2003.

Figure 4 illustrates that the calculated minimum prices of biofuels (levy-free!) are always higher (+20 tot + 140%) than their energetic equivalent in fossil fuels. So, with no taxes being levied on biofuels, substantial extra financial stimuli will be needed to make biofuels competitive and to persuade farmers to switch from classical arable production to energy crops for liquid fuels.

Figure 5. Margin of energy crops compared with the current actual average margin for arable crop production
(horizontal line)



Source: Stedula, 2003.

Figure 5 illustrates that for short rotation coppices there is also a significant gap between the maximum attainable margin derived from the current green electricity penalty of EUR 0 12 per kWh and the current actual margin of arable production (EUR 1 091 per ha): even the most profitable combinations of crops and processes are EUR 300 less than classical arable production.

Conclusions

Although it is not easy to find a path through the abundant and scattered information and data on energy crops, we conclude that for Flanders short rotation coppices are the most obvious track to follow since they show the highest production of usable energy per ha and the highest energetic efficiency. We should add that these advantages are only valid when the produced heat is also used efficiently (co-generation).

In general, we observed that compared with other alternatives of green energy (*e.g.* solar and wind energy) energy crops require an extremely large proportion of the open space, which is rather limited in Flanders.

Moreover, from an economic point of view, none of the possible combinations of energy crops and conversion techniques is yet competitive with classical arable production. Substantial extra financial stimuli (on top of *e.g.* tax exemption) are needed to make energy crops an alternative worth considering for agriculture.

We conclude that energy crops will never constitute a significant part of Flemish energy production and we would advise that more "energy" should be directed towards finding alternative sources of renewable energy. Finally, society should also reconsider its ever-increasing consumption of energy. Using less energy in a more rational way is of more use than hundreds of hectares of energy crops: the greenest energy is the one we do not use.

BIBLIOGRAPHY

Ampère commissie (2000), Sectie F: Hernieuwbare en alternatieve energieën.

Badger, P.C., N.R. Clark, A. Esper, Y. Hashimoto, J.L. Hernanz, B.M. Jenkins, T. Jungbluth, I. Karaki, O. Kitani, R.L. Legge, T. Maekawa, F.R. Magdoff, M. Michelozzi, W. Muehlbauer, H. Nishina, J. Ortiz-Canavate, R.M. Peart, K. Roy, G. Riva, T. Saiki, V. Schnitzer, G. Schumm, D. Scott, F. Sissot and V. Vidrich (1999), *CIGR Handbook of Agricultural Engineering. Energy & Biomass Engineering, Volume V*, ASAE [American Society of Agricultural Engineers].

Boerenbond (2001), "Hernieuwbare energie - hernieuwbare grondstoffen. Welke rol kan landbouw hierin spelen", *Studiedag Groene Energie*, 21 May 2002, Hof ter Gracht - Moorsele, Belgium.

Boerenbond (2002), "Werkgroep ad hoc 'hernieuwbare energie'. Aanpassingen".

CLE-CEA (2002), De rendabiliteit van het landbouwbedrijf in 1999 (boekjaar 1999-2000): www.clecea.fgov.be/publicat/raprent2000n.pdf.

Dalgaard,T., N. Halberg and J.R. Porter (2001), "A model for fossil energy use in Danish agriculture used to compare organic and conventional farming", *Agriculture, Ecosystems & Environment* 87, pp. 51-65.

Fortech (2002), "Diesel op plantenolie": www.fortech.be/Plantenolie01.htm.

Hauben, P., R. El Asri and J. De Ruyck (2000), Kennis van de CO2-emissies, Fase 2, Elektriciteitsproductie uit biomassa en gelijk te stellen afvalstromen, Vrije Universiteit Brussel.

IPA [Interprovinciaal Proefcentrum voor de aardappelteelt vzw] (2002), Kwaliteitsanalysen voor aardappelen, uitgevoerd in de labo's van PCA:

www.proefcentrum-kruishoutem.be/PCA/pag/voorl/kwaliteitsanalysen.htm#DS_DS.

Janssen, W. (2002), "Diesel motoren op plantaardige olie. Planten: de batterij van zonne-energie voor warm water, elektriciteit en transport", *Leefmilieu* 2002, pp. 110-116.

Lettens, S., B. Muys, R. Ceulemans, E. Moons, J. García, J. and P. Coppin (2003), "Energy Budget and Greenhouse Gas Balance Evaluation of Sustainable Coppice Systems for Electricity Production, *Biomass and Bioenergy* 19.

Lewandowski, I., A. Kicherer and P. Vonier (1995), "CO_2-balance for the cultivation and combustion of miscanthus", *Biomass and Bioenergy* 8, pp. 81-90.

Macpherson, G. (1995), *Home-grown Energy from Short-rotation Coppice*, Farming Press Books.

Martin, J., and J.L. Vanhemelryck (1992), Les combustibles et carburants d'origine agricole, Rapport final, Unité Term., UCL.

Ministerie van Middenstand en Landbouw (2001), "De Belgische landbouwteelten: een overzicht".

Moens, V., Hoeben, R., Goeminne, M. and G. Ampe (1995), *Invloed van afrijping en loofdoding op de kwaliteit van aardappelen cultivar Bintje, Verslag Teeltjaren 1993-1994,* http://taoren.rug.ac.be/~rudi/docs/publ/verslag94n.pdf .

NIS [Nationaal Instituut voor de Statistiek] (2002), Productie van Landbouwteelten 2002, www.statbel.fgov.be/downloads/crp2002_nl.xls.

Novak-Zdravkovic, A. and J. De Ruyck (2002), "Embedded Generation: a Global Approach to Energy Balance and Grid Power Quality and Security", Internal Report I – second version, IWT 010055.

Novem (1992), *De haalbaarheid van de productie van biomassa voor de Nederlandse Energiehuishouding*.

Persoons, T. (2002), "Sachs integreert conventionele startmotor en generator in DynaStart", *Nieuwsbrief ENERGIE*.

Stedula [Flemish Policy Research Centre for Sustainable Agriculture] (2003), *Energiegewassen in de Vlaamse landbouwsector, Stedula* – publicatie nr. 1, Belgium, Brussels.

US Department of Energy (1996), "Buying an Energy-efficient Electric Motor", Motor Challenge Factsheet: www.oit.doe.gov/bestpractices/motors/factsheets/mc-0382.pdf.

Van den Schoor, F. (2002), "Re: Een vraag over energieconversie", internet communication.

Van den Spiegel, F. and F. Roose (2001), "Biomassa vergassing en co-verbranding van het syngas in een Belgische kolengestookte ketel", unpublished paper.

Verstraete, W., J. Poels, P. Tavernier, D. Valcke, A. Van den Bergh and A. Vermeiren (1981), Biogas, Stichting Leefmilieu v.z.w.

Vlaamse regering (2001), "Persmededeling van de Vlaamse regering", Vergadering van 28 september: www.vreg.be/documenten/persberichten_vlaamse_regering/persbericht.280901.pdf.

Xylowatt (2002), Le fournisseur belge de centrales électriques par gazéification de bois: www.xylowatt.com.

2. Environmental Dimension

Page

A Framework for Evaluating the Environmental Impact of Biofuel Use
Jane Feehan and Jan-Erik Petersen, European Environment Agency (EEA), Denmark *151*

Utilisation of Grass for Production of Fibres, Protein, and Energy
Stefan Grass, Biomass Project Services, Switzerland *169*

Linking Bioenergy with Carbon Storage: a Sequential Decision Approach to the Threat of Abrupt Climate Change
Peter Read, Massey University, New Zealand *179*

The Effects of Bioenergy Crops on Farmland Birds in the United Kingdom – a Review of Current Knowledge and Future Predictions
G.Q.A. Anderson, L.R. Haskins and S.H. Nelson,
Royal Society for the Protection of Birds, United Kingdom *199*

Powerswitch! The Role of Bioelectricity in the Future of Sustainable Energy
Giulio Volpi, WWF, Belgium; and Thomas Cross, XYLOWATT sa, Belgium *219*

Harvesting Energy with Fertilisers
Christian Pallière, European Fertilizer Manufacturers Association, Belgium *223*

Potential for Agricultural Biomass to Produce Bioenergy in the Czech Republic
Sergej Usťak and Marie Usťaková, Research Institute of Crop Production,
Czech Republic *229*

Emissions from Biogas Plants in Austria
Werner Pölz and Gerhard Zethner, Federal Environment Agency Ltd., Austria *241*

Biogas Production from Pig Slurry in Korea
Jong-sik Lee, Woo-kyun Park, Dong-kyu Im, Mun-hwan Kho and Kee-an Roh,
National Institute of Agricultural Science and Technology (NIAST), Republic of Korea *251*

A FRAMEWORK FOR EVALUATING THE ENVIRONMENTAL IMPACT OF BIOFUEL USE

Jane Feehan and Jan-Erik Petersen[1]

Abstract

With increasing emphasis on renewable energy, the role of biomass as an environmentally friendly energy source is becoming more important. Transport is a sector where other renewables will not play a major role in the foreseeable future, making the contribution of biomass and biofuels particularly significant. The issue of biofuel use in transport is one of the cross-sectoral themes that the European Environment Agency is planning to address during the coming years.

This paper summarises recent EU policy developments regarding biofuels. It then sets out a framework for evaluating the environmental impact of current biofuel use, drawing on existing studies and assessment approaches developed at the EEA and linking with the existing OECD agri-environment indicator structure. This framework is intended to facilitate more integrated, holistic thinking on how best to assess the impact of increased biomass production and use. It aims to set out the parameters of an *ex ante* evaluation of measures to expand biomass production and use. Recent policy developments present a range of options for increasing biofuel use in the EU, and it is hoped that the framework will help to develop appropriate approaches for local and regional circumstances. To test our conceptual approach, the framework is applied to two different types of biofuel production. Lastly, the paper draws conclusions from the case study exercise about the usefulness of the assessment framework in evaluating the environmental implications of future biofuel development.

Introduction

There is now a renewed interest in the use of biomass for the efficient and clean production of heat and electricity and for the production of renewable transport fuels. Biomass from agricultural, forestry and waste sources provided over 63% of the European Union's (EU) renewable energy in 1999 and it appears to be the renewable energy source with the highest potential to contribute to a future sustainable energy supply for the European Union (European Energy Association [EEA], 2002*a*). In Finland, Sweden and Austria, it currently covers 23%, 18% and 12% of the primary energy demand (Groscurth *et al.*, 2000). Biomass is a particularly attractive option for a number of reasons.

- It is widespread, diverse and renewable, contributing both to the security of energy supply and to the diversification of energy sources.
- It can produce a low-carbon source of electricity.
- Modern biomass conversion technologies have brought emissions down to very low levels.

1. European Environment Agency, Copenhagen, Denmark.

- Energy plantations, if carefully planned and managed, can yield benefits such as watershed protection, habitat and amenity value and the rehabilitation of degraded areas.

- Biomass production can provide an alternative market for agricultural production, contributing to agricultural diversification and rural development.

Table 1 shows some of the main agricultural and forestry biomass resources, ranging from dedicated energy crops, such as oil and starch crops, to secondary residues, such as sawmill waste. Some crops, such as sugarbeet, have a high energy yield per hectare but little use can be made of their by-products. Others, such as oilseed rape, have a lower energy yield per hectare but yield a number of useful by-products (high-protein animal feed, glycerine) that contribute to the overall energy balance.

Energy content is only one feature of these crops. Some can only be grown in rotation with other crops, may require more irrigation and chemical inputs than others, and some provide useful cover for wildlife. Some are being exported, while others are already being imported. A simple cost-benefit analysis does not capture the full range of costs and benefits that arise, and nor does a simple comparison between biomass fuels and their fossil alternatives. An integrated framework for assessing the broader, cross-sectoral environmental impact of expanding biomass production and use is needed to ensure that all the important factors are taken into account.

This paper attempts to set out such a framework. This framework is not intended to provide a blueprint for assessment, rather to facilitate more integrated, holistic thinking on the approach that is needed. It aims to set out the parameters of an *ex ante* evaluation of measures to increase biofuel production and use in an environmentally friendly way. We welcome feedback on the proposed framework and aim to improve it in the future.

Table 1. Agricultural and forestry biomass resources

Biomass type	**Source**
Dedicated crops	• Oil crops (rapeseed, sunflower, soya) • Starch crops (sugarbeet, sugarcane, wheat, barley) • Short rotation forestry (willow, poplar) • High-yielding grasses (miscanthus, switchgrass)
Primary residues / By-products from agriculture and forestry	• Forestry (thinnings, felling residues) • Straw from cereal crops • Other agricultural residues
Secondary residues / By-products	• Manure, slurry (fermentation for biogas) • Sawmill waste • Sewage sludge • Non-agricultural sources (used cooking oil, organic solid waste)

Source: Authors.

Two uses of biomass: combined heat and power and biofuels for transport

This paper examines two uses of biomass: the use of short rotation coppicing of willow for combined heat and power production (CHP), and the use of oilseed rape for biodiesel generation.

Bioelectricity represents about 1% of the electricity production capacity in OECD countries, with an installed capacity of about 18.4 GW (gigawatts). Most plants are of the CHP type, where heat is generally used for industrial purposes or district heating (Bauen *et al.*, 2003). A well-developed bioelectricity sector depends on ready availability of a biomass feedstock and most bioelectricity production in OECD countries is associated with forestry and wood-processing industry activities. Some countries – Finland in particular – have considerable experience with co-firing biomass with fossil fuels and waste. For the OECD area, an ambitious but realistic target for bioelectricity by 2020 could consist of the exploitation of 25% of potentially harvestable residues from agriculture and forestry, and by dedicating 5% of the crop, forest and woodland area to biomass growth for energy (Bauen *et al*., 2003).

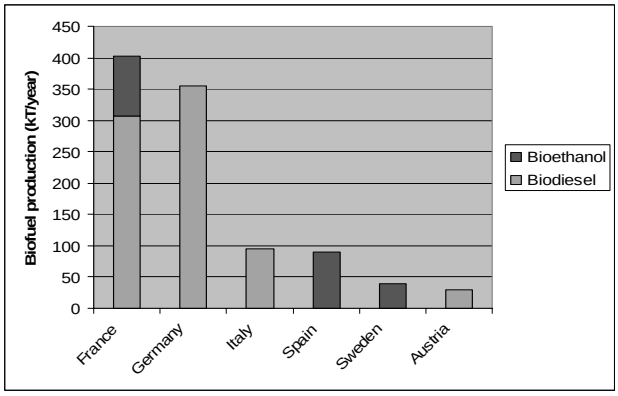
Transport is a sector with limited renewable fuel options. Energy sources such as wind and solar power cannot be harnessed for transport in the foreseeable future, and so the EU's transport sector is set to increase the use of biofuels in the coming years. With transport's 98% dependence on oil, a shift towards biofuels offers some attractive advantages: a reduction in CO_2 emissions, a fostering of improved security of energy supply, a new path for the diversification of agriculture and a medium-term stepping stone to the more distant technology of hydrogen fuel cells. It has been suggested that wood crops converted to alcohol or hydrogen could in the long term satisfy most United Kingdom (UK) road transport fuel demand (Eyre *et al.*, 2002).

A recent Directive (2003/30/EC) on increasing the use of biofuels in the EU is promoting the use of biomass for transport fuel. Currently, almost all biofuel use in the EU is accounted for by six member states (Figure 1), and much of this is biodiesel manufactured from rapeseed or sunflower oil. The Directive sets out a wide range of alternative fuel options to encourage a diversification of fuel supply. National targets for the use of biofuels are to be set across the EU, aiming towards the indicative goal of replacing 5.75% of all transport fossil fuels by 2010. Countries will be asked to report on the environmental impact of planned biofuel-encouraging measures, including factors such as land use, the degree of intensity of cultivation, the use of pesticides, the protection of watercourses and energy efficiency. Appropriate environmental measures will need to be taken to reduce the impact of biofuel crop cultivation. The overall goal is to expand the use of biofuels in a considered way on the basis of clear evidence of their environmental benefits, while taking into account competitiveness and security of supply. There is a need to develop complementarity between the different biofuel options available in the EU.

Current tools for conducting environmental assessment

Straightforward impact assessments are often partial, looking only at certain sets of impacts and making it more difficult for policy makers to assess trade-offs and to compare different scenarios when deciding on a specific course of action (Willis, 2002). Integrated environmental assessment (IEA) and life-cycle analysis (LCA) attempt to overcome this limitation by including a broader set of impacts. Features of these tools are useful for assessing more comprehensively the environmental consequences of biomass production and use.

Figure 1. Use of biofuels for transport in the European Union, 2001



Source: European Commission, 2002.

A current focus of the work in the EEA is to develop expertise in integrated environmental assessment (IEA, see Thomas, 1995) in order to evaluate policy effectiveness. IEA is a process that requires a broad, systemic approach to building environmental knowledge, and it must be relevant and useful to policy development processes (Rothman and Robinson, 1996). Because of its integration of policy relevance with a multi-disciplinary approach, IEA is increasingly recognised as an important technique for managing the environmental impacts of human actions. Thomas (1995) has defined IEA as "*The interdisciplinary process of identification, analysis and appraisal of all the relevant natural and human processes and their interactions which determine both the current and future state of environmental quality, and resources, on appropriate spatial and temporal scales, thus facilitating the framing and implementation of policies and strategies.*"

Integration is a continuous spectrum, and there are many ways to approach it. The most frequent way is so-called *vertical integration*, which incorporates the whole causal chain of socio-economic driving forces, pressures on the environment, the resulting state of the environment, the impacts and the required responses from policy and society. The DPSIR framework (Driving force, Pressure, State, Impact, Response), summarises this end-to-end cycle. This framework can facilitate a good understanding of the dynamics of the system, ensuring that the assessment is properly comprehensive and "integrated".

A second approach is *horizontal integration*, which entails broadening the study across disciplines within a single link of the causal chain. To take environmental pressures as an example, we can distinguish between different types of pressures from different activities and sectors. Thus nutrient loading in water bodies arises from a variety of sources (agriculture, industrial activities, sewage treatment plants). To properly assess their combined pressure, a combination of agronomic, engineering and environmental knowledge is required. Combining vertical and horizontal integration is the main challenge of IEA (Vos, 2001).

Life-cycle assessment is also known as "life-cycle analysis", "life-cycle approach" or "cradle-to-grave analysis". It is a system-orientated approach estimating pollution potential, energy and resource usage associated with a product or operation throughout its life cycle (EEA, 1996). In general, "life-cycle thinking" can be a useful spur to creative thought on the wider dimensions of a problem (EEA, 1997). Among the newer concepts in LCA is "life-cycle management" (LCM), which is an integrated approach to minimising environmental burdens throughout the life cycle of a product, system or service.

A typical LCA study consists of the following stages:

1. Goal and scope definition.
2. A detailed life-cycle inventory (LCI) analysis, with compilation of data both about energy and resource use and on emissions to the environment, throughout the life cycle.
3. An assessment of the potential impacts associated with the identified forms of resource use and environmental emissions.
4. The interpretation of the results from the previous phases of the study in relation to the objectives of the study.

Impact categories are discussed in some detail in Appendix 4.2 of the EEA (1997) publication.

A framework for evaluating the environmental impact of current biofuel use

The production and use of biomass has cross-sectoral effects, touching on transport, energy, trade and agriculture. Different stages in the production chain – cultivation, fuel manufacture, use of by-products, CHP technology, transport use – have very different sets of environmental impacts.

The cultivation of biomass for energy has various potential impacts on soil, water, air and biodiversity. These impacts can be listed as follows.

- Biodiversity (changes in the use of chemical inputs, changes in crop rotations, possible arable conversion of grassland, potential creation of landscape elements);
- Soil (organic matter content, soil structure, nutrient content);
- Quality of water and watersheds;
- Air and atmosphere (ozone, acidification, particulate emissions, GHGs [greenhouse gases]);
- Energy efficiency;
- Human health (pollution of air and water, allergenic pollen from crops);
- Amenity value.

Each of these impact types needs to be assessed for the biomass type in question, and for each stage in the processing and refinement of that biomass type.

In developing an integrated framework for assessing the environmental impact of biofuel production and use, both horizontal and vertical integration are necessary to achieve effective evaluation. Stages of the production process should be considered one by one and looked at from the point of view of parameters that affect the environmental outcomes: agriculture and land use, energy, transport and trade. Economic assessment – including cost-benefit analysis – is also important, but is beyond the scope of this paper.

At each stage of this multi-sectoral life-cycle assessment, the DPSIR cycle is kept in mind. This maintains a useful causal continuity throughout the framework. Instead of a list of factors, the framework retains a sense of the underlying reasons for, and possible responses to, each factor.

The evaluation framework is illustrated in Table 2.

Table 2. Framework for integrated evaluation of environmental impact of biomass production and use

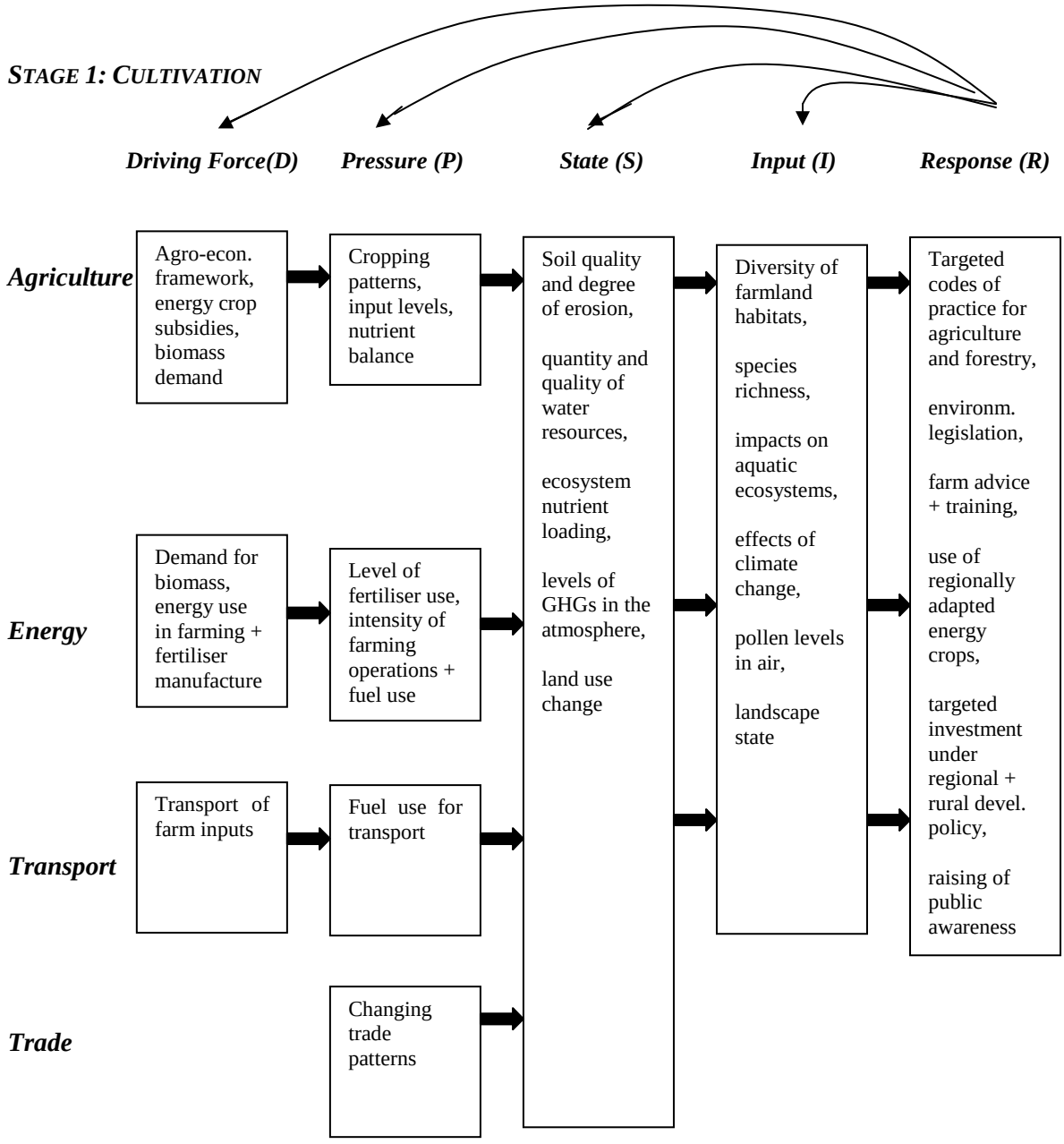
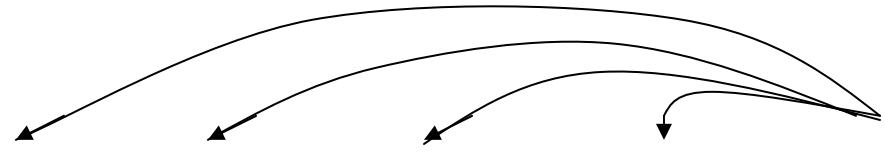


Table 2 (*continued*)

STAGE 2: PROCESSING



	D	***P***	***S***	***I***	***R***
Transport	Spatial distribution of processing plants and biomass crops	Transport of raw materials + processed fuel	Change in particulate levels in air; levels of GHGs in the atmosphere	Pollution impacts on health and ecosystems, effects of climate change	Domestic production of raw materials, siting of facilities close to source
Energy and Industry	Biofuel type, demand + support for CHP, efficiency of production	Emissions from processing facilities, by-products			Use of BAT / BATNEEC Support for technol. research

STAGE 3: END PRODUCTS: CONSUMPTION AND WASTE

Transport	Develop-ment of fuel distribution network, demand for biofuels, pure or blended	Distribution infrastruc-ture	**Lower emission levels of GHGs,** diversified fuel sources	Pollution impacts on health and ecosystems, (reduced) effects of climate change	Engine modification support for biofuel use, distribution network
Energy	Investment in CHP facilities and infrastruc-ture	new CHP + heat pipeline infrastruc-ture			Measures to encourage development of CHP

Note: The product life cycle is divided into three stages: cultivation, processing and end-product consumption. Individual factors may have negative or positive effects.

BAT: Best available technology. Defined in the IPCC Directive as best available techniques, which is a broader definition including management practices.
BATNEEC: Best available technology not entailing excessive costs.
Source: Authors.

Application of the framework

In order to test the framework, it will be applied to two different types of biomass use: biodiesel (fatty acid methyl ether [FAME]) production from oilseed rape, and woody biomass use for CHP. These "test runs" of the framework are not intended to be comprehensive: rather, they are intended to assess its usefulness, and to highlight key features of these two biomass use types. The examples chosen represent on the one hand a fairly well-developed approach to biofuel production for transport, and on the other hand a less well-developed approach for bio-energy generation. The first option can be easily integrated in current crop rotations, whereas the second option entails the introduction of new, long-term crops.

Biodiesel production from oilseed rape

Biodiesel can be produced from several raw materials: oilseed rape, sunflowers, soya, other oil crops, and non-agricultural sources of oil such as used cooking oil. In the EU, oilseed rape is the main agricultural raw material for biodiesel.

Oilseed rape is the agricultural crop that is most widely used for fuel production at present. Industrial oilseed rape was grown on approximately 2.9 million hectares in the EU-15 in 2002. Compared to bioethanol yield from starch crops, the biodiesel yield from oilseed rape is relatively low: one hectare of oilseed rape produces between 0.5 and 1.5 tonnes per hectare.

There are three main stages to the production process. Cultivation of the crop is followed by harvesting and pressing to obtain the oil. The high-protein cake that remains is a valuable animal feed. The oil is then esterified and purified to produce biodiesel. It may be blended with fossil diesel for use in unmodified engines – most current blends contain 5% biodiesel – or distributed in pure form for use in suitably adapted engines. Finally, the fuel needs to be transported to distribution points. In Germany over 900 filling stations offer pure biodiesel to supply a growing market that has been fostered by favourable taxation.

In accordance with the proposed framework, key features of this process are listed in Table 3.

STAGE 1: Cultivation (Land availability, input intensity and greenhouse gas balance)

At the cultivation stage, two aspects of particular importance are the high fertiliser requirements of oilseed rape, and the relatively low yield of biodiesel (FAME) per hectare (0.5-1.5 T Ha^{-1}). It is an intensive crop that is best cultivated in areas already dominated by high-input arable cropping, in order to avoid negative impacts in more extensive areas. The yield of biodiesel per hectare means that very large areas of land are required to produce significant quantities of fuel, substantially more than are required to produce some types of bioethanol (for petrol replacement). In countries that do not have a high proportion of arable area, land availability could therefore become a particularly important criterion in selecting approaches for biofuel production. Use of waste oil as a feedstock can help to boost the availability of feedstock materials for biodiesel production (Eibenstiner and Danner, 2000).

Table 3. Assessing the environmental effects of biodiesel production from oilseed rape

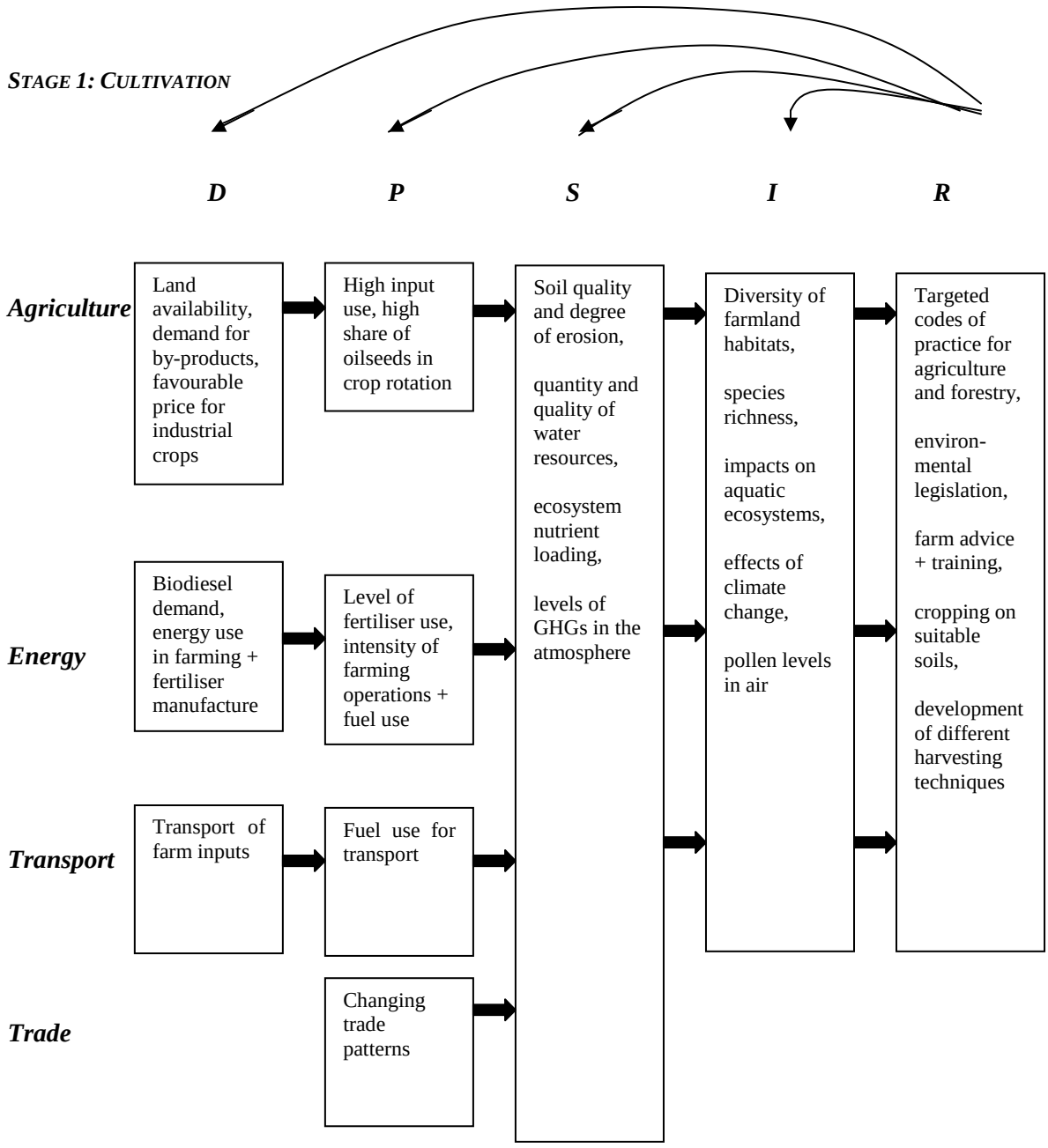
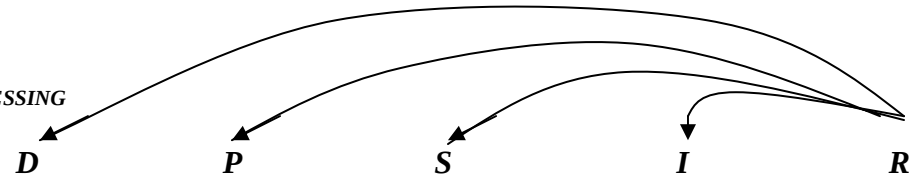


Table 3 (*continued*)

STAGE 2: PROCESSING



Transport	Location of processing plants versus main rapeseed areas	Transport of raw materials + processed fuel	Change in particulate levels in air; Levels of GHGs in atmosphere	Pollution impacts on health and ecosystems, effects of climate change	Domestic production of raw materials, siting of facilities close to source
Energy and Industry	Societal demand for biodiesel, efficiency of production	Emissions from processing facilities, by-products			Use of BAT/ BATNEEC Support for technolog-ical research

STAGE 3: END PRODUCTS: CONSUMPTION AND WASTE

Transport	Developm't. of fuel distribution network, biofuel tax exemption, pure or blended use	distribution infrastruc-ture	**Lower emission levels,** diversified fuel sources	Pollution impacts on health and ecosystems, (reduced) effects of climate change	Engine modification support for biofuel use, distribution network, raising of public awareness

Source: Authors.

N_2O (nitrous oxide) is 300 times more potent as a greenhouse gas than CO_2, and it is released in significant quantities from cultivated fields, particularly with intensive fertiliser use. Oilseed rape has high fertiliser requirements, and is therefore associated with higher N_2O emissions. Projections for emissions from soils use the IPCC (Intergovernmental Panel on Climate Change) methodology which assumes that 1.25% of the nitrogen contained in mineral fertilisers is released directly as N_2O, with further quantities arising from volatisation and subsequent deposition of NH_3 and NOx from fertiliser application (EEA, 2002*b*), totalling approximately 10% of the N contained in the fertiliser (Wilson, personal communication). Excluding N_2O emissions data, FAME produces a greenhouse gas saving of 53%, but taking N_2O emissions (calculated using IPCC methods) into account the saving drops to approximately 10% for FAME (Concawe, 1995) (Table 1).

STAGE 2: Processing (Use of by-products)

At the processing part of the production cycle, sale of by-products is particularly important to the economic balance of biodiesel. In fact, the high-protein animal feed produced from oilseed rape is more important than a by-product, because its importance as feed product has been boosted in the wake of the BSE crisis. Glycerine is also a by-product of biodiesel production. In the event of a large increase in production, there is a possibility of market-damaging overproduction of glycerine.

STAGE 3: End products: consumption and waste (Diesel market and introduction of biofuels)

Regarding use of and demand for end-products, diesel compression ignited (CI) engines are 15-20% more efficient than gasoline spark ignited (SI) engines, and so there is a strong demand for diesel in the EU market. Most diesel is produced from straightforward distillation, and a second fraction is obtained by cracking heavier hydrocarbons, a process which is much more expensive both in energy and economic terms. There is great interest in diesel substitutes, making the biodiesel market a promising one (albeit dependent on continuing government subsidies). If an increase in biodiesel were to incur a reduction of this second fraction, clear energy-saving gains would result.

The use of pure biodiesel avoids the environmentally damaging effects of the fossil diesel in biodiesel/diesel blends. However, it requires engine modifications and a separate distribution network, which are more easily achieved for captive fleets. Examples include buses in the German district of Heinsberg and in Kuala Lumpur, Malaysia (where biodiesel is manufactured from white palm oil), and garbage trucks, snow ploughs and refrigerator truck fleets in the US. In Germany over 900 filling stations offer pure biodiesel to supply a growing market that has been fostered by tax exemption for pure biodiesel.

Woody biomass used for CHP

CHP or co-generation is a highly efficient use of biomass that could contribute significantly to the economic viability of electricity from biomass. It is a particularly efficient form of energy generation: electricity is generated from steam or gas turbines fuelled by the biomass, and the “waste” heat is used to heat water which is piped to households to provide heating. The use of woody biomass for CHP is a more straightforward process than the production of biodiesel. Feedstocks include woody biomass from short rotation coppicing (SRC) of a variety of species including willow and poplar, wood from managed forests, forestry thinnings, sawmill waste and various agricultural wastes. In this paper dedicated short rotation willow plantations on agricultural land will be considered. The main stages in the process are the cultivation of the trees, harvesting, transportation to the power plant, combustion and harnessing of the energy released.

Woody biomass production or SRC is particularly low in input requirements and has potential wildlife and amenity benefits. Because biomass is an ideal renewable fuel for energy and heat generation, these products have several outlets: CHP and liquid biofuel production when technology is further developed, together with several useful by-products.

In accordance with the proposed framework, key features of this process are listed in Table 4.

STAGE 1: Cultivation (Effects on landscape, habitats and environmental resources)

The following recommendations for the planning and cultivation of short rotation willow plantations illustrate key factors for the assessment of this stage (Perttu, 1999).

1. Plantations should be planned to suit the local landscape, preserving existing sensitive habitats. Small "islands" around features such as open ditches, cairns etc. should be retained.

2. The coppice should be located close to existing forests to enlarge the continuous available habitat.

3. Variation in the landscape can be increased by planting several small stands which can be harvested in different years, rather than one large stand.

4. Several species and clones should be planted. This reduces the risk of damage from fungi, insects and frosts.

5. A higher proportion of male clones will favour early spring pollinators.

6. Weed control should be adjusted to need without over-application of herbicides. In most cases, weed control is necessary during the establishment phase but can usually be avoided in a full-grown stand.

7. Fertiliser application should be adjusted to stand development, and minimised accordingly.

Willow has a pronounced capacity to take up nutrients and heavy metals, including cadmium; and willow stands have been shown to be adaptable as vegetation filters in order to purify water and soils. The purification efficiency of willow vegetation filters has been demonstrated in several countries, such as Sweden, Poland, Denmark and Estonia.

STAGE 2: Processing (Technological aspects)

In the processing stages, use of BAT (best available technology or techniques) is particularly important in achieving the best environmental outcomes. Combustion technologies and co-firing with coal are commercial technologies on which the current bioelectricity industry is based. Gasification technologies are commercial in niche markets, and for specific feedstocks. Gasification could lead to more efficient and cleaner use of biomass for electricity production. Its demonstration and commercialisation using a wide range of biomass feedstocks could be very important for economically viable and environmentally sustainable bioelectricity production. Furthermore, biomass gasification can lead to future biomass facilities being integrated with advanced conversion technologies such as fuel cells and co-production of additional outputs, such as transport fuels (Bauen *et al*.).

Table 4. Assessing the environmental effects of combined heat and energy production using willow biomass

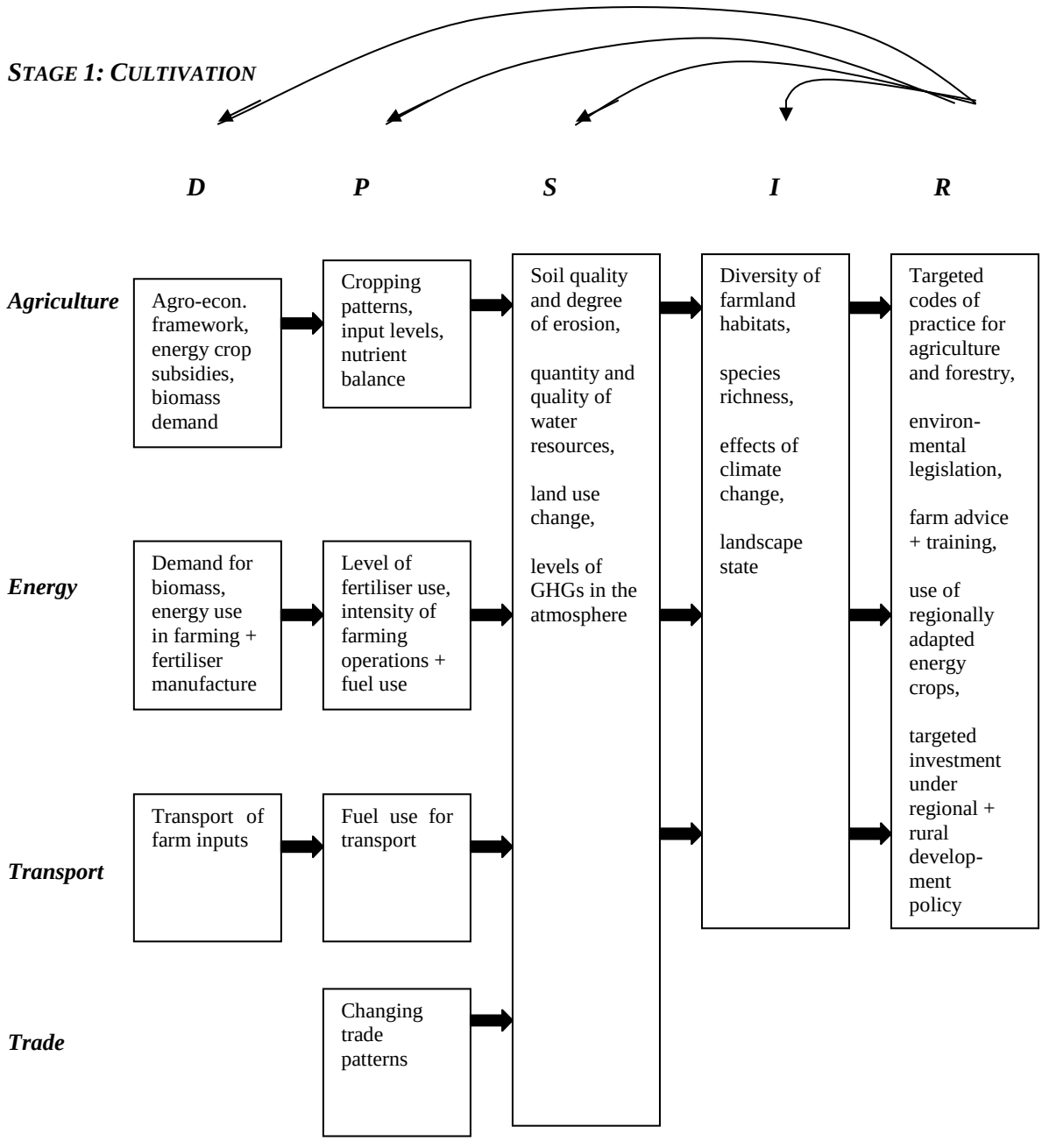
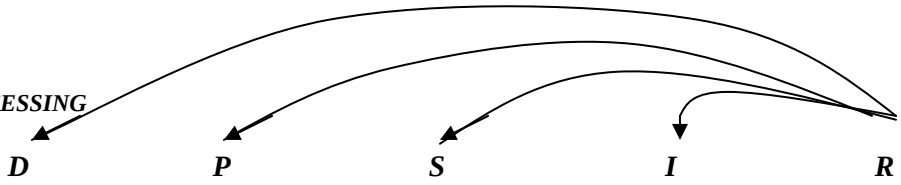


Table 4 (*continued*)

STAGE 2: PROCESSING



Transport	Location of processing plants versus SRC plantations	Transport of raw material	Change in particulate levels in air, levels of GHGs in the atmosphere	Pollution impacts on health and ecosystems, effects of climate change	Domestic production of raw materials, siting of facilities close to source
Energy and Industry	Demand + support for CHP, efficiency of production	Emissions from CHP plants, by- products			Use of BAT/ BATNEEC Support for techno-logical research

STAGE 3: END PRODUCTS: CONSUMPTION AND WASTE

Energy	Investment in CHP facilities and infra-structure	New CHP + heat pipeline infrastruc-ture **change in GHG emissions** **ash toxicity and disposal**	**Lower emission levels**, diversified energy sources	Pollution impacts on health and ecosystems, (reduced) effects of climate change	Measures to encourage development of CHP

Source: Authors.

STAGE 3: End products: consumption and waste (Policy responses and support)

As bioelectricity expands, the market pull for energy crops will need to come from the energy sector, but agricultural and forestry policy needs to provide the conditions for biomass feedstock to be delivered in an efficient and environmentally sound way.

An existing biomass industry base and a readily available biomass feedstock are strong factors behind the relatively more developed bioelectricity sector in some countries. Usually, however, the development of bioelectricity has also been a result of regulations favouring the input of bioelectricity into the electricity grid and policies supporting the price of bioelectricity, or due to taxes on the use of conventional fuels on environmental grounds. Therefore, a significant increase in bioelectricity use will require strong policy commitment and needs to be accompanied by regulations and guidelines that ensure its environmental sustainability.

For example in Austria, the Housing Promotion Act in the provincial governments provides financial support for renewable energies, particularly solar technologies and biomass boilers. Besides the Housing Promotion Act, special support for biomass, solar and heat pump systems are offered to the consumers by the provincial governments in the order of up to 20% of the investment costs.

Conclusions: evaluation of assessment framework and biofuel options

Evaluating the framework

Existing environmental assessments of biomass and biofuels generally restrict themselves to partial evaluations of the effects of production and use of the fuels concerned. Agricultural and land use implications are often neglected, particularly in assessments of transport biofuel production where the focus is usually on the fuels themselves and comparisons with their fossil counterparts. The framework proposed in this paper addresses these gaps, pointing to the need for an integrated environmental assessment of each stage in the biomass product life cycle, while keeping a causal continuity throughout by bringing in the DPSIR approach. The framework is flexible: it does not have to be exhaustively completed, but it does provide a structure that facilitates a comprehensive analysis of the important elements of these complex product life histories. Other types of impact can be added to it as appropriate. In clarifying potential environmental impacts it helps to show trade-offs between different benefits and disadvantages of biofuel options. However, by itself it does not resolve the often difficult decisions that policy makers face in this context, including other important issues such as cost-effectiveness.

The two case studies show how aspects of the framework can be applied as part of a comprehensive approach to assessing the environmental impact of the fuels concerned. However, it should be said that applying the framework does require a more detailed quantitative approach than is provided here. Without such a real-life test its usefulness can ultimately not be judged. Further work needs to be done to compile relevant data and information and test the framework on that basis at regional or country level.

Comparison of biofuel options

If a given area of land is used to produce transport biofuels, the net greenhouse gas reduction would be much less than if that same area of land was used to grow biomass for energy generation such as CHP. This is because the production of transport biofuels involves energy-expensive processing to produce a high-specification product, and because most biofuel crops require high levels of nitrogen fertiliser, which is very energy-expensive to produce. Biomass crops for energy generation

on the other hand do not need as much fertiliser, nor do they do not need much processing. It is a considerably more efficient production chain: after harvesting, the raw materials can be burned, or put through thermochemical conversion (charcoal-making) process. However, renewable options in the transport sector alone are limited. The many benefits of CHP do not address the very large – and rising – greenhouse gas output of this sector, and therein lies the justification for developing biofuels for transport.

There is a land use trade-off between crops for transport biofuel manufacture, and crops for energy generation. The Biofuels Directive recognises this cross-sectoral trade-off: if a country sets targets for transportation biofuels that are lower than the indicative levels of 2% by 2005 and 5.75% by 2010, it can justify the shortfall by showing its progress in developing biomass for energy generation. Both biofuel options require significant public support for large-scale production and use although the necessary price subsidisation of CHP energy compared to fossil fuel alternatives appears to be smaller than in the case of FAME biodiesel.

The potential impact of short rotation coppice (mainly used for CHP at present) on agricultural landscapes and habitats appears more favourable than that of rapeseed production. This is due to the increase in landscape diversity and breeding habitats that such plantations provide in comparison to oilseed rape, which is already a widely grown crop. However, introduction of the latter in cereal-dominated crop rotations could also provide benefits for seed-eating birds (Anderson *et al*., 2003).

The overall effect of biofuel crops on farmland habitats and diversity depends on the present intensity of agricultural land use and cropping patterns as well as the specific characteristics of the individual crops for biomass production. These aspects are of particular interest to the EEA in the further development of environmental assessment frameworks for biofuel production.

BIBLIOGRAPHY

Anderson, G.Q.A., L.R. Haskins and S.H. Nelson (2003), "The Effects of Bioenergy Crops on Farmland Birds in the United Kingdom – a Review of Current Knowledge and Future Predictions" (paper presented to the OECD Workshop on Biomass and Agriculture, Vienna, June (see Part I, 2 of this publication).

Bauen, A., J. Woods, J. and R. Hailes (2003), *Bioelectricity Vision: achieving 15% of electricity from biomass in OECD countries by 2020*, Report for WWF International, Imperial College London and E4tech (UK) Ltd, United Kingdom.

Concawe Report (2/95) on Alternative Fuels, cited in Armstrong *et al.* (2002), *Energy and greenhouse gas balance of biofuels for Europe – an update*, Brussels: Concawe.

Directive (2003/30/EC) Promotion of the use of biofuels or other renewable fuels for transport, European Parliament and the Council, 8 May 2003, *Official Journal*, 17.5.2003 L 123/42.

European Commission (2002), The Altener Programme, *Renewable Energy Journal*, No. 12, DG Research, Brussels, Belgium.

EEA [European Environment Agency] (1996), *Environmental Taxes Implementation and Environmental Effectiveness*, Environmental Issues Series No. 1, EEA, Copenhagen, Denmark.

EEA (1997), *Life Cycle Assessment (LCA), A guide to approaches, experiences and information sources*, Environmental Issues Series No. 6, EEA, Copenhagen, Denmark.

EEA (2002*a*), *Energy and environment in the European Union*. Environmental Issues Report No. 31, EEA, Copenhagen, Denmark.

EEA (2002*b*), *Analysis and comparison of national and EU-wide projections of greenhouse gas emissions*, Topic Report No. 1, EEA, Copenhagen, Denmark.

Eibenstiner, F. and H. Danner (2000), *Biodiesel in Europe*. *System analysis non-technical-barriers*, SYsan IFA report.

Eyre N., M. Fergusson and R. Mills (2002), *Fuelling Road Transport – Implications for Energy Policy*, Institute for European Environmental Policy [IEEP], London, United Kingdom.

Groscurth, H.-M. *et al.* (2000), "Total costs and benefits of biomass in selected regions of the European Union" *Energy* 25, pp. 1 081-1 095.

Perttu, K.L. (1999), "Environmental and hygienic aspects of willow coppice in Sweden", *Biomass and Bioenergy* 16, pp. 291-297.

Rothman and Robinson (1996), quoted in C. Gough (2000), "Integrated Assessment at the European Environment Agency – Historical and Future Perspectives" in *Report of the Special Session of the European Forum for Integrated Environmental Assessment (EFIEA) at the EEA in Copenhagen*, Annex VI, November 2000, EEA, Copenhagen, Denmark, and EFIEA, Amsterdam, the Netherlands.

Thomas, R. (1995), *A general strategy for integrated environmental assessment at the European Environment Agency*, scoping study prepared by the National Institute of Public Health and Environment (RIVM), Bilthoven, the Netherlands.

Vos, H. (2001), *Integrated Environmental Assessment at the European Environment Agency. Taking stock and formulating next steps*, draft paper, EEA, Copenhagen, Denmark.

Willis, R. (2002), "Communication from the Commission on impact assessment", paper presented at an Environmental Evaluation Workshop, EEA, June.

Wilson, D. (2003), personal communication, Faculty of Agriculture, University College, Dublin, Ireland, 27 January.

UTILISATION OF GRASS FOR PRODUCTION OF FIBRES, PROTEIN AND ENERGY

Stefan Grass[1]

Abstract

Grassland has a number of well recognised, positive effects on the environment, *e.g.* groundwater protection, habitat for species, soil stabilisation and soil sanitation. It covers 70% of total Swiss agricultural land use. For utilisation of grass, a new process was developed, which converts grass to technical fibres, protein and energy. This process, using a *biorefinery* was developed and implemented by the Swiss Agency for Energy and the Swiss Agency for Environment, Forests and Landscape.

A first biorefinery started operation at the end of 2001 in Schaffhausen, Switzerland. The plant produced technical fibres and biogas, and had a throughput capacity of around 0.8 tonnes of dry matter per hour. Market introduction of the blow-in insulation product *2B Gratec*, made from grass fibres, was successful. Biogas was converted to power, which was marketed as the certified label product "Nature Made Star". However, the Schaffhausen installation was not economically viable and operation ceased in summer 2003. The technical concept is now being re-designed and directed to the production of insulation boards with a much higher market value compared to the "blow-in" insulation product. The production of boards can be realised in simple plants of small scale. Production of commercial boards for insulation purposes has been proved economically viable.

This paper addresses questions related to raw materials, processing, products and the economics of a biorefinery. The author has been appointed contact person by the Swiss Agency for Environment, Forests and Landscape.

Introduction to grassland and grass

Environmental benefits of grassland

Most people have very positive associations with grassland: leisure time, picnics, the gentle movement of the wind, mountain hikes, grazing cows, but, besides that, it is well known and documented that grassland offers a number of environmental benefits. The most important are:

- ***Groundwater protection**:* grass is a perennial crop and forms a dense root system throughout the year. This root system prevents leaching of nitrates and pesticides into the groundwater. (Nitrates and pesticides in groundwater are a concern for several drinking water wells in Switzerland.)

1. Biomass Project Services, Illnau, Switzerland.

- ***Habitat for species**:* grassland is inhabited by many different species, some of them belonging to the red list of endangered species. Survival and multiplication of some species depend on the availability of extensive grassland with a late first cut (semi-natural habitat).

- ***Stabilisation of soil, hills, and slopes**:* the perennial nature and the root system of grass act to stabilise soil systems. Soil erosion on cultivated crop land can cause soil losses. Soil stabilisation is also an important factor in preventing mudslides in mountain areas.

- ***Soil sanitation in crop rotation systems**:* grass and clover/grass-mixtures prevent build-up and proliferation of root diseases. In integrated production systems, grassland can reduce utilisation of pesticides.

Swiss policy decisions for the preservation of grassland

Grassland covers around 70% of the total Swiss agricultural production area. From this point of view, it is the most important agricultural crop. However, grass utilisation is decreasing in many European Union countries and regions, due to decreasing milk and beef production. Even small decreases in milk and beef production have a major effect on the economic value of grassland. In some areas, the rent for grassland has come very close to zero.

The Swiss government has taken a number of measures to preserve grassland and utilisation of grass. These measures include:

- Direct payments for maintenance of grassland. These payments depend on the level of production intensity: low-input systems receive compensation for reduced productivity.

- Specific support of mountain eco-systems and semi-natural habitats.

- Support of technology development for new uses of grass.

Properties of grass as an industrial raw material

Grass is composed of raw fibre (cellulose, 20-30% of dry matter), hemi-cellulose (15-25%), lignin (3-10%), protein (6-25%), fat and starch (1-2.5% each), ash (5-20%) and water-soluble extracts (20-55%). This composition defines the potential for creation of value added. The following fractions of grass are of particular interest:

- *Cell wall components* (cellulose, hemi-cellulose, and lignin): the basis of fibre products. Due to the low lignin content, wet grass fibres can be fibrillised without the addition of chemicals. Hydrolysis of cellulose and hemi-cellulose to monomeric sugars can be achieved with moderate levels of energy input and acid/enzyme addition.

- *Proteins:* grassland can yield more then 2 tonnes of dry matter of protein per hectare. This is about 50% higher compared to peas, beans or soya. The amino acid composition varies between clover and grass and is suitable for animal feed.

- *Water-soluble extracts:* these contain a considerable amount of sugars (*e.g*. glucose, fructose, galactose) and can be used as a full fermentation medium for the production of single-cell protein, lactic acid, ethanol, or biogas.

Grass is also subject to considerable raw material variation, which must be handled in an industrial process. Raw material variation is due to:

- The origin of the material: permanent pasture, grass sown in crop rotation systems, growing in a semi-natural habitat, or by the roadside.
- Growth stage of grass at harvest (*e.g.* full shooting, blossoming).
- The relative ratios of grass, clover and herbs in the harvested material.
- The species involved, level of fertilisation, type of soil, exposition to the sun, and many other factors.

The most relevant quality parameters are the content of raw fibre, protein and digestible energy. Depending on the origin, grass often contains considerable amounts of small branches, stones, sand and loam. It is very important to design a process which takes into account the probable quality of the raw material. Raw material quality standards must be established and strictly enforced.

Another critical parameter is grass storage. Favourable conditions for fibrillation are given at a moisture content <40% of dry matter. This is given with fresh or wilted grass as well as silaged grass. During buffer storage, carbohydrates contained in fresh grass degrade rapidly. This reduces significantly the energy production potential. Practical knowledge of grass silaging is widespread in the agricultural community.

The market price for grass

Since there is not much trade with fresh grass or silaged grass, there is no established market with a transparent price for this raw material. Agricultural research stations in many countries have conducted numerous calculations on the production cost of grass. But sometimes the production cost fails to reflect the market value of grass.

An established market does, however, exist for hay. In Germany, the hay price has decreased over the past few years and is today around EUR 70/tonne, including drying, baling and storage. Delivery of fresh grass requires less labour and should therefore be cheaper (based on dry matter content) than hay. The cost of grass silaging should not be higher than for hay because it allows more flexibility with respect to weather conditions.

Naturally, the cost of grass varies, due to agricultural policy, climatic conditions, the regional agricultural structure, the general cost of agricultural land and labour, and other reasons.

Price schemes for grass delivered to a technical processing plant (biorefinery) should be established with respect to the raw material characteristics required to achieve the expected end-product yield and quality parameters. This requires a thorough understanding of the relation between the raw material and the quality of the end product.

New products made from grass

Grass fibres

Grass fibres can be recovered at a length of 2-30 mm. Variation is due to raw material variation and process conditions. Grass fibres are suitable and competitive for short fibre applications. The following products can be made from grass fibres:

- Insulation products.
  - Insulation boards can be produced in a density range between 60 and 160 kg/m^3. The heat conductivity is 0.04-0.045 W/mK, depending on the density of the board. Resistance against fire and fungi can be achieved using additives. Advantages compared with mineral wool include the high specific heat capacity, which results in a 10-12 hours delayed release of outside heat to the inside and improved summer heat protection. Boards can be used for thermal insulation in ventilated facades and cavity masonry, steep-pitched roofs, over rafters and for sound insulation. Possible applications of grass-based insulation boards cover around 80% of all insulation applications.
  - Blow-in insulation is successful at a blow-in density of 55-60 kg/m^3. The heat conductivity is 0.04 W/mK. Resistance against fire and fungi can be achieved by using additives. Quality control must include settling properties. Blow-in insulation is an industrial standard in many countries and makes about 1.4% of the total insulation volume in Germany.
- Natural fibre re-enforced plastic: specifications include filling grade and mechanical properties.
- Paper: specifications include colour and mechanical properties.
- Combustion pellets: specifications include mechanical stability, levels of ash, nitrogen, and sulphur content and ash melting point. To reduce the ash content, low or medium-quality grass requires washing.

Grass protein

The value of grass as a ruminant feed is based on its raw protein content. Separation of the protein fraction from the cell wall components opens marketing opportunities for non-ruminants, *e.g.* pigs and hens.

Juice pressed from silaged grass has been fed successfully to pigs and piglets. A dried protein product from fresh grass contains around 40% raw protein, 10% raw fat and 15% raw ash, depending on raw material quality and processing conditions. The high methionine content of grass protein makes it particularly suited to laying hens. However, protein extraction and drying are significant cost factors.

Energy

For the production of energy from grass using biological conversion, two processes were developed:

- Conversion to ethanol using yeast. Common yeast only converts C6-sugars to ethanol – C5-sugars remain unused. Since raw material storage as silage results in conversion of C6-sugars into lactic acid, grass must be processed when it is fresh. Hydrolysis of the cellulose content, using heat and dilute acid or enzymes, can extend the C6-sugar basis to around 400 kg per tonne of dry matter. Using good-quality grass and an enzymatic hydrolysis process, an ethanol yield of 150-200 litres per tonne of dry matter (raw material) was achieved during a pilot scheme. This translates to an energy yield of 900-1 100 kWh per tonne of dry matter of grass. This yield could be increased by around 40% using a genetically modified yeast for conversion of C5-sugars. Ethanol can be used as an industrial raw material or as a liquid transportation fuel. However, the costs involved in an enzymatic hydrolysis process are considerable, and the price of ethanol is lower than the price of the fibre products discussed above.

- Conversion to biogas offers the advantage that all substrate components are consumed and no heat losses occur. The water-soluble fraction of good-quality grass yields 200-250 m^3 of biogas (or 1 200-1 500 kWh per tonne of dry grass matter). Utilisation of biogas includes combustion in a combined heat and power machine, as well as feeding into the natural gas distribution network or gas fuelling stations (after purification and compression).

The biorefinery – a new technology concept for whole crop utilisation

General concept of a biorefinery

A biorefinery is a technical concept for whole crop utilisation. It applies fractionation to separate different fractions from the raw material, thereby optimising the value added. It is suited to processing large quantities of raw materials and to supplying volume markets, so it can be a land use option. No chemicals are used for the fractionation and no waste is generated. Nutrients are recycled, and wastewater streams are minimised (recycled as processed water).

Key process steps and process innovations

The innovation of raw material fractionation

Fractionation is a defining process step of a biorefinery. It can be engineered according to the specific aims of a process. This can be the fibre recovery at a specific length distribution profile or the extraction of proteins or lactic acid, or the optimised recovery of soluble chemical oxygen demand (COD) for biogas production.

The fractionation step is normally defined by process conditions such as pH, temperature, water content, mechanical energy input, residence time, type of equipment, enzyme addition, and other factors. The efficiency of this step in processing can be assessed by the fractionation efficiency, or the specific energy input.

The innovation in the design of the biogas reactor

Another new process is the adoption of the up-flow anaerobic sludge bed (UASB) reactor design for biogas production from the water-soluble extracts of grass. This reactor design is widely applied in breweries, the sugar industry and various other industries. High-rate anaerobic reactors, such as UASB reactors offer advantages for soluble substrates and larger-scale applications. They also offer scale-up advantages for biorefinery systems applying solid/liquid separation. Scale-up can significantly reduce the cost of power production from renewable raw materials.

The grass washer innovation

Grass deliveries from permanent pasture often contain considerable amounts of soil (sand and stones). This is particularly true for late cuts in autumn, when mice move soil into and onto grass. In order to protect machinery and secure product quality, such material must be washed. The washer should perform the continuous, automated removal of sand and stones.

Such a washer has to be designed and built specifically for the biorefinery. It is a cost factor which must be considered.

The innovation in board production

For the production of boards, a new process has been designed and developed. This process includes the ad-mixing additives (protection against fire and funghi); does not require binders for board stabilisation; allows the production of several product types (*e.g.* density of 60 or 100 kg/m^3) on the same machine; and is cost efficient at small scale. This innovation largely improves the economics of a biorefinery, and makes the technical utilisation of grass economically feasible at relatively small scale. Initial production and marketing of commercial boards is due to begin in 2004.

Economic considerations

Generation of value added

The total value that can be generated from grass is listed in Table 1. The following price assumptions were made:

- The raw material cost is EUR 65 per tonne of dry matter;
- The feed-in tariff for power is EUR 0.1/kWh;
- For the blow-in product, the net sales price *ex* factory is EUR 0.40/kg;
- For insulation boards with a density of between 60-100 kg/m^3, the net sales price *ex* factory is EUR 0.80/kg. The net sales price of stone wool products, in the same density range and recommended for the same applications, is between EUR 0.80 and 1.00/kg;
- For combustion pellets, the net sales price *ex* factory is EUR 0.13/kg.

The use of net sales prices, *ex* factory, considers the margins necessary for product marketing and distribution.

Table 1. Creation of value added

Raw material	Cost of raw material	Sales (energy)	Sales (non-energy)	Total sales	Value added	Value factor
	EUR/ha	EUR/ha	EUR/ha	EUR/ha	EUR/ha	
Grass – power + blow-in insulation[1]	650	500	2 200	2 700	2 050	4.1
Grass – power + insulation boards[1]	650	500	4 400	4 900	4 250	7.5
Grass – power + combustion pellets[2]	390	657	0	657	267	1.7
Rapeseed – liquid fuel + animal feed	641	660	450	1 110	469	1.7

Notes:

1. Mid-intensive production, harvest 10 t/ha dry matter.
2. Extensive production, harvest 6 t/ha dry matter.

Source: Author.

The value added is defined as total sales minus raw material cost. The value factor is defined as total sales divided by raw material cost.

Table 1 shows that attractive fibre products such as insulation boards help to generate an attractive value added. The value factor 1.7, as determined for the production of power and combustion pellets from grass, as well as for the production of liquid fuel and animal feed from rapeseed, is too low to support an expensive process (such as processing grass), but possibly sufficient for a low-cost process such as oil extraction. Utilisation of low-quality grass from semi-natural habitats for the production of insulation boards has not yet been proven.

Plant concept and size

Determining the value added of a potential product from a biorefinery helps to develop and design a viable plant concept. Other essential plant design criteria are the investment and operating costs for a specific production line, the related yield per tonne of raw material, and the marketability of the product on a large scale.

Table 2 lists these criteria for the evaluated products and defines the overall attractiveness of a product for integration into a biorefinery concept. Production of biogas and power requires high investment, but generates low value added and is therefore not an attractive option for a biorefinery. Grass juice for animal feed purposes can be an interesting by-product outlet. Insulation boards appear to be the most attractive of the products reviewed.

Products requiring high investment, but offering low or medium value added, can only generate profit at a large scale of production. However, small-scale operations have advantages to offer:

- Raw material transport over long distances can be avoided;
- The number of raw material suppliers for one processing plant is small, therefore organisation of raw material delivery and raw material quality control is easier;

- Silaging of very large quantities of raw material for winter production requires a significant surface area; and

- Levels of investment are lower, which makes financing feasible for agricultural organisations.

First implementation of a biorefinery

The first production-scale biorefinery was built and commissioned in Schaffhausen, Switzerland, at the end of 2001. Technological development and implementation were conducted by the Swiss company 2B AG. Technological development was supported by the Swiss Agency for Environment, Forests and Landscape. For the implementation in Schaffhausen, the Swiss Agency for Energy provided an investment subsidy of around 18% of the total plant cost.

The Schaffhausen installation was not economically viable and operation was stopped in summer 2003. Production-related reasons for the failure include low revenues from product sales (blow-in insulation) and the unsatisfactory performance of some plant components (*e.g*. fibre drying and packaging).

The plant produced technical fibres and biogas from grass. The innovations regarding raw material fractionation, production of biogas in the UASB reactor, and grass washing were demonstrated successfully. The technical fibres were further processed on-site for production of a blow-in insulation product marketed under the brand name *2B Gratec*. Certification and market introduction of *2B Gratec* were successful. Biogas was utilised in a combined heat and power plant. Heat was used internally for drying the fibres. The power was certified and marketed under the label "Nature Made Star". The plant had a raw material throughput capacity around 0.8 tonnes of dry matter per hour. The yield of *2B Gratec* was 500-600 kg per tonne of dry matter and the biogas yield was 150-250 m^3 at around 6 kWh/m^3, depending on raw material quality.

Table 2. Product attractiveness

	Investment cost	**Yield**	**Value added**	**Large-scale product marketing**	**Overall attractiveness**
Fibre insulation boards	high	high	high	possible	high
Fibre blow-in insulation	high	high	medium	difficult	medium
Grass juice for animal feed	low	high	low	possible*	medium
Dried protein for animal feed	high	medium	medium	easy	low
Biogas/energy	high	medium	low	easy	low

* In small-scale production units.

Source: Author.

Conclusions

Grass offers good prospects as an industrial raw material. However, production design and engineering, product development and marketing – as well as plant operation and management – require know-how and experience. During extensive production-scale testing, it was found that:

- Wet fractionation of grass is a powerful tool for the generation of value added from several products;
- Insulation boards combine high yield with high value added and appear as the most attractive of the products examined;
- Production of ethanol, biogas and power is cost-intensive and contributes little to the overall economics of a biorefinery;
- Linking two or more expensive new production lines results in the spreading of risks and should be avoided.

Despite the commercial failure of the first biorefinery at Schaffhausen, the Swiss agency for Environment, Forests and Landscape has decided to give further support to the development of the technical utilisation of grass. This decision is based on the high potential of this raw material for industrial utilisation and related environmental benefits. The agency has appointed the author of this paper as the contact person for related questions.

LINKING BIOENERGY WITH CARBON STORAGE: A SEQUENTIAL DECISION APPROACH TO THE THREAT OF ABRUPT CLIMATE CHANGE

Peter Read[1]

Abstract

The National Academy of Science report "Abrupt Climate Change: Inevitable Surprises" (2001), and the negative emissions energy concept of Bio-Energy with Carbon capture and permanent Storage (BECS), creates a new situation. Responding to the threat of abrupt climate change can now be taken out of the "too hard" basket to which it was consigned during the post-1995 negotiation of the Berlin Mandate (when, given the maintained assumption that the best approach would be to limit emissions by putting a high price on carbon, even Gradual Climate Change was hard enough).

Any robust ("Be Prepared") strategy involves two key characteristics, with at least two examples of each relevant to being prepared for bad news of ACC precursor signals:

1. Focus research on what we need to know

a) What would be the likely precursors of plausible ACC (abrupt climate change) events, and how to detect them?

The view of the author is that one, at least, is staring us in the face, in terms of the halving in thickness of North Polar sea ice over the last half-century.

b) Where are the deep saline aquifers for CO_2 disposal – not only in fossil fuel areas but also in potential biofuel areas?

2. Start on activities with long lead times and low early costs – build the Ark before the flood

c) Start a programme of ACC-related land use change through community friendly plantation projects, in the process creating a " buffer stock" of carbon in standing forests, mainly in developing countries;

d) Start a programme of capacity building (*e.g.* through a network of collaborating tertiary institutions) to enable an expansion of country-driven bioenergy projects yielding synthetic gasoline, diesel, etc., and rural electricity supplies from woody raw material.

1. Massey University, Palmerston North, New Zealand.

Responding to ACC through being prepared to implement BECS (Bio-Energy with Carbon capture and permanent Storage) (b, c and d, above) involves focusing on driving needed technological change. This is more industry-friendly than Kyoto because:

A. "Buffer stock" mitigation of carbon in the atmosphere is decoupled from industrial change in developed countries, avoiding "stranded assets".

B. Bioenergy is much more compatible with existing infrastructure than non-fuel renewables.

C. If industry's hopes that there is no climate change problem turn out to be better founded than scientists generally believe, the wood could be used for timber (saving biodiverse natural forests).

D. Carbon capture and storage is favoured by industry and adding on bioenergy involves little cost or price increase so long as the policy instrument "spreads the cost" rather than adding the marginal cost to all sales. This approach is rationalised in economic theory by "internalising the learning externality".

E. Consumers and markets are then minimally disturbed.

Numerous ancillary benefits follow from addressing ACC in this way:

I. The "buffer stock" creates an assured supply of bioenergy raw material, remedying a market co-ordination failure between suppliers and users (separated by decades, by oceans and by language and culture) that frustrates bioenergy take-off, *per contra* rapid wind and solar progress.

II. Hence, faster CO_2 reductions are achieved than through Kyoto-style "domestic action".

III. Increased energy security for developed countries.

IV. Improved farm support in developed countries.

V. Economic take-off and sustainable rural development in many land-rich but otherwise impoverished countries.

Such a programme could attract many constituencies and might provide a basis for a revival of the 1992 bi-partisan spirit in the United States Congress. This could help towards a rapprochement over climate change between the United States and the European Union, and eventually facilitate the greater involvement of developing countries. It might be implemented through a second ACC Protocol tied to Article 3.3 of the United Nations Framework Convention on Climate Change (UNFCCC).

Introduction

Taking steps to insure against abrupt climate change (National Academy of Science, 2001) was identified by Schelling (1992) as the primary rationale for greenhouse gas mitigation. ACC was recognised in the Third Assessment Report of the IPCC as an issue that "haunts the climate change problem" (IPCC, 2001). However, ACC has been neglected by policy makers, who, without regard to the specific technological requirements of ACC insurance, have struggled to achieve consensus

through negotiated commitments to generalised emissions reductions in response to the "absent problem" of gradual climate change (Michaelson, 1998). Recent advances in technological understanding (Obersteiner *et al.*, 2001) suggest the availability of an insurance strategy that addresses the issue in terms of policy-driven technological change, whilst offering side benefits in terms of fuel security and sustainable development. Crucial to such a strategy would be improved scientific understanding of ACC to yield the capacity to recognise precursor signals of an imminent bifurcation in climate dynamics. Also not discussed in detail in this paper is an aspect of the new technological understanding that is advancing rapidly, *i.e.* technologies for CCS, disposing of CO_2 underground and maybe in deep oceans.

Both CCS and bioenergy are technology types rather than specific technologies. CCS involves either pre- or post-combustion separation of CO_2 in either new plant or retrofitted, and its disposal in a variety of receptors, including secondary oil recovery, coal bed methane, exhausted hydrocarbon reservoirs, saline aquifers, and maybe deep oceans. Bioenergy can provide energy carriers to meet final demands for both stationary and transportation needs, through a variety of technology chains involving numerous sources of biomass raw materials derived from wastes or from dedicated land used for energy plantations or for annual energy crops. Whichever is specified, the combination of a pair of technologies involving one from each type leads to an energy system with negative emissions characteristics, *i.e.* BECS and – in combination with raised energy efficiency and non-fuel renewables – it leads also to the potential to return rapidly to pre-industrial CO_2 levels (Obersteiner *et al.*, 2001).

Negative emissions energy systems are the key to responding to ACC because – taking account of rising levels of non-CO_2 greenhouse gases, for which no means exist for accelerating natural removal processes – the need may be to get to CO_2 levels below pre-industrial levels, which cannot be done by natural absorption, even with zero emissions energy. This is because zero emissions will result in CO_2 levels converging asymptotically – eventually very slowly – on the levels in natural absorbers, in particular in the surface layers of the ocean that turn over very slowly, and which now have levels elevated above the pre-industrial period, due to a century of absorption from the atmosphere's raised levels. Note that, apart from BECS as a negative emissions energy technology, it has been proposed that power station-sized CO_2 absorbers, one for each power station and roughly doubling the cost of power generation, could be located in non-fertile areas (Keith and Ha-Duong, 2002). If the power plant itself uses CCS, then the overall system is also a negative emissions energy system. The author does not envisage that this technology would have a role unless land shortages become acute.

In the present context it should be noted that the "two times CO_2" criterion much cited in the literature, is a social construct devised as a basis for model comparison and influenced by out-dated ideas as to what level it is feasible to aim for: it has no scientific basis as an indicator of what the UNFCCC's Article 2 "non-dangerous" level is, and does not indicate a threshold for precipitating ACC. In the absence of appropriately focused new research, and given the inertia of the climate system, which obscures the eventual possibly abrupt effects of current and past emissions, climate science cannot tell us whether any excursion above the pre-industrial levels of greenhouse gases, as has occurred in the last century, does or does not significantly increase ACC risks.

Sequential decisions in relation to ACC

ACC is taken here to be a shift in climate regime that may have only minor impacts, to which adaptation is acceptable, or which may be more serious, even catastrophic. Of the latter variety are shifts into and out of the major reallocations of surface water that characterise both ice ages and ice-free periods (of which the latter have not occurred since half a million years ago, when the present ice

caps formed, and the former many times during that period, with the onset of some glaciation episodes having taken no more than a few decades). Such a rapid transition is a potential feature of non-linear dynamic systems, like earth's climate system, and are generally heralded by precursor signals: for instance, when heated, a kettle "bumps" before the transition from convective circulation to mixed-phase (steam-water) turbulent boiling. The detection of such precursors in relation to ACC depends upon the type of climate transition that is anticipated, but given the timescale of the shifts that are of concern, precursor detection may be expected – or at least hoped – to give several decades' warning, giving the prospect, where the driver in raised CO_2 levels and perhaps in other cases, of effective response using negative emissions energy technology.

Providing research is done to enable recognition of such precursors, climate scientists might (*e.g.* in relation to the melting of North Polar sea ice, reported to be half as thick now as half a century back) state in 2020 that an Albedo-driven climate instability would be initiated with, say, 10% likelihood, unless a target reduction in CO_2 levels is achieved by a target date. Supposing that 10% likelihood is the political trigger for a "Manhattan project"-style climate stabilisation action plan, then timely preparations could make the difference between feasibility and infeasibility. This is illustrated qualitatively in Table 1, where capitalised Yes and No [YN] relate to the situation with a robust strategy involving preparedness for large-scale use of BECS, as illustrated later in this paper, and lower case yes and no [yn] relates to initial business as usual, without preparedness measures. No calculations have yet been conducted to back up what are, hopefully, plausible guesses, informed by modelling work presented elsewhere (Read and Lermit, 2003).

Achieving feasibility involves meeting the informational requirements for a robust strategy, *i.e.:*

- Climate science capacity to recognise precursor signals of ACC;
- Development of CCS technology, and capability to link with bioenergy systems;

and it also entails initiating programmes that involve a long lead time, *i.e.:*

- A land use change programme, potentially on a very large scale, to be prepared for bad scientific news that may reveal the need for "Manhattan project"-style carbon management;
- A capacity-building programme related to the preceding item.

Table 1. Hypothetical target feasibility with and without robust strategy

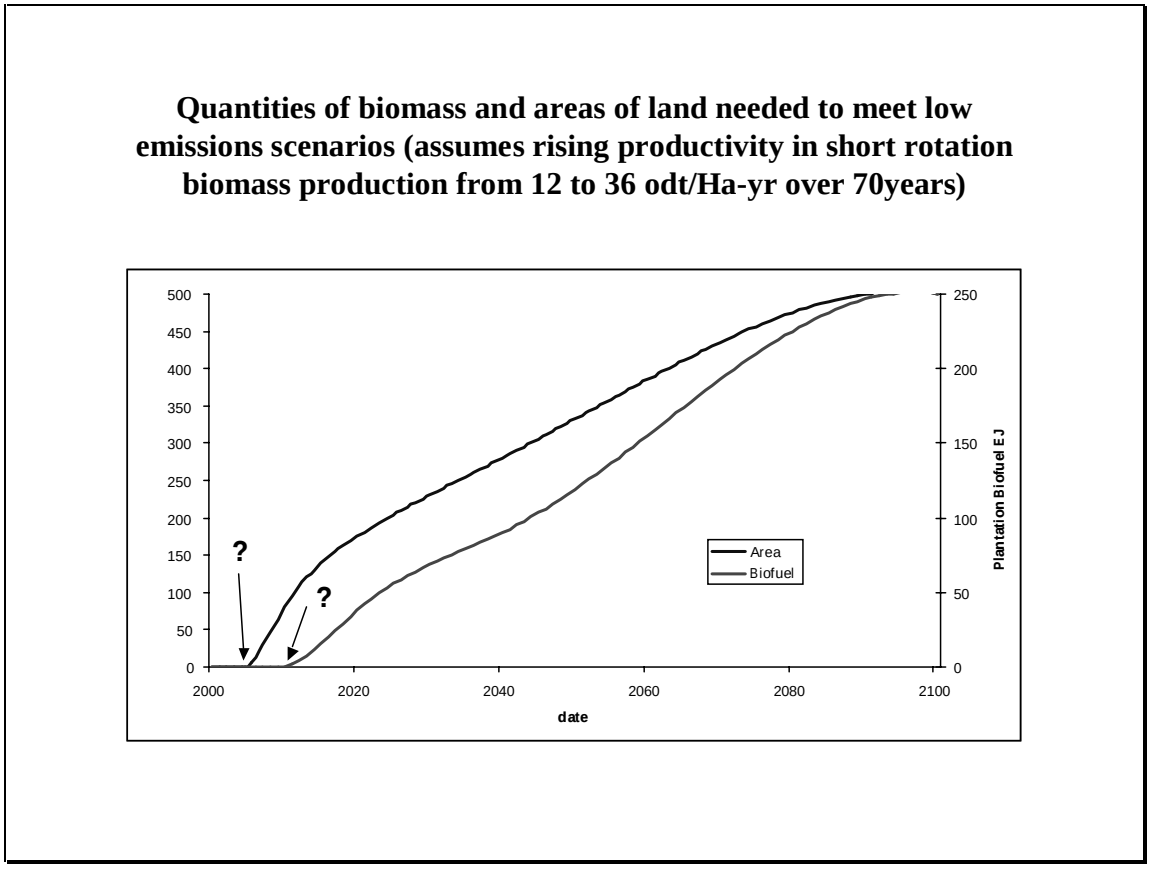
Target level / Target date	500	450	400	350	300	250	200ppm*
2030	Yn	Yn	Yn	Yn	Nn	Nn	Nn
2050	Yy	Yy	Yn	Yn	Yn	Nn	Nn
2070	Yy	Yy	Yy	Yn	Yn	Yn	Yn

Notes:
* ppm : parts per million.
CO_2 equivalents of non-CO_2 gases are expected to reach 100 ppm by the end of this century.
Source: Author.

Thus a robust strategy requires a more technologically focused approach than is stimulated by Kyoto, including a more positive commitment to land use change as the basis for the major role for BECS that may be needed. It may be noted that such a programme of land use change is in any case needed for bioenergy to take the place that is envisaged for it in most non-nuclear low emissions scenarios – see Figure 1. This plots a smooth curve through the bio-energy component of a number of low emissions energy supply scenarios developed in the 1990s, including the Tellus institute's "fossil free energy scenario" (ffes) used as one of the reference scenarios in the modeling work reported later in this paper, and the related land use implications. The threat of ACC may therefore serve to stimulate bioenergy development that is currently lagging behind these scenarios, frustrated, it would seem, by a co-ordination failure between landowners, as prospective biomass producers, and energy managers, as future biomass users, possibly separated by distance, time (given time to grow for plantations) and cultural barriers.

With these preparedness measures in place, BECS technology can then be envisaged in three stages of implementation: plantation establishment and growth, utilisation of product for joint output of bioenergy and timber, and integration with CCS. It should be noted that only the last stage is high cost, requiring a high price on carbon emissions, as appropriate under a "Manhattan project"-style response to imminent ACC threats.

Figure 1. Failure of bioenergy systems to take off in parallel with wind and solar systems



Source: Read, 2001.

These stages are taken to represent the outcomes of different sequential decisions in different places. In land-rich but otherwise impoverished developing and least-developed countries, the first stage is to instigate a shift from unsustainable subsistence patterns of land use, with traditional bioenergy, to a cash-based agro-forestry rural economy with high-efficiency domestic bioenergy; the second stage is to provide access to modern energy carriers in rural locations whilst yielding an import saving/liquid-biofuel-export-led development strategy in the face of potentially rising oil prices; and the third stage, at higher cost, is in response to elevated carbon prices resulting from bad climate science news of precursor signals of imminent ACC. In developed countries, decisions on the three stages would be differently motivated – the first as a farm support policy that establishes a buffer stock of biomass fuel raw material in response to concerns over security of energy supplies; the second as a precautionary demonstration of the technology chains needed for a negative emissions energy system, thus driving learning by doing with BECS (learn then act – Manne and Richels, 1994); and the third, again, as a response to high carbon prices reflecting imminent ACC.

Role of BECS

Order of magnitude (energy security)

Assume 500 GJ (gigajoules)/ha is produced over 500 million hectares globally by 2030. This is ~ 40% of the usable land described by the FAO as surplus to agricultural needs in 2050 (when population is projected to peak) and a productivity less than half that achieved commercially with best-case sugarcane in Zambia and eucalypt in Brazil (Moreira, 2002). Then there is a supply of 250 EJ (exajoules) annually which, with 30% efficient conversion, can displace 115 EJ of crude oil (assuming five-eighths transportation fuel fractions) annually. (The 30% value corresponds to the prototype technology of the following section. Advances in technology may be expected to raise this figure towards 50%, yielding more oil displaced but less CO_2 in the "smokestack" for capture and disposal underground). Allowing for slow initial build-up, 8 000 EJ of oil will be displaced this century, equivalent to about 1.5 millions of millions of barrels, *i.e.* 1.5 times global proved reserves, or 50 times current annual consumption, and – with 12 000 EJ renewable each subsequent century – plausibly sufficient to keep pace with rising demands for fuel for transportation, given continuing increases in plantation productivity, conversion efficiency and vehicle fuel economy (*e.g.* with fuel cells and biomethanol as a hydrogen carrier). With delivered costs of bioenergy raw material of under 2/GJ, and regardless of carbon in atmosphere (C_{at}) considerations, there would seem to be a significant case on security of supply grounds for growing liquid fuel raw material as well as drilling for it.

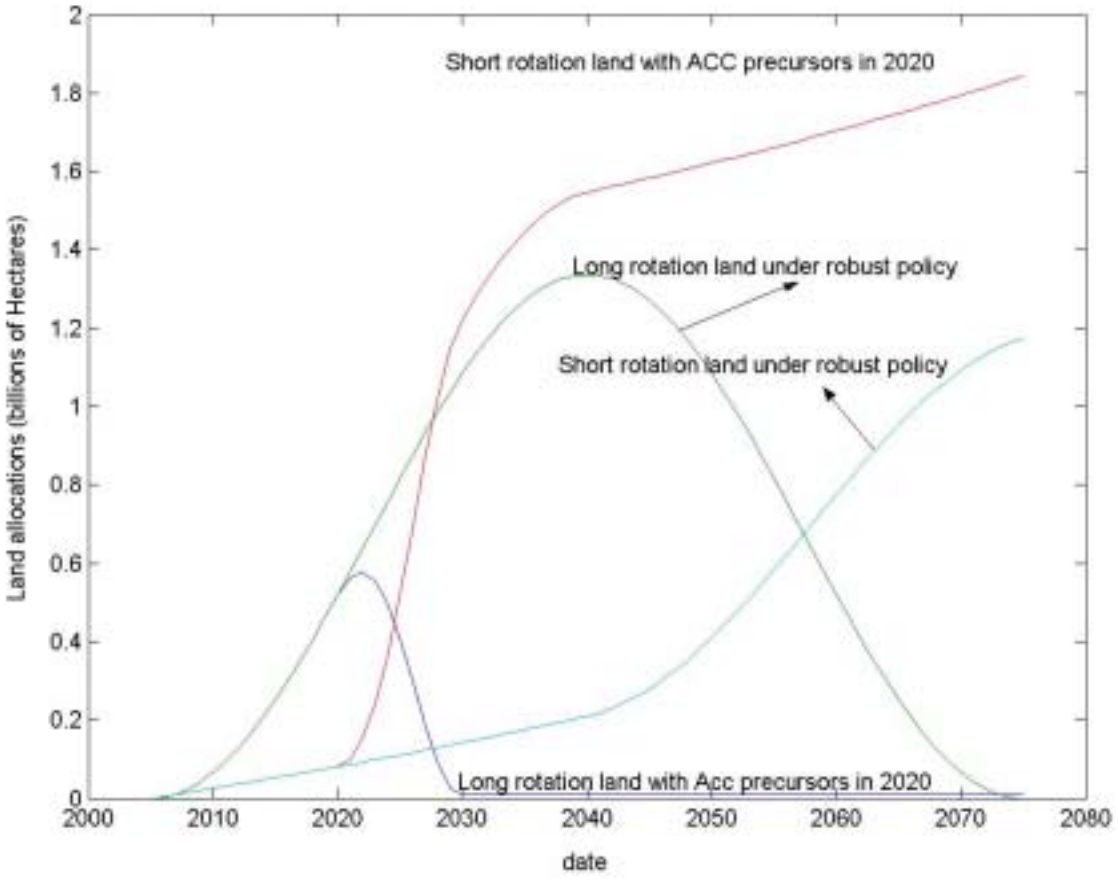
Technological characterisation

Meeting the variety of demands for different final energy services with negative CO_2 emissions entails a portfolio of specific BECS technologies with the bioenergy component related to the pattern of demand and the carbon storage aspect related to local geo-physical potentials. The current paper is concerned with the C_{at} implications of BECS and takes the characteristics of "once through" Fischer-Tropsch joint production of liquid fuels and electricity (Larson and Jin, 1999) as typical. This conversion technology is suitable for linkage with community-scaled biofuel plantations (Read, Sims and Adams, 2001) and, in combination with pre-combustion removal of CO_2 and disposal in saline aquifers (Stevens and Gale, 2000) is taken as a prototype BECS technology. Aggressive plantation development that is neglectful of local conditions is subject to fire hazard from aggrieved former land users. Thus community scaled plantations are envisaged as the basis for socio-economically attractive sustainable rural development, to underpin a global expansion of bioenergy in line with low emissions scenarios.

Under a “Be Prepared” policy case it is assumed that CCS technology is applied to fossil fuel on an initially small but expanding scale and that the land use change programme used in previous work is initiated from 2005. This programme (Figure 2) has two components, first a long rotation conventional forest rotation (35 years), planted in a half sinusoidal pattern over years 1 to 35 of the 70-year modelled period, and felled as it reaches maturity for use partly as timber and partly as bioenergy, with the split dependent on the relative product price. And second a short rotation crop mainly for bioenergy, planted on an initially small but exponentially increasing land area, to which is added half the long rotation land as it is cleared from year 35 (*e.g.* 2040) on.

These activities are modelled to absorb carbon at 3 tonnes carbon/ha/year, constant, for the mature forestry technology and 6 tonnes carbon/ha/year, rising to 18 tonnes carbon/ha/year over the 70-year model time horizon, assuming bio-technological progress with novel energy cropping systems for the short rotation activity. If wholly used for energy, these figures correspond to ~ 120, 240 and 720 GJ/ha and may seem conservative in relation to the figures for current commercial-scale production (Moreira, 2002). Carbon in biofuel is assumed to displace carbon in fossil fuel in the ratio 10:9, and carbon in timber is assumed to remain sequestered after felling, since the additional timber supply reduces demands to fell forests elsewhere, most likely where forest residues are left to decay.

Figure 2. Land use under robust policy with and without an ACC precursor event in 2020



Source: Read (1999).

Assumptions employed to represent a "Manhattan project"-style response to ACC precursors

It is assumed that in 2020, *i.e.* 15 years after a 2005 start date for the model, climate science convinces the political process of the existence of an unacceptable risk of ACC unless one of the more ambitious targets suggested in Table 1 is achieved – say 300 ppm CO_2 by 2050. Then the following actions are undertaken in the decade 2020-30:

1. Retrofitting of all large point source fossil and biofuel emitters with CCS technology;

2. All new large fossil and biofuel plant fitted with CCS technology;

3. A system of gathering pipelines installed to collect captured CO_2 and deliver to below-ground storages;

4. All long rotation policy land converted to short rotation biofuel production (see Figure 2) with the part-grown long rotation woody biomass material used wholly for biofuel;

5. Shift from a half-hearted (under Kyoto reference scenario) to a full-on programme of accelerated technological progress (atp) for non-fuel renewable energy and technological progress.

The effect of these measures is that emissions per tonne of fossil fuel fall from 0.025 tonnes carbon/GJ to 0.015 tonnes carbon/GJ, and per tonne of biofuel from zero to –0.01 tonnes carbon/GJ, with biofuel supply rapidly dominating the market. The outcome in terms of C_{at} concentration is shown in Figure 3, which demonstrates that targets for CO_2 reductions that have so far seemed infeasible can be achieved with BECS technology providing that the necessary low-cost measures to be prepared for bad news of ACC precursors are put in hand – "learn then act" may be appropriate for gradual climate change, but Noah built the Ark before the rain started.

Order of magnitude (carbon in atmosphere under "Manhattan project"-style urgency)

Area under long seq. curve = ½ x 20yrs x .6 Gha x 3 tC/ha-yr = 18 Gt C , plus:
Area under short rotation curve to 2030 = ½ x 10 yrs x 1.2 Gha x 10 tC/ha-yr = 60 Gt C.

Assume 90% replacement of Fossil fuel C emissions = ~ 70 Gt C not emitted = 35 ppm below "ffes" trajectory or ~ 400 ppm. By 2040 a further 10 yrs x 1.4 Gha x 12 tC/ha-yr = ~ 150 GtC not emitted. Total = ~ 80 ppm below "Kyoto" reference trajectory by 2040. Remaining reduction illustrated in Figure 3 is due to CCS technology used with coal and increased energy efficiency and non-fuel renewables under full atp.

Caveats: environmental and socio-economic effects

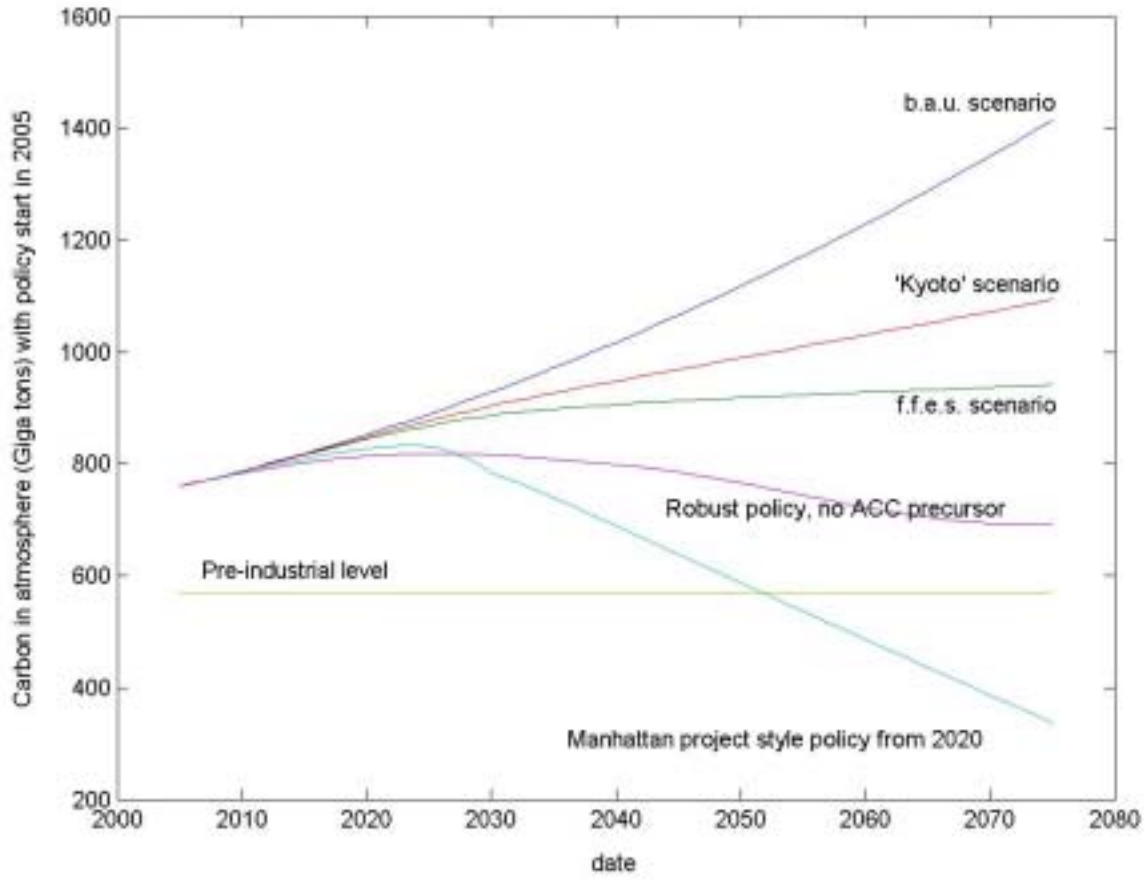
Parallel action

It should be noted that, although the focus of the FLAMES model is on the additional impact of policy-driven land allocations, the surprisingly low C_{at} levels noted previously (Read, 1998, 1999; IPCC, 2000) that result from large-scale land allocations are only reached with the simultaneous application of the low and zero emissions energy technologies involved in the ffes scenario: in other words, the large-scale, policy-driven land use allocations illustrated in this paper are a necessary but not sufficient condition for the achievement of the low C_{at} levels mentioned above. By the same token, in order to attain the below pre-industrial C_{at} levels illustrated in this paper, large-scale negative emissions – achieved through widespread application of BECS technology – is a necessary but not sufficient condition.

Land constraint

Additionally, it should be noted that the very large land allocations that have been used in the FLAMES model are taken to be "maximal". No decision taken this decade can pre-determine the land allocations that will be made some decades ahead, and the implication of modelling large allocations over such a long period is that the initial phases of the programme will be successful in meeting socio-economic and environmental constraints and hence stimulating – or at least not inhibiting – the on-going sequence of policy makers' and landowners' decisions that is represented by such a maximal programme. Thus such maximal allocations are a representation of the maximum amount of land that might be used for policy-desirable activities if the appropriate incentives were put in place, and sustained, to reward current landlords and land users so as to ensure they engage continuously in such policy-desirable land use. Implicitly it is assumed that they desist from current land-profligate slash and burn subsistence, nomadic herding, forest clearance, etc., investing their rewards so as to meet their food and other land-based needs better than at present, and more sustainably.

Figure 3. Carbon in atmosphere profiles under various reference scenarios and under robust policy with and without an ACC precursor event in 2020



Source: Read, 1999.

Conceptually, the modelled maximal allocations are intended to represent the maximum possible policy-induced effect on the pattern of land use, constituting a change in the trend of land use and the following of a new path, starting from a near-future bifurcation in the evolution of land use policy and practice towards stewardship rather than exploitation. And, logically, no degree of policy urgency can accelerate land use allocations defined as maximal: if pushed too fast, disaffected communities will simply set fire to the plantations. This is not to claim that the land allocations modelled here are empirically maximal in this sense: if a better estimate of what is maximal can be made, then that estimate should replace the pattern modelled here. The point is that whatever can be done starting in 2010, more can be done, and ACC threats better managed, by starting in 2005.

Community scale and socio-economic and environmental compatibility

Providing policy safeguards are in place to secure good project design, fears regarding potential negative socio-economic and environmental impacts from large-scale afforestation are misplaced. Rather than large-scale monocultural plantations, good design involves a very large number of community-scaled forestry and agro-forestry projects spaced out over the 5-6 billion ha of unforested and often thinly populated land that is feasible globally for new forestry. Trees can be grown in areas unsuitable for cultivation and, although the 1.3 billion ha of cultivable land said to be surplus to food production needs in the IPCC's Third Assessment Report (IPCC, 2001), would most likely be the most suitable from a productivity point of view, environmental concerns for desalination and desertification control may suggest the use of marginal land unsuitable for cultivation. A large-scale afforestation programme in support of carbon cycle management and eventual bioenergy uses could restore the balance of land cover to the pre-industrial state and still leave 4-5 billion ha for eco-tourism-funded conservation wilderness areas, including migration trails, and, in populated areas, for intensified modern agriculture capitalised through carbon credit income and exports of liquid biofuel products. As regards competition for land for food production, note that famine is the result of poverty, not land shortage (Sen, 1981), and that traditional land use is unsustainable, given expected population increase, hoped-for rising living standards, and projected climate change.

Community scaling is enabled by modern conversion technologies that are efficient in small-sized applications (Larson and Jin, 1999; Bowman and Lane, 1999). Rural electricity, and renewable fuelwood utilised in modern appliances, provide improved rural employment prospects and reduced health risks. Environmental benefits from well-designed projects that increase tree cover are: reduced air pollution with sulphur-free biofuel-based liquid fuels; reduced high country soil degradation and water run-off, with reduced downstream siltation; improved capture of polluting agricultural run-off; and the productive utilisation of organic wastes for plantation fertilisation, avoiding landfill (Woods and Hall, 1994). Community scaling involves a large number of dense plantations small enough to fit between existing settlements, together with agro-forestry developments close to such settlements to meet local needs (Sims and Read, 2000).

Prejudicing these prospects is the lack of appropriate human capital in prospective host countries. Unless host countries are well prepared to ensure that projects are country-driven, such projects will reflect the emissions reduction priorities of donor firms, with only lip-service paid to host-country development priorities. There is a risk that, unless a start is made to building human capacity to respond effectively to rising demand for country-driven projects, the CDM process will falter. This could be caused either by disillusion on the part of donor country firms over host-country un-preparedness, or by adverse host-country community reaction to projects poorly related to development priorities and local needs. The latter outcome would be to follow in the long tradition of unfortunate experience with donor-driven projects that end up neglected or abandoned once the donor agency's attention diverts elsewhere (OECD, 1998). Effective preparedness entails human capacity-

building at all levels: creating a receptive community through short courses for bureaucrats, local entrepreneurs, non-governmental organisation leaders, etc.; through the training of professional country-driven project implementation personnel ("Project Champions" [PCs]); and through expanding research capacity to explore the frontiers of sustainable development. One possible approach is outlined in the Annex, involving collaborations between tertiary institutions in host and donor countries.

Global human capacity building

This risk demonstrates the need for a corps of trained professional personnel, eventually numbering 20-30 000 thousand worldwide, with an annual intake of about 5 000 (see Annex) to act as PCs. Each would have a portfolio of a few to many projects, depending on size and complexity. At a training cost of up to USD 10 000 each, this will require expenditure possibly totalling USD 500 million over the next two decades, in a new Operational Program in the Climate Change Focal Area of the GEF, yielding incremental mitigation costs trending down from an initial cost of USD 1.7/tonne carbon in 2005, to 4 cents/tonne carbon by the end of the Kyoto Protocol first commitment period (with 3.2 GtC [giga tonnes of Carbon] of cumulative additional mitigation) and 0.3 cents/tonne carbon by 2040 (with over 100 GtC of cumulative additional mitigation).

The role of PCs would vary over the life of a project. Initially entrepreneurial, the role involves:

a) conceiving emission-reducing projects in line with host-country sustainable development policies and priorities;

b) seeking out appropriate specialist technological advice, including prospective technology transfer from overseas firms;

c) gathering a prospective stakeholder conjunction of interests in the range of benefits associated with reducing emissions (*e.g.* employment, reduced local pollution, health, biodiversity, flood control, etc.), including:

   - community commitment at the project location;
   - entrepreneurial commitment to project management;
   - capital finance – both risk-bearing and aid programme-related, where relevant;
   - involvement of overseas carbon credit-seeking firms; and
   - bureaucratic commitment to facilitation of the project;

d) developing project proposals, including greenhouse gas emissions reductions estimates to the stage of a scoping study for presentation to stakeholders;

e) recruiting project management acceptable to both the foreign investor and local stakeholders and transferring operational responsibility for the project.

Subsequently the role would shift to:

f) monitoring scheme progress for delivery of

- carbon credits and reporting requirements under the UNFCCC; and
- sustainable development objectives of the host government;

g) providing extension services to the community to ensure on-going delivery of community benefits needed to ensure its continued commitment to the project;

h) securing high-level support and research services in relation to non-routine problems arising from longer-term project evolution.

Policy instrument

It is assumed in the modelling that underlies these conclusions that a dynamically efficient instrument is employed to drive the desired pattern of technology change, rather than simply putting a price on carbon, which has been shown to be inefficient. It is ironic that, in the same year that Baumol and Oates published the first edition (1975) of their seminal work, Kneese and Schultz (1975) reported that, in the long run, conflicts between environmental quality and economic well-being are resolved by technological change. Unfortunately the negotiations that followed the Berlin Mandate of 1995 were dominated by adherents of Baumol and Oates's theory.

Complex non-linear dynamics characterise the process of technological change, so that energy sector transformations which are technologically quite easy to envisage, and quite low-cost on a "bottom up" analysis, may nevertheless fail to come about as the result of policy measures which might superficially appear adequate. "Lock-in" of inefficient technology is familiar from the QWERTY story and managerial myopia can be a contributing factor. This may present a barrier to entry for sustainable technology in the energy sector, given the powerful position of fossil fuel-based incumbent firms.

"One outstanding characteristic of Arthur's viewpoint is its emphatically dynamic nature. Learning by doing or using plays an essential role. … Prices … are not given the exaggerated importance of much current economic orthodoxy" … (Arrow, in foreword to Arthur, 1994). "Nonconvexities and positive feedback mechanisms are now central to modern theorising in international trade theory, growth theory, the economics of technology, industrial organisation, macroeconomics, regional economics, economic development and political economy" (Arthur, 1994). But the dynamic implications of learning in relation to technological change have not yet been extended into the field of environmental policy.

The intuition is that the price paid for abatement innovations (the marginal cost of abatement) generally needs to be set higher than the market value of permits. This is because learning by doing yields a positive inter-temporal externality, whereas whatever is learned from the consumer pain of doing without is not applied systematically by non-specialist consumers. This reflects an assumed asymmetry, based in the innovation literature, that cost-reducing innovation is, typically, the activity of specialising firms seeking competitive advantage. Of course individual home-improvers may double-glaze their homes, but what they learn dies with the investment. On the other hand, if a power supplier double-glazes some of its consumers' homes, say in the context of "demand side management", then the learning accrues to the power supplier and its contractor, and leads to lower-cost double-glazing in the next double-glazing project they do.

So future abatement is lower-cost on account of current abatement and it is worthwhile to invest more now in abatement innovations, in order to secure a return later in the form of lower abatement costs. Modelling endogenous technological progress shows that, taking a sufficiently long view, it is efficient (least-cost) to devote all the income from sales price increases to innovations in policy-desirable technology for a decade or so ahead. Such an outcome follows from renewable portfolio standards and other policy devices that secure an increasing proportion of adoptions of the desired technologies. Such "spreading across" of the initial high costs of new product lines is indeed normal business practice. The raising of all prices by the marginal cost of the new technology, and consequent generation of large carbon tax surplus revenues for recycling outside the energy sector leads to the unnecessary disruption of markets and needless consumer pain.

Conclusion

Industry has been engaged in a massive geo-engineering project over the last 200 years, most intensively in the last 50, that has seen 200 billion tonnes of carbon moved from deep underground into the atmosphere, with additional amounts into near-surface absorbers. To reverse that outcome is equally a geo-engineering project that, unlike most of the geo-engineering concepts that have been proposed, is benign in its side effects rather than "expensive, unreliable, dangerous, ugly and unwise" in the view of many (Michaelson, 1998, who attempts to rebut this view in relation to a variety of geo-engineering concepts that do not include BECS). To use Michaelson's terminology of a "Manhattan project"-style approach is to recognise that this analogy is appropriate to the situation that would – or at least should – arise in the event of credible scientific demonstration of abrupt climate change precursors.

However, the earlier stages of the robust strategy that has been outlined constitute a measured and rational geo-engineering project in carbon management that aims to remedy the anthropogenic cause of climate change, rather than, as with other geo-engineering, respond to the symptoms. It should commend itself to environmentalists when their well-intentioned objections to "sinks" in the Kyoto Protocol come to be seen as an over-zealous concern for the integrity of an emissions reductions target that, in reality, is a somewhat misdirected first step in a long process (save, that is, for "deep environmentalists", who see the true causes in a perversion of human nature manifest as consumerism, and whose concern is to change the ways of society: however much sympathy one may have for that view, it seems an impractical approach to the problem of abrupt climate change, which may become acute in a decade or so if climate science comes to focus on detecting its precursors). Most clearly will it be seen to be misdirected when it is appreciated that it ignores the dictum that, in the long run, conflicts between environmental objectives and economic well-being have to be ameliorated by technological change (Kneese and Schultz, 1975). Then it becomes clear that a better direction for the long process is to drive the necessary transformation of energy technology directly (*e.g.* by renewable portfolio standards) rather than to penalise emissions, an approach that inevitably provokes resistance. Also, in focusing on limiting emissions, environmentalists have neglected the reality that even driving emissions to zero is inadequate for rapidly reversing the outcome of the last two centuries, as may be needed in the face of ACC, and that technology for carbon management that potentiates such rapid action is both necessary and potentially benign.

The benign side-effects of remedying the cause are discussed elsewhere (Read, 2002) but include:

- Stimulation of the pattern of land use change that is needed to meet the raw material demands of the bioenergy component embodied in most low emissions scenarios.

- Restoration of the pre-industrial tree coverage (differently located, owing to human settlement, but restoring the former capability of forests to act as lungs to the living earth).

- Empowerment of many developing countries to initiate their own “country-driven” projects as the building blocks of their own sustainable energy development path.

- Potential export-led growth for such countries, as bio-based liquid fuels take an increasing role in global transportation fuel supply, stimulating global macro-economic growth.

- Improved security of liquid fuel supplies, and reduced dependence on unstable Middle-East oil supplies.

- Improved farm support in agricultural surplus developed regions.

These side benefits follow from the first two stages of the decision sequence discussed previously – at low, possibly negative, cost, depending on the trend of oil prices under alternative, unsustainable, fossil fuel-dependent energy sector evolution. The availability of the possibly costly third stage yields the separate and primary objective of robust policy, that is, the capability to respond quickly to precursor signals of abrupt climate change. Such robustness, in relation to the threat of abrupt climate change due to warming of the unstable climate system induced by elevated levels of CO_2 (and maybe induced otherwise) involves four measures to be implemented soon:

1. A greater focus in climate science research on characterising possible climate instabilities and being able to recognise precursor signals of abrupt climate change;

2. Continuing vigorous research into CCS technology, including linking it to bio-fuel-based energy conversion systems;

3. Initiation of a potentially large-scale and enviro-socio-economically beneficial land use change programme, as the prospective raw material supply for meeting projected bioenergy demands, and potentially linked to CCS technology to comprise a negative emissions BECS energy system;

4. A capacity-building programme to train “project champions” to enable the land use change programme to be implemented through country-driven projects that reflect the sustainable development objectives of host countries and the needs and aspirations of the communities that occupy the land involved.

It has also been suggested (Read, 2002) that this strategy, focusing on technology change rather than emission limitation, offers the prospect of an industry-friendly approach to climate change mitigation that could provide the basis for rapprochement between those Annex 1 Parties to the UNFCCC that have ratified the Kyoto Protocol and those that have not.

ANNEX

A numerical illustration of a capacity building programme addressed to the ultimate objective of the UNFCCC

Year	Cost	Trainees	Total Trained (1 Jan.)	Drop-outs	Professional Corps (1 Jan.)	New Projects*	Total Projects allow for winding up after 10 yrs	New Project Productivity	New Project Mitigation	Projects Wound Up	Net Mitigation Change	Mitigation in Year	Aggregate Mitigation
	USDm	No.	No.	No.	No.	No.	No.	KtC** per project	MtC*** per year	MtC per year	MtC per year	MtC	GtC
2001	0.3	10 (pilot)											
2002	1.6	40											
2003	4.8	100	50		50	50	50	20	1		1	1	
2004	7.8	200	150		150	125	175	21	3		3	4	
2005	10.4 24.9	450	350		350	275	450	22	6		6	10	
2006	13.0	1200	800		800	625	1075	23	14		14	24	
2007	13.5	2500	2000		2000	1600	2675	24	38		38	62	0.1
2008	14.6	4000	4500		4500	3500	6175	25	112		112	174	
2009	14.7	4000	8500		8500	6250	12425	26	163		163	337	
2010	15.0 70.8	4000	12500		12500	8250	20675	27	223		223	560	
2011	15.5	3500	16500		16500	10250	30925	28	287		287	847	
2012	15	3000	20000		20000	11750	42675	28	329		329	1176	3.2
2013	15	3000	23000		23000	13000	55625	29	377	1	376	1552	
2014	15	3000	26000	2000	26000	14500	70000	30	435	3	432	1984	
2015	15 75.5	2500	29000	4000	27000	16000	85725	30	480	6	474	2458	

Notes:

* These projects and related CO_2 mitigation are land use change projects supplying raw material to biofuel projects based on the prototype technology outlined in the paper. They do not include the effect of CCS technology to which they may be linked in the event of a "Manhattan project"-style response to ACC precursors.

** KtC : kilo tonnes of Carbon ; *** mega tonnes of Carbon.

ANNEX
(continued)

Year	Cost	Trainees	Total Trained (1 Jan.)	Drop-outs	Professional Corps (1 Jan.)	New Projects	Total Projects allow for winding up after 10 yrs	New Project Productivity	New Project Mitigation	Projects Wound Up	Net Mitigation change	Mitigation in Year	Aggregate Mitigation
	USDm	No.	No.	No.	No.	No.	No.	KtC per project	MtC per year	MtC per year	MtC per year	MtC	GtC
2016	15	2500	31500	4000	25500	14000	99100	31	434	14	420	2878	
2017	15	2500	34000	4000	24000	13250	110750	32	424	38	386	3264	15.3
2018	15	2500	36500	3500	23000	12750	120000	32	408	112	296	3560	
2019	15	2500	39000	3000	22500	12500	126250	33	412	163	249	3809	
2020	15 75	2500	41500	3000	22000	12250	130250	34	416	223	193	4002	
2021	15	2500	44000	3000	21500	12000	132000	34	408	287	121	4123	
2022	15	2500	46500	2500	21500	12000	132250	35	420	329	91	4214	35.0
2023	15	2500	49000	2500	21500	12000	131250	36	432	377	55	4269	
2024	15	2500	51500	2500	21500	12000	128750	36	432	435	-3	4266	
2025	15 75	2500	54000	2500	21500	12000	124750	37	444	480	-36	4230	

ANNEX
(continued)

Year	Cost	Trainees	Total Trained (1 Jan.)	Drop-outs	Professional Corps (1 Jan.)	New Projects	Total Projects allow for winding up after 10 yrs	New Project Productivity	New Project Mitigation	Projects Wound Up	Net Mitigation change	Mitigation in Year	Aggregate Mitigation
	USDm	No.	No.	No.	No.	No.	No.	KtC per project	MtC per year	MtC per year	MtC per year	MtC	GtC
2026	15	2500	56500	2500	21500	12000	122750	38	456	434	22	4252	
2027	15	2500	59000	2500	21500	12000	121500	38	456	424	32	4252	
2028	15	2500	61500	2500	21500	12000	120750	39	468	408	60	4344	
2029	15	2500	64000	2500	21500	12000	120250	40	480	412	68	4412	
2030	15 75	2500	66500	2500	21500	12000	120000	40	480	416	64	4476	
2031	15	2500	69000	2500	21500	12000	120000	41	492	408	84	4560	
2032	15	2500	71500	2500	21500	12000	120000	42	504	420	84	4544	78.7
2033	15	2500	74000	2500	21500	12000	120000	42	504	432	72	4616	
2034	15	2500	76500	2500	21500	12000	120000	43	516	432	84	4700	
2035	15 75	2500	79000	2500	21500	12000	120000	44	528	444	84	4784	
2036	15	2500	81500	2500	21500	12000	120000	44	528	456	72	4856	
2037	15	2500	84000	2500	21500	12000	120000	45	540	456	84	4940	102.6
2038	15	2500	86500	2500	21500	12000	120000	46	552	468	84	5024	
2039	15	2500	89000	2500	21500	12000	120000	46	552	480	72	5096	
2040	15 75	2500	91500	2500	21500	12000	120000	47	564	480	84	5180	

Source: Haque *et al.*, 1999.

BIBLIOGRAPHY

Arthur, W.B., 1994. (ed.) "Increasing Returns and Path Dependency in the Economy", University of Michigan Press, United States.

Baumol, W.J. and W.E. Oates (1975 and 1988 [2nd edition]), *The Theory of Environmental Policy*, Cambridge, Cambridge University Press.

Bowman, L. and N.W. Lane, 1999, "Micro Scale Biomass Power" in R.P. Overend and E. Chornet (eds) *Proceedings of the 4th Biomass Conference of the Americas, Oakland, CA*, Elsevier, Science, Oxford, pp. 1 445-1 452.

Haque, A.K.E., P. Read and M.E. Ali, (1999), "The Bangladesh MSP Pilot Project proposal for GEF funding of capacity building for country driven projects", Working Paper, IDESS, North-South University, Dhaka, Bangladesh.

IPCC [Intergovernmental Panel on Climate Change] (2000), *Land Use, Land-use Change and Forestry*, Cambridge University Press, Section 4.5.2 and pp. 277-280.

IPCC (2001), *Third Assessment Report, Contribution of Working Group III*, Cambridge University Press, Section 10.1.2.4.

Keith, D.W. and M. Ha-Duong (2002), "Climate strategy with CO_2 capture from the air", GHGT-6, Kyoto, October: www.andrew.cmu.edu/user/dk3p/.

Kneese, A. and C. Schultz (1975), *Pollution, Prices and Public Policy*, Brookings Institution, Washington, D.C., United States of America.

Larson, E.D. and H. Jin (1999), "Biomass Conversion to Fischer-Tropsch Liquids: Preliminary Energy Balances" in *Proceedings of the 4th Biomass Conference of the Americas, Oakland, CA*, Elsevier Science, Oxford.

Manne, Alan S. and Richard Richels (1992), *Buying Greenhouse Insurance - the Economic Costs of Carbon Dioxide Emissions*, MIT Press, Cambridge, MA.

Michaelson, J. (1998), "Geoengineering: a climate change Manhattan Project", Stanford Environmental Law Journal: www.metatronics.net/lit/geo2.html.

Moreira, J.R. (2002), *Global Renewable Energy Potential*, Third Workshop of Latin-American Network on Biomass – LAMNET, Brazilia, 2-5 December.

National Academy of Science (2001), *Abrupt Climate Change: Inevitable Surprises*, N.A. Press, Washington, D.C., United States of America.

Obersteiner, M., C. Azar, P. Kauppi, M. Mollerstern, J. Moreira, S. Nilsson, P. Read, K. Riahi, B. Schlamadinger, Y. Yamagata, J. Yan and J.-P. van Ypersele (2001), "Managing Climate Risk", *Science* 294, (5 543): 786b.

OECD (1998), *Key Issues in the Design of New Mechanism under the Kyoto Protocol: A Scoping Paper*, OECD, Paris, France.

Read, P. (2002), "Precautionary climate policy and the somewhat flawed protocol: linking sinks to biofuel and the CDM to the Convention", *Climate Policy* 2/1, pp. 89-95.

Read, P. (2001), "The Role of Plantation Sinks", *Energy and Environment*, 12/5 and 6, pp. 511-520.

Read, P. (1999), "The Role of Biomass in Meeting Greenhouse Gas Reduction Targets: Land Allocation Modeling of Key Market Impacts", Discussion Paper 99.16, Department of Applied and International Economics, Massey University, Palmerston North, New Zealand.

Read, P. (1998), "Dynamic Interaction of Short-Rotation Forestry and Conventional Forestry in Meeting Demand for Bioenergy", *Biomass and Bioenergy*, 15.

Read, P. and J. Lermit (2003), "Landowner decisions in the joint production of energy and timber under policy induced land use change" (in preparation for Second Annual Carbon Sequestration Conference, Washington, D.C., United States of America, 5-8 May).

Read, P., R.E.H. Sims and J.F. Adams (2001), "Community scaled bioenergy systems", 1st International Congress on Biomass for Metal Production and Electricity Generation, Belo Horizonte, October.

Schelling, T.C. (1992), "Some Economics of Global Warming", AER, 1-14.

Sen, A.K. (1981). *Poverty and Famines: An Essay on Entitlement and Deprivation*, Clarendon Press, Oxford.

Stevens, S. and J. Gale (2000), "Geologic CO_2 Sequestration", *Oil and Gas Journal*, 15, May, pp. 40-44.

Woods, J. and D.O. Hall (1994), *Bioenergy for Development: Technical and Environmental Dimensions*, Food and Agriculture Organization of the United Nations, Energy and Development Paper No. 13, Rome, Italy.

THE EFFECTS OF BIOENERGY CROPS ON FARMLAND BIRDS IN THE UNITED KINGDOM: A REVIEW OF CURRENT KNOWLEDGE AND FUTURE PREDICTIONS

Guy Q.A. Anderson, Lucy R. Haskins and Sarah H. Nelson[1]

Abstract

Large areas of bioenergy crops planted on farmland in the United Kingdom could have a potentially major impact on the population of farmland birds and all other components of farmland biodiversity. This paper summarises current knowledge on the impacts of bioenergy crops on farmland bird populations and make predictions where data are lacking.

Woody and perennial grass bioenergy crops represent a large ecological shift from conventional farmland habitats. Both may support a range of flora and fauna and there is evidence from short rotation willow coppice that overall bird species diversity may be higher than on conventional farmland. However, vegetation structure is likely to make these crops an unsuitable breeding habitat for several open-field species of high conservation concern. It is unlikely that these crops will provide significant annual food resources for seed-eating birds, which are a group of particular conservation concern.

The scale, spatial arrangement and geographic location of bioenergy crops are likely to have a significant influence on bird populations using the crops. Where bioenergy crops represent an increase in land use heterogeneity – for example, by introducing an arable system into a grassland-dominated area – biodiversity benefits are likely. Conversely, if energy crops are concentrated in large blocks of monoculture, biodiversity at the landscape level is likely to be reduced. Measures to increase habitat heterogeneity within areas of bioenergy crops and to maintain land use diversity should be encouraged to maximise the benefits to farmland birds and other wildlife.

Replacement of land use with high wildlife value, such as set-aside, by bioenergy crops is likely to impact negatively on farmland bird populations. Such changes should be prevented or adequately mitigated against to prevent further declines of farmland bird species already suffering heavily from the effects of agricultural intensification.

Introduction

The current drive towards developing sources of renewable bioenergy is likely to result in the planting of large areas of agricultural land with “bioenergy crops”; plants grown to provide fuel, either directly or following post-harvest processing. Currently these crops fall into two broad categories,

1. Royal Society for the Protection of Birds, Bedfordshire, United Kingdom.

those providing large quantities of carbohydrate (cellulose, lignin, starch, sugars) for direct combustion or fermentation to produce liquid or gas fuels, and those grown to produce oils for use as hydrocarbon fuel. The former are typically fast-growing woody species, grasses, cereals or root crops, and the latter oilseed crops such as rape (oilseed rape) and sunflower.

Although bioenergy crops offer clear environmental benefits over sources of non-renewable energy on a global scale, through reductions in net carbon emissions, their impact on agricultural ecosystems needs to be understood and should be properly evaluated before large-scale production is undertaken.

It is now widely accepted that large-scale, widespread declines in biodiversity on agricultural land in Europe, North America and in other "developed" regions of the world have resulted from changes in land management practice over recent decades, aimed at maximising productivity and efficiency and collectively termed "agricultural intensification". These effects have been best documented in well-monitored groups, particularly birds (Krebs *et al.,* 1999; Anderson *et al.,* 2001; Donald *et al.,* 2001*c*). It is therefore imperative to ensure that future changes to our agricultural land management systems do not exacerbate a biodiversity situation that is already serious, and further deplete floras and faunas that are already impoverished.

This review attempts to summarise what is currently known about the effects of bioenergy crops on bird populations on farmland in the United Kingdom (UK), and on key resources required by those birds, specifically the availability of suitable nesting sites and the abundance and accessibility of plant and invertebrate food. Relatively little research has been carried out on the biodiversity value of bioenergy crops, as the technology is still being developed and the availability of significant areas of crop for study has so far been limited. Therefore this review will also attempt to predict some of the possible impacts of crops for which there is currently very little data available. The emphasis will be on crops likely to be commercially viable in North-West Europe currently or in the near future. The review will consider effects on biodiversity on the field-landscape levels. Its should also be considered that bioenergy crops may have much broader scale impacts on avian biodiversity through a reduction in net carbon emissions and consequent effects on global climate. These are not dealt with here.

Four categories of crops are considered, those with greatest current or future potential for commercial-scale use as sources of bioenergy in North-West Europe:

1. Woody biomass crops, *e.g.* short rotation willow *Salix* spp. or poplar *Populus* spp. coppice (SRC);
2. Perennial grasses, *e.g. Miscanthus* spp;
3. Oilseed crops, *e.g.* oilseed rape *Brassica napus*;
4. Conventional arable crops grown for sugar or starch content, *e.g.* wheat, potatoes, sugarbeet.

The impacts of bioenergy crops on agricultural land will be considered at three levels:

1. The intrinsic biodiversity value of the crop itself;
2. The biodiversity value of the crop relative to alternative types of land use, especially those most likely to be replaced by the bioenergy crop.
3. Landscape-scale effects – how the distribution and regional location of these crops will impact on biodiversity.

Biodiversity value of individual bioenergy crop types

Short rotation coppice

Crop structure, growth patterns and management

Fast-growing willow (and, to a lesser extent) poplar species, which produce vigorous regrowth after coppicing, are the longest-established and currently the most widespread type of bioenergy crop in the UK. Hence they are also the best known in terms of their effects on farmland biodiversity. Plants can be established at high density (approximately 1m spacing) and harvested every 3-5 years. Harvesting is carried out in winter. Rootstocks allow approximately 6 harvests, giving a productive life of 20-30 years. In the initial year of crop establishment the vegetation is low, increasing in subsequent years into a dense uniform crop up to 5m in height.

Structurally, SRC shares many features with young traditional coppice woodland. However, management features of SRC (single-species planting at high density, fertilisation, weed control and ex-agricultural soils with associated seed-banks) are likely to result in substantial differences in associated ground floras and invertebrate communities (Robertson and Sotherton, 1992), both key potential food resources for different bird species.

During the establishment phase, weed control is considered important as the young trees are not good competitors, but once good vegetation cover is attained (after 2-3 years) this is of less concern. Commercial guidelines suggest pre-planting treatment (in spring) with a broad-spectrum herbicide to remove perennial grasses and broad-leaved plants (British Biogen 1996, Danfors *et al.*, 1998). Fertilisation may be required throughout the life of the crop, being applied after each cut.

Both poplar and willow have extensive and penetrating root systems and require deep moisture-retentive soils for proper growth. Regions with thin, sandy or calcareous soils are therefore unlikely to be suitable for these crops. Willow, which can withstand periods of water logging, is likely to be better suited to the wetter soils. On farmland in the UK, these wetter areas are found in the west and north of the country, and are currently dominated by grassland farming systems.

Growing SRC to supply fuel on a commercial scale (either for direct combustion or for the production of bioethanol) will require large areas of land to be planted (Sage and Rich, 2001). SRC crops are likely to be concentrated in areas close to suitable power stations or processing plants to minimise fuel transportation costs.

Effects on bird populations – breeding season

During the breeding season, relatively small, pre-commercial or experimental willow SRC plantations have been found to hold high densities of passerines characteristic of scrub, woodland and ruderal vegetation (Göransson, 1990; Kavanagh, 1990; Sage and Robertson, 1996; Coates and Say, 1999). Total density and species diversity of breeding birds in these plantations are generally higher than occurs with other arable crops and improved grasslands (Kavanagh, 1990; Göransson, 1994; Sage and Robertson, 1996; Coates and Say, 1999).

In the UK and the Republic of Ireland, bird species found at high density in developing and mature SRC crops during the breeding season are mostly common and widespread resident and migrant species, currently of low/medium conservation concern. Characteristic species include pheasant *Phasianus colchicus*; wren *Troglodytes troglodytes*; robin *Erithacus rubecula*; blackbird *Turdus merula*; sedge warbler *Acrocephalus schoenobanus*; willow warbler *Phylloscopus trochilus*

and chaffinch *Fringilla coelebs*. Notable additions are two "red-listed" species of high-conservation concern (Gregory *et al.,* 2002): reed bunting *Emberiza schoeniclus* and, at lower density, song thrush *Turdus philomelos* (Kavanagh, 1990; Göransson, 1994; Sage and Robertson, 1996; Coates and Say, 1999).

Maturing SRC crops share structural features with traditional coppiced woodland and "withy beds" (plantations of osier *Salix viminalis* grown and coppiced for handicrafts) that are considered attractive to many bird species, particularly in terms of dense shrub-layer vegetation (Fuller and Henderson, 1992). There are also clear similarities in breeding bird communities between these traditionally managed habitats and the pre-commercial SRC plantations studied (Fuller and Henderson, 1992; Sage and Robertson, 1994).

In the one-to-two years following crop establishment, and possibly at least in the year following each cut, a different suite of bird species has been recorded breeding in pre-commercial SRC plots. These are species more characteristic of open landscapes and include several birds of medium or high conservation concern in the UK: lapwing *Vanellus vanellus*, skylark *Alauda arvensis*, meadow pipit *Anthus pratensis*, yellow wagtail *Motacilla flava flavissima* and corn bunting *Miliaria calandra* (Coates and Say, 1999). As the SRC crops mature, the vegetation height and density becomes too great for these birds and they are replaced by species more typical of scrub, young woodland and dense ruderal habitats. The suitability of SRC crops in their post-establishment or post-harvest years for ground-nesting species (including all five birds listed above) may be severely compromised by nest destruction from frequent mechanical weed control as is suggested by some current commercial SRC growing guidelines (Danfors *et al.,* 1998).

Other red-listed species characteristic of farmland have only been recorded at low frequency in SRC plots during the breeding season. These include Turtle dove *Streptopelia turtur*; spotted flycatcher *Muscicapa striata*; house sparrow *Passer domesticus*; tree sparrow *Passer montanus*; linnet *Carduelis canabina;* lesser redpoll *Carduelis flammea;* bullfinch *Pyrrhula pyrrhula* and yellowhammer *Emberiza citrinella* (Sage and Robertson 1996; Coates and Say, 1999). Some of these species, *e.g.* spotted flycatcher, house and tree sparrows, are unlikely to breed within SRC crops due to the lack of suitable nesting sites. They may, however, be able to use the crops for foraging.

Changes in bird communities with crop age similar to those mentioned above have been recorded in North American poplar SRC crops (Beyea *et al.,* 1995). Birds characteristic of ruderal vegetation and scrub were most abundant in young plantations, being replaced by woodland and woodland-edge species as the crops matured. Open-field species (*e.g.* grasshopper sparrow *Ammodramus savannarum*; vesper sparrow *Pooecetes gramineus*; meadowlarks *Sturnella* spp. and bobolink *Dolichonyx oryzovorus*) were rarely recorded in the SRC, which was considered an unsuitable habitat for these birds. Bird (and mammal) communities within mature SRC crops were found to be significantly less diverse than those inhabiting natural forest (Christian *et al.,* 1997), a result also suggested for birds by Sage and Robertson (1996).

Sage and Robertson (1996) found that willow SRC plantations held greater abundance and diversity of passerine species than poplar, and that this could be attributed to differences in vegetation structure. Poplar is typically planted at lower stool density and produces fewer stems per stool, thus having lower vegetation density at most heights in the crop. The more open structure of poplar plantations compared to willow may be preferred by grey partridge *Perdix perdix*, however (Baxter *et al.,* 1996).

These studies suggest that willow SRC planted on farmland may provide new areas of suitable breeding habitat for some woodland, scrub and ruderal vegetation species, possibly resulting in local population increases. However, species characteristic of open farmland habitats, such as lapwing *Vanellus vanullus*, skylark, and corn bunting, are unlikely to use SRC crops as a breeding habitat except in the years immediately following crop establishment and each winter cut. Where SRC is planted on open farmland, the suitability of these areas as a breeding habitat for these open-field species may decrease, at least for most years within the crop rotation. Studies on willow SRC planted on farmland in Sweden have produced similar conclusions: the mature crop provided a suitable habitat for species preferring bushy nesting habitats (*e.g.* marsh warbler *Acrocephalus palustris* and garden warbler *Sylvia borin*), but was avoided by open-habitat bird species (Göransson, 1990; Göransson, 1994).

The likely effect of farmland SRC crops on resources required by bird species of conservation concern is summarised in Table 1. Three key resources are considered: availability of nesting sites and the availability of suitable food in summer and in winter.

Effects on bird populations – non-breeding season

Coates and Say (1999) recorded a wide range of bird species making use of pre-commercial SRC crops in winter, suggesting that the crops may provide valuable cover and/or feeding sites. However, it is not possible to determine from this study which species were actively foraging in the crops and which were simply roosting or resting. A clear effect of crop age was detected, with young (0-1 years after establishment) crops harbouring birds and characteristic of open landscapes, with older crops harbouring greater numbers of woodland and scrub species. Species of medium to high-conservation concern (amber or red-listed species; Gregory *et al.*, 2002) regularly recorded using young SRC crops included: kestrel *Falco tinnunculus*; grey partridge *Perdix perdix*; common snipe *Gallinago gallinago*; skylark; woodlark *Lullula arborea*; meadow pipit; dunnock *Prunella modularis*; linnet; yellowhammer and reed bunting. More mature crops produced regular records of common snipe; woodcock *Scolopax rusticola*; dunnock; fieldfare *Turdus pilaris*; song thrush; bullfinch and reed bunting.

Numbers of seed-eating species characteristic of open farmland (skylark, finches and buntings) decreased rapidly with increasing crop age, being replaced by woodland species. Therefore, for most of the crop rotation, SRC is unlikely to provide a suitable foraging habitat for open-field species in winter (including other species such as lapwing; golden plover *Pluvialis apricaria*; skylark; starling *Sturnus vulgaris* and corn bunting).

The suitability of SRC crops for seed-eating birds in winter (a group of species about which there is particular conservation concern due to recent large-scale and continuing population declines) may depend to some extent on crop husbandry. Efficient control of annual and perennial plants within the crop may have the effect of reducing the sources of seed needed by these species. Intensive weed control is particularly likely during the establishment and young crop stages – periods when the relatively short, sparse vegetation structure will be most suitable for seed-eating passerines foraging on the ground (*e.g.* Moorcroft *et al*., 2002).

Effects on invertebrates

The diversity of insects and other invertebrates has the potential to be high in willow SRC crops, when compared to other conventional crop types in the UK. Willows are known to provide a habitat for more insect species than most other trees (Kennedy and Southwood, 1984); however, studies on SRC have so far shown that this diversity is only partly reflected in pre-commercial crops (Sage and Tucker, 1997; Coates and Say, 1999). Diversity is likely to be increased if ground floras are allowed to develop within the crop, thus providing a wider range of host plants. This is likely to depend on the intensity of the weed control measures implemented.

Table 1. Predicted effects of short rotation coppice bioenergy crops in providing key resources for UK farmland and woodland birds of conservation concern

Bird Species	Nesting sites	Summer food	Winter food
Grey partridge*	+ year 1?	+ ?	-
Corncrake*	+ year 1-3?	?	n/a
Stone curlew*	-	-	n/a
Lapwing*	- (+ year 0?)	?	-
Woodcock	nd	nd	+
Turtle dove*	nd?	- (+ year 0-1?)	n/a
Lesser spotted woodpecker	nd	+ ?	+ ?
Skylark*	- (+ year 0?)	-	-
Tree pipit	+ ?	+ ?	n/a
Song thrush	+	+	+
Spotted flycatcher	nd	+ ?	n/a
Willow tit	nd	+ ?	+ ?
Marsh tit	nd	+ ?	+ ?
Starling	nd	-	-
House sparrow	nd	+ ?	-
Tree sparrow*	nd	+ ?	-
Linnet*	nd	- (+ year 0-1?)	- (+ year 0-1?)
Lesser redpoll	+ ?	+ ?	+ ?
Bullfinch	+ year 3-5?	+	+ ?
Reed bunting	+	+ ?	+ year 0?
Yellowhammer*	+ edge?	+ edge?	- (+ year 0?)
Cirl bunting*	+ edge?	+ edge?	- (+ year 0?)
Corn bunting*	- (+ year 0-1?)	+ edge?	-

Notes:

* Farmland specialist species

All bird species are listed in the UK government's Biodiversity Action Plan and/or are Red List species. Symbols indicate the likely effect (positive or negative) of introducing SRC crops onto conventional farmland in the UK. It is assumed for the purposes of this comparison that all current land use types on UK farmland are retained in their current proportions, and that none, including set-aside land, is completely replaced, or that any boundary/marginal farm habitats are affected.

+ = positive effect of SRC crops on resource; - = negative effect of SRC crops on resource; nd = no effect; n/a = not applicable; ? = unknown or uncertain benefit.

"Years" indicates the potential for specific periods within the SRC crop rotation to provide a benefit. Year 0 = the year of cutting plus first season of regrowth. "Edge" indicates the potential for SRC crop edge habitats to provide suitable resources.

Source: Gregory *et al.*, 2002.

Communities of predatory terrestrial insects in SRC differ in species composition from those of open farmland, without any overall difference in species richness (Coates and Say, 1999). Flowering willow plants within SRC crops may also provide food resources for insects in spring (Reddersen, 2001).

The headlands and rides of pre-commercial SRC plots were found to contain densities of common and widespread butterfly species (browns Satyridae, whites Pieridae and nymphalids Nymphalidae) comparable to those of traditionally managed woodland. However, areas of mature crop were found to contain only low densities of these species (Sage *et al.*, 1994).

Some insects have been identified as potential pests for SRC crops, for example the leaf beetle *Phratora vulgatisssima* (Coleoptera: chrysomelidae) (Sage and Tucker, 1998). Use of insecticides to control these crops is likely to seriously reduce their invertebrate biodiversity value.

Effects on plant communities

It is considered that SRC requires less intensive weed control than most other arable crops, as it is relatively unaffected by the presence of ground flora. Hence, there is potential for SRC crops to harbour plant communities of biodiversity value (Sage and Robertson, 1994) and studies have shown a wide range of plant species present in pre-commercial SRC crops (Sage *et al.*, 1994).

Plant communities in pre-commercial SRC in the UK differ according to geographic region, herbicide use, time since crop establishment and period within the crop harvest cycle (Sage, 1995). Increasing time since crop establishment and increasing time since last harvest were both associated with a gradual change from an annual-dominated community to one dominated by short-lived invasive perennials and, finally, one with an increasing abundance of long-lived perennial species. Herbicide use after harvesting may have impacted most upon the perennial species, allowing annual-dominated communities to persist for longer (Sage, 1995). Annual species are important sources of seed for farmland passerines (Wilson *et al.*, 1996*a*). Their dominance in only young crop stages, when broad-spectrum weed control is most likely in commercial SRC crops, may mean their importance as a potential food resource for granivorous birds is reduced. Effective weed control (and/or shade) in commercial poplar SRC plantations in North America may result in sparse ground vegetation (Christian *et al.*, 1994).

Ground flora in SRC crops depends also on previous land use and geographic area. SRC on arable land may retain many plant species characteristic of typical arable crop types, rather than developing a flora characteristic of established woodland (Sage, 1995).

Comparison of pre-commercial and full-scale SRC crops

Most of the information currently available on the flora and fauna associated with SRC crops in the UK relates to pre-commercial plantations, which may differ considerably from future commercial-scale crops in terms of crop unit area, structural heterogeneity and management methods (specifically the extent and methods of weed and insect pest control). The effects of commercial-scale SRC crops on biodiversity are currently under investigation in the UK (Sage and Rich, 2001). The potential effects of larger areas of land under SRC and other bioenergy crops are discussed below.

Perennial grasses

Several species of perennial grass and grass-like plants have been suggested as potential bioenergy crops that could be grown in temperate areas. These include *Miscanthus* spp. (Lewandowski *et al.*, 2000); reed canary grass *Phalaris arundinacea*; switchgrass *Panicum virgatum*; reed *Phragmites australis*; cord-grass *Spartina* spp. and sedge *Cyperus* spp. (Potter *et al.*, 1995). Very little research has been carried out into the impacts on biodiversity of growing these crops in the UK or Europe; however, some tentative predictions can be made from knowledge of crop structure, phenology and husbandry. In the UK, at least, *Miscanthus* seems set to become the most widely grown grass bioenergy crop, being supported by establishment grants, and currently being authorised on set-aside land (DEFRA, 2000). Therefore, predicting the effects on biodiversity will concentrate on this species.

Miscanthus – crop structure, growth patterns and management

The plants are tall, perennial, rhizomatous grasses, indigenous to Africa and Asia. The crop is established in early spring, using rhizomes. During the first 15 months, pre- and post-planting weed control is considered essential to allow crop development. The crop grows rapidly from May-July and can reach 3m in height in summer from the second year following planting onwards. Lower leaves senesce as the crop grows, forming a dense litter layer, which, along with a high degree of shade from the crop canopy, acts to prevent weed growth almost completely (DEFRA, 2001). Stems are harvested in the autumn or winter of the second year after establishment and then at annual intervals. *Miscanthus* is likely to require only low fertiliser input (Bullard, 2000) but broad-spectrum herbicides can be used between the harvest and new shoot emergence in spring. Herbicides are less necessary once the crop is well-established (1-2 years), when litter accumulation and shade from the canopy prevent weed emergence (Bullard, 2000).

Predicted effects of Miscanthus on farmland birds

The height and vegetation structure of a mature *Miscanthus* crop will share similarities with SRC and other tall perennial grass habitats such as reedbeds *Phragmites australis*. The crops may therefore provide suitable habitats for species characteristic of reedbeds and dense herbaceous vegetation or scrub. There is anecdotal evidence that species such as the reed warbler *Acrocephalus scirpaceus* and reed bunting may be able to use the crops as a nesting habitat. Winter harvesting, as with SRC, will not destroy the nests of any, even late-nesting, bird species within the crop.

The crop structure is unlikely to provide a suitable nesting habitat for open-field, ground-nesting birds, except early in the breeding season, when new shoots are still short (March-April). In this respect the crops may act in a similar manner to conventional autumn-sown cereal crops for species such as the skylark, allowing early breeding, but preventing enough successive number of nesting attempts for the birds to maintain adequate productivity (Wilson *et al.*, 1997; Donald *et al.*, 2001*b*). Indeed, crop growth during May and June may be so rapid that the crops could act as a breeding trap for ground-nesting birds, the vegetation structure being suitable at the start of the breeding attempt, but becoming impenetrable before the chicks can fledge successfully, leading to nest abandonment. At present, this has not been confirmed.

The suitability of the crop as a summer foraging resource for farmland birds will depend on the invertebrate fauna associated with the crop and the accessibility of these invertebrates. Crop structure is likely to be unsuitable for birds that typically feed in open situations. Crop development during the summer may result in increasing vegetation complexity and hence encourage a greater diversity of invertebrates, but this effect may be limited as i) the crop is non-native and is therefore unlikely to

support any specialist invertebrates, and ii) the crop may be effectively a monoculture due to suppression of weed growth. No major insect pests of *Miscanthus* in the UK have as yet been identified during agronomic trials, therefore widespread use of insecticides on the crops is currently unlikely (Bullard, 2000). However, at least two Lepidopteran species which may cause agronomic problems in the future have been identified (Nixon, 1997). If this potential is realised, possibly through the expansion of the scale and geographic distribution of *Miscanthus* crops, the need for chemical control of insects may increase, which may reduce the value of the crops as foraging areas for insectivorous bird species.

The combination of crop shade, dense litter layer and the ability to use broad-spectrum herbicides in spring is likely to result in a species-poor ground flora within *Miscanthus* crops. It is therefore unlikely that the crops will provide much, if any, food resource for seed-eating species. In addition, varieties of *Miscanthus* currently being promoted as bioenergy crops are non-seeding, so the crop will not provide any seed food resource itself. The value of *Miscanthus* as a foraging area for seed-eating species in winter is therefore likely to be low.

Miscanthus may provide useful cover and roosting sites for some bird species in winter, particularly gamebirds, and species such as reed bunting, which frequently roost in reedbeds.

Other grass bioenergy crops – predicted effects

Other grasses grown on a commercial scale in the future as bioenergy crops are likely to have similar characteristics to *Miscanthus*, *i.e*. high yield from rapid growth rate resulting in a tall, dense crop. Structurally, therefore, other grass species may affect farmland biodiversity in a similar way to *Miscanthus*, although species-specific differences in crop husbandry may have significant effects. Species native to the UK, such as reed or reed canary grass, are likely to support a greater diversity of invertebrates than non-natives, such as *Miscanthus* or switchgrass, and hence may be inherently more valuable as a biodiversity resource. Any crop species that set seed may provide an important food resource for granivorous birds or other animals.

Studies on switchgrass in North America have shown that this bioenergy crop can provide a suitable nesting habitat for a range of bird species characteristic of natural grasslands (Beyea *et al.*, 1995). Overall species diversity and abundance were greater in switchgrass than in conventional arable crops (Beyea *et al.*, 1995), but lower in more botanically-diverse, shorter grass fields (McCoy *et al.*, 2001).

Oilseed crops

A range of oilseed crops have been proposed as potential bioenergy crops. These include oilseed rape, mustard, sunflower, flax and linseed. Some information is available on the biodiversity effects of oilseed rape as the crop is already grown on a commercial scale in Europe, but there is little existing information on other oilseed crop types.

Predicted effects of oilseed rape bioenergy crops on farmland birds

Oilseed rape is already grown on a large scale as a commercial crop in Europe. The ecology and biodiversity value of bioenergy crop rape is likely to be very similar to that already grown, unless there are differences in crop varieties, or crop husbandry techniques, especially the level of weed and insect pest control. If higher levels of weed contamination can be accepted in a bioenergy crop than in a conventional rape crop, the necessity for weed control may be less, making the crop of more value to biodiversity.

Rape crops can provide feeding and nesting resources for a range of farmland bird species. Skylark, yellow wagtail, sedge warbler, reed bunting and corn bunting will nest within oilseed rape crops (Steibel 1997; Wilson *et al.;* 1997, Watson and Rae, 1998; Tryjanowski and Bajczyk 1999; Burton *et al.*, 1999), although the crops' suitability for open-field nesting species decreases with crop growth through the season (Steibel 1997; Wilson *et al.*, 1997). This is particularly the case for autumn-sown rape crops, which hold relatively low densities of skylark territories compared to other conventional arable crops throughout the summer (Wilson *et al.*, 1997), and which are strongly avoided by yellow wagtail in terms of territory area (Mason and Macdonald, 2000). The productivity of reed buntings (and probably other species) nesting in rape crops can be increased by delaying cutting the crop until as late as possible. This can be achieved by spraying with dessicant, rather than swathing, to dry the crop prior to harvesting (Burton *et al.*, 1999).

Rape crops are used in the breeding season by a range of bird species foraging for invertebrates, including the tree sparrow (RSPB, unpublished data); reed bunting (Burton *et al.*, 1996) and yellowhammer (Stoate *et al.*, 1998). This suggests that invertebrate numbers and diversity within the crop are relatively high, a conclusion supported by the wealth of agricultural scientific literature on the different insect pests that inhabit the crop (*e.g.* Wise and Lamb, 1998). Whitethroats *Sylvia communis* and linnets have shown preferences for hedgerow nesting sites adjacent to oilseed rape fields (Mason and Macdonald, 2000). In a study of 18 bird species in hedgerows in lowland Britain, Green *et al.*, (1994) found that the incidence of bird species was positively and consistently influenced by the presence of oilseed rape crops adjacent to the hedgerow.

Unripe rape seeds are also taken from the standing crop by granivorous birds, including the house sparrow, greenfinch *Carduelis chloris*, bullfinch and linnet (RSPB, unpublished data; Moorcroft and Wilson, 2000). The increasing availability of this food resource during the 1980s may have helped slow the decline of the UK's linnet population (Moorcroft and Wilson, 2000). Ripe rape seeds are also eaten by a range of granivorous species, including tree sparrows (Perkins and Anderson, 2002) and reed buntings (Wilson *et al.*, 1996*a*).

Rape stubble is a favoured wintering habitat for granivorous passerines (Wilson *et al.*, 1996*b*), although the persistence of the stubble throughout the winter will depend on the crop rotation system in operation. Autumn-sown rape crops are a preferred wintering habitat for skylarks (which will eat green leaf material) relative to autumn-sown cereals (Gillings and Fuller, 2001). Autumn-sown rape crops are generally avoided by insectivorous bird species in winter, however (Tucker, 1992).

Oilseed crops, and specifically oilseed rape, therefore appear to have some biodiversity benefits for declining farmland specialist bird species, especially spring-sown crops with associated over-winter stubble. However, as with the other categories of bioenergy crop, the overall impact of the crop on farmland bird populations is likely to depend also on what habitats these crops replace, their geographic distribution, and spatial arrangement within the landscape (see below).

Conventional arable crops grown for sugar or starch content

Conventional arable crops with high sugar or starch contents may be used to produce "bioethanol" through a fermentation process. Potentially suitable "sugar/starch crops" include wheat, barley, potatoes and sugarbeet. The intrinsic value of these crop types is likely to be the same as their conventional crop counterparts unless, for example, differences in crop variety or crop management arise through a change in the need for chemical composition, pest control or altered tolerance or weed contamination in the harvested crop.

Increases in the area of spring-sown sugar/starch crops (potatoes, sugarbeet) are expected to have major benefits on farmland birds. These crops provide suitable nesting sites for open-field species such as skylarks and yellow wagtails (Mason and Macdonald, 2000); however, they may be relatively poor in terms of providing summer invertebrate food compared with cereal and oilseed crops (Holland *et al.,* 2002). Their main benefit possibly comes from the associated over-winter stubble that typically accompanies spring-sown arable crops. These provide key winter food resources for seed-eating birds, especially if the stubble is weedy and follows a cereal or oilseed crop (Gillings and Fuller, 2001, Moorcroft *et al.,* 2002).

Effects of replacing existing farmland types with bioenergy crops

The overall effect of large-scale bioenergy crop production on farmland biodiversity will depend to a large extent on what the crops are replacing. When bioenergy crops are grown on intensively managed farmland, overall bird species diversity and breeding density in the area may be either little affected, or increased (Sage and Robertson, 1996; Christian *et al.,* 1998). In the case of SRC or perennial grass bioenergy crops, bird species requiring open-field habitats for nesting or foraging may be negatively affected, due to the large increase in vegetation height and density. Loss of high wildlife-value habitats (such as wetlands, wet meadows, extensively managed semi-natural grassland and scrub) through conversion to bioenergy crops will clearly have negative impacts on some bird species and other components of farmland biodiversity. Marginal farmland habitats such as hedgerows, grass field margins and small areas of unmanaged grassland also provide valuable wildlife habitats and any net loss of these due to bioenergy crop planting is likely to have negative effects.

In the UK, the Department for Environment, Food and Rural Affairs (DEFRA) has published Environmental Impact Regulations in order to protect valuable semi-natural habitats. These Regulations have been designed to prevent any agricultural intensification of unimproved land that would result in detrimental environmental consequences (DEFRA, 2002). DEFRA's Energy Crop Scheme also requires that an Environmental Impact Assessment be carried out for new energy crop plantations of over 2 to 5 ha (depending on location) to determine whether they would have a significant impact on the environment. These regulations should provide an important safety mechanism to control the development of this new industry in the UK.

There may be significant biodiversity benefits in the development of certain types of bioenergy crops in predominantly grassland areas, however. Local extinctions and reductions in species richness of farmland bird species have been particularly marked in pastoral areas of the UK in the last 30 years (Chamberlain and Fuller, 2001). There is evidence that even small areas of arable land within a grassland-dominated landscape can have a relatively large positive effect on the abundance of some farmland birds, especially the seed-eating species (Robinson *et al.,* 2001). The introduction of an arable crop or an analogue of this to a grassland-dominated area may, therefore, have significant benefits for bird populations. The availability of seed food on these arable habitats is likely to be an important factor in this apparent benefit. If this is the case, then of the four main bioenergy crop types currently available, oilseed and sugar/starch crops are likely to be the most beneficial on grassland areas, as these are likely to be more suitable as foraging areas for seed-eaters.

One farmland habitat particularly likely to undergo conversion to bioenergy crop production under current EU legislation is set-aside. This is of particular concern from the biodiversity point of view as set-aside land is known to provide important feeding and nesting resources for many farmland birds (Evans *et al.,* 1997; Donald *et al.,* 2001*a* and 2001*b*; Stoate and Parish, 2001). In the breeding season, set-aside holds relatively high densities of many bird species, compared to other arable land use types (Henderson *et al.,* 2000*a*; and 2000*b*) and provides important nesting opportunities for species of high conservation concern, *e.g.* skylark (Wilson *et al.,* 1997).

In winter, “rotational” set-aside on arable land, where crop stubble is left for a year after harvest, provides crucial feeding habitats for many seed-eating bird species (skylark, sparrows, finches, buntings [Wilson *et al.,* 1996*b*; Brickle and Harper, 2000; Donald *et al.,* 2001*a*]). A significant number of seed-eating farmland bird species have undergone dramatic population declines in the UK, and more widely across Europe, as a direct result of agricultural intensification, and are now of high conservation concern (Gregory *et al.,* 2002). The most likely common factor that has driven the population declines of these species is a reduction in the availability of seed food on farmland, causing reduced survival and/or body condition of fully grown birds. Any further reduction in the availability of suitable feeding habitats for these species is likely to exacerbate their already parlous situation.

Stubble remaining after the harvesting of oilseed crops or sugar/starch crops would provide winter food resources for birds comparable to rotational set-aside in a conventional arable system. However, without some form of incentive payments, such as agri-environmental payments, it is unlikely that planting such crops in spring, following a winter stubble, will be as economically viable as planting higher-yield, autumn-sown crops shortly after harvesting.

Through a combination of unsuitable vegetation structure (in the case of SRC and perennial grasses) and a lack of seeds due to canopy shade (SRC and perennial grasses), autumn cultivation (oilseeds and sugar/starch crops) and effective weed control (all crops), commercial-scale bioenergy crops may represent poor foraging habitat for seed-eating birds in winter. An exception may be the young growth stages of SRC, where the value of the crop to these birds will depend largely on the composition of weed communities within the crop.

Thus, the replacement of large areas of set-aside land with bioenergy crops is likely to be detrimental to a range of farmland bird species, unless appropriate mitigating measures are developed and implemented in parallel to the developing industry.

Effect of scale and spatial distribution of bioenergy crops

The flora and fauna associated with an area of any individual land use type are likely to depend to a large extent on the context of that area within the surrounding landscape. The variation of land use types within a landscape will have considerable influence on the biodiversity of the landscape and individual components, alike. The general effect of greater habitat variability within an area being associated with greater species diversity is well known. The species richness of woodland edge habitats for birds is a particularly well-studied example of this effect. Bird species richness is known to increase with the greater heterogeneity of poplar SRC plantations in North America (Hanowski *et al.,* 1997) and lower density of some species of birds and small mammals has been recorded in the centre of large, continuous SRC plots compared with edge areas (Göransson 1990; Christian, *et al.*, 1994). Sage and Robertson (1996) also found that the abundance of some bird species (finches) in SRC plots was dependent on the presence of non-crop woody habitats adjacent to the crop (hedges and woodland).

The general rule of heterogeneity being good for biodiversity is also supported by studies at the landscape level. There is evidence from the UK that areas of mixed farming systems are more beneficial for farmland birds than areas of specialised arable or grassland systems. In the face of agricultural intensification, areas retaining mixed farming systems were less likely to be associated with declines in species abundance or contraction in species ranges than arable or grassland-dominated areas (Chamberlain and Fuller, 2001). Mixed farming areas also harboured higher densities of farmland birds in winter than arable or grassland-dominated areas (Atkinson *et al.*, 2002).

Thus, changes in land use tending to simplify the landscape in terms of habitats and vegetation structure are likely to lead to biodiversity losses in that landscape as a whole. There would appear to be several economic and policy drivers which may lead to the development of large, relatively uniform areas of bioenergy crops – simple economies of scale apply to many farming systems, bioenergy crops included. More specifically though, relatively large areas of bioenergy crops will be required to provide significant amounts of energy. In addition, the costs of transporting large amounts of bioenergy crops to power stations or processing plants are relatively high, and the economics of the crops may depend to a large extent on their proximity to these facilities. Indeed, in the UK, grant funding for bioenergy crops specifies that they should be grown as close as possible to the end user (usually within 25 miles). In combination, these factors have the potential to create large, uniform areas of bioenergy crops in the area surrounding a suitable end-user facility. It is likely that this spatial arrangement of bioenergy crops will reduce the biodiversity benefits of the crops themselves. Smaller bioenergy facilities designed to meet local needs are more likely to have beneficial effects on biodiversity. Guidelines aimed at ensuring diversity within bioenergy crop areas may help offset this effect. Currently, the best developed guidelines are those relating to SRC plantation design, with the specific aim of increasing the biodiversity value of the crop by including features such as rides, headlands and stands of different age/class to increase habitat heterogeneity (Sage *et al.,* 1994; British Biogen, 1996). As the results of bird studies on SRC suggest, maintaining a variety of age/classes within stands will be crucial for preserving populations of both open-field species as well as birds of woodland and scrub habitats, within a landscape dominated by these crops (Coates and Say, 1999).

Bioenergy crop management to maximise environmental benefit

The increasing interest in the cultivation of bioenergy crops is the result of a number of factors including agricultural diversification, energy security but – most importantly – the need for countries to diversify their energy sources in order to meet national renewable energy targets and to honour global agreements on reducing greenhouse gas emissions. This paper reviews the likely effects of an increase in the production of crops cultivated specifically for use as bioenergy. The possible negative impacts it has identified centre mainly on the loss of habitats important for open-farmland species of conservation concern. However, there is also scope for a well planned bioenergy industry to produce biodiversity benefits.

In order to maximise the carbon savings of bioenergy sources, the level of inputs required during the cultivation of the crop must be critically assessed. The optimal cultivation regime for any particular bioenergy crop – balancing energy production with the overall carbon balance of the crop – will depend on location. Crops managed under a low-input regime are likely to provide greater carbon savings than those receiving large amounts of energy-intensive inputs. Reductions in the level of fertilisers and pesticides applied to the crop will benefit farmland biodiversity by providing both increased insect and seed resources (Freiben and Kopke, 1996; Chiverton, 1999; Moreby and Southway, 1999); consequently, such a low-input regime could provide a double benefit by benefiting local biodiversity in addition to the wider global environment. Such an approach would deliver wider public benefits, our farmed landscape being valued as much as a place to visit and a home for wildlife as it is for food production. A strategically planned bioenergy industry could deliver multiple objectives.

In seeking to build a policy framework which facilitates bioenergy production, the management regime of the crop will be a key factor in determining the public benefits of cultivation. The profitability of the crop will depend on the agricultural subsidies, grant schemes and market support mechanisms in place. The cost effectiveness of bioenergy production can be measured in terms of the greenhouse gas savings (Mortimer *et al.,* 2003). The decision to use public money to support a

bioenergy industry could be based on an analysis of the greenhouse gas savings and the public goods delivered in terms of biodiversity benefits and benefits to the rural economy. Government and stakeholders must work together to ensure that any policy framework deigned to support a bioenergy industry requires that the management of the crop is quality controlled, in terms of both local and global impacts on the environment.

Recommendations

In order to capitalise on bioenergy as a tool in the race against climate change, whilst ensuring that biodiversity is not damaged, the authors recommend that:

- Production of bioenergy crops should constitute part of a long-term strategy for Non-food Crops, based on a strategic environmental assessment. This should include an appraisal of areas suitable for bioenergy developments and areas where, for environmental reasons, such developments should be prohibited. The strategy should take into account national and regional energy strategies.

- Bioenergy crops should be supported by a buoyant renewable energy market rather than by agricultural production subsidies. Local sourcing and use should be encouraged.

- Producers should be obliged to follow new guidelines for growing energy crops according to high conservation standards to ensure that they are produced in a manner compatible with the "green" ethics behind their industrial usage (*e.g.* mixed-age stands, use of native species, integrated crop management techniques).

- Environmental Impact Assessments carried out before the creation of new plantations should take into account the possible impact of the change in land use on species in the current habitat, particularly species of conservation concern.

- The potential biodiversity value of set-aside land should be recognised. To ensure that this valuable resource is not damaged by the cultivation of energy crops, the authors suggest that 50% of set-aside should be managed for conservation until an equivalent area of land can be managed environmentally through the second pillar of the Common Agricultural Policy.

Future research priorities

Clearly there is much that is currently unknown about the effects of large-scale bioenergy crop production on farmland bird populations and farmland biodiversity in general. The authors suggest that important specific studies need to be carried out, including the following:

1. Comparison of pre-commercial with large-scale commercial SRC crops: studies by the Game Conservancy Trust are currently underway in the UK.

2. More detailed studies of species ecology within SRC crops: the presence of a species within a habitat may not necessarily imply successful reproduction or adequate survival rates. Much of the work currently available on SRC has looked simply at the diversity and abundance of species present in the crops, and not established whether the local populations of these species in the crops are acting as sources or sinks.

3. Assessment of the biodiversity effects of *Miscanthus* crops in Europe, as one of the most likely perennial grass bioenergy crops to be grown on a commercial scale: the study should cover multiple sites and be conducted at a plot scale relevant to commercial crops. Comparisons with other potential grass bioenergy crops that may become commercially viable in the future should also be made.

4. Much of the existing information on oilseed bioenergy crops and bird populations comes entirely from conventional oilseed rape crops: other oilseed crops may differ markedly in their vegetation structure, growth patterns and crop husbandry, thus having very different effects on farmland flora and fauna. Varieties and husbandry of oilseed rape grown for bioenergy crops may also differ from conventional crops. The implications of any such differences need to be understood, requiring detailed field-based research.

5. The effects of replacing set-aside land with bioenergy crops needs to be investigated more thoroughly: if large-scale loss of rotational set-aside land is likely to occur as a result of policy mechanisms supporting bioenergy crops, the impacts on farmland biodiversity need to be predicted and, if necessary, mitigated against.

BIBLIOGRAPHY

Anderson, G.Q.A., R.B. Bradbury and A.D. Evans (2001), *Evidence for the effects of agricultural intensification on wild bird populations in the UK*, RSPB Research Report No. 3, Royal Society for the Protection of Birds, Sandy, Bedfordshire, United Kingdom.

Atkinson, P.W., Fuller, R.J. and Vickery, J.A. (2002), "Large-scale patterns of summer and winter bird distribution in relation to farmland type in England and Wales", *Ecography* 25, pp. 466-480.

Baxter, D.A., R.B. Sage and D.O. Hall (1996), "A methodology for assessing gamebird use of short rotation coppice", *Biomass and Bioenergy* 10, pp. 301-306.

Beyea, J., J.H. Cook and W. Hoffman (1995), *Vertebrate species diversity in large-scale energy crops and associated policy issues*, Annual Progress Report to the Biofuels Feedstock Development Program, Oak Ridge National Laboratory, Oak Ridge, United States of America.

Brickle, N.W. and D.G.C. Harper, (2000), "Habitat use by Corn Buntings *Miliaria calandra* in winter and summer" in *Ecology and Conservation of Lowland Farmland Birds* (Aebischer, N.J., A.D. Evans, P.V. Grice and J.A. Vickery, eds), British Ornithologists' Union, Tring, United Kingdom, pp. 156-164.

British Biogen (1996), *Short rotation coppice for energy production: good practice guidelines*, British Biogen, London, United Kingdom.

Bullard, M. (2000), *Miscanthus agronomy (for industrial and fuel uses)*, MAFF Scientific Report No. NF0403, DEFRA, London, United Kingdom: www.defra.gov.uk.

Burton, N.H.K., P.N. Watts, H.Q.P. Crick and N. Carter (1996), *The effects of pre-harvesting operations on birds nesting in Oilseed Rape (Brassica napus)*, BTO Research Report 171, British Trust for Ornithology, Thetford, United Kingdom.

Burton, N.H.K., P.N. Watts, H.Q.P. Crick and P.J. Edwards (1999), "The effects of preharvesting operations on reed buntings *Emberiza schoeniclus* nesting in oilseed rape *Brassica napus*", *Bird Study* 46, pp. 369-372.

Chamberlain, D.E. and R.J. Fuller (2001), "Contrasting patterns of change in the distribution and abundance of farmland birds in relation to farming system in lowland Britain", *Global Ecology and Biogeography* 10, pp. 399-409.

Chiverton, P.A. (1999), "The benefits of unsprayed cereal crop margins to grey partridges *Perdix perdix* and pheasants *Phasianus colchicus* in Sweden", *Wildlife Biology* 5, pp. 83-92.

Christian, D.P., P.T. Collins, J.M. Hanowski and G.J. Niemi (1997), "Bird and small mammal use of short-rotation hybrid poplar plantations", *Journal of Wildlife Management* 61, pp. 171-182.

Christian, D.P., W. Hoffman, J.M. Hanowski, G.J. Niemi and J. Beyea (1998), "Bird and mammal diversity on woody biomass plantations in North America", *Biomass and Bioenergy* 14, pp. 395-402.

Christian, D.P., G.J. Niemi, J.M. Hanowski and P. Collins (1994), "Perspectives on biomass energy tree plantations and changes in habitat for biological organisms", *Biomass and Bioenergy* 6, pp. 31-39.

Coates, A. and A. Say (1999), *Ecological assessment of energy coppice*, Report B/W5/00216/00/REP, Energy Technology Support Unit, Harwell, United Kingdom.

Danfors, B., S. Ledin and H. Rosenqvist (1998), *Short rotation willow coppice growers' manual*, Swedish Institute for Agricultural and Environmental Engineering, Uppsala, Sweden.

DEFRA [Department for Environment, Food and Rural Affairs] (2001), *Planting and growing Miscanthus – Best practice guidelines for applicants to DEFRA's energy crops scheme*, London, United Kingdom: www.defra.gov.uk/farm/acu/energy/miscanthus-guide.pdf.

DEFRA (2000), *The energy crops scheme: Establishment grants for short-rotation coppice and* Miscanthus – *explanatory booklet*, London, United Kingdom: www.defra.gov.uk/corporate/regulat/forms/erdp/ecs/guidancesrc.pdf.

DEFRA (2000), *Environmental impact assessment for use of uncultivated land or semi natural areas for intensive grassland purposes – Guidelines*, London, United Kingdom: www.defra.gov.uk/environ/eia/guidelines.pdf.

Donald, P.F., D.L. Buckingham, D. Moorcroft, L.B. Muirhead, A.D. Evans and W.B. Kirby (2001*a*), "Habitat use and diet of skylarks *Alauda arvensis* wintering on lowland farmland in southern Britain", *Journal of Applied Ecology* 38, pp. 536-547.

Donald, P.F., A.D. Evans, D.L. Buckingham, L.B. Muirhead and J.D. Wilson (2001*b*), "Factors affecting the territory distribution of Skylarks Alauda arvensis breeding on lowland farmland," *Bird Study* 48, pp. 271-278.

Donald, P.F., R.E. Green and M.F. Heath (2001*c*), "Agricultural intensification and the collapse of Europe's farmland bird populations", *Proceedings of the Royal Society of London, Series B - Biological Sciences* 268, pp. 25-29.

Evans, A., J. Curtoys, J. Kew, A. Lea and M. Rayment (1997), "Set-aside: conservation by accident…and design?", *RSPB Conservation Review* 11, Royal Society for the Protection of Birds, Sandy, Bedfordshire, United Kingdom, pp. 59-66.

Freiben, B. and U. Kopke (1996). "Effects of farming systems on biodiversity" in *Biodiversity and Land Use: The Role of Organic Farming*, 1st ENOF Workshop (Isart, J. and S. Llerena, eds) 11-21, European Farming Network for Scientific Research Coordination in Organic Farming, Bonn, Germany.

Fuller, R.J. and A.C.B. Henderson (1992), "Distribution of breeding songbirds in Bradfield Woods, Suffolk, in relation to vegetation and coppice management", *Bird Stud*y 39, pp. 73-88.

Gillings, S. and R.J. Fuller (2001), "Habitat selection by Skylarks *Alauda arvensis* wintering in Britain in 1997/98", *Bird Study* 48, pp. 293-307.

Göransson, G. (1994), "Bird fauna of cultivated energy shrub forests at different heights", *Biomass and Bioenergy* 6, pp. 49-52.

Göransson, G. (1990), "Energy foresting in agricultural areas and changes in the avifauna," *Fauna norvegica Series C, Cinclus*, Supplement 1, pp. 17-20.

Gregory, R.D., N.I. Wilkinson, D.G. Noble, J.A. Robinson, A.F. Brown, J. Hughes, D. Procter, D.W. Gibbons and C.A. Galbraith (2002), "The population status of birds in the United Kingdom, Channel Islands and Isle of Man: an analysis of conservation concern 2002-2007", *British Birds* 95, pp. 410-448.

Green, R.E, P.E. Osborne and E.J. Sears (1994), "The distribution of passerine birds in hedgerows during the breeding season in relation to characteristics of the hedgerow and adjacent farmland", *Journal of Applied Ecology* 31, pp. 677-692.

Hanowski, J.M., G.J. Niemi and D.C. Christian (1997), "Influence of within-plantation heterogeneity and surrounding landscape composition on avian communities in hybrid poplar plantations", *Conservation Biology* 11, pp. 936-944.

Henderson, I.G., J. Cooper, R.J. Fuller and J.A. Vickery (2000*a*), "The relative abundance of birds on set-aside and neighbouring fields in summer", *Journal of Applied Ecology* 37, pp. 335-347.

Henderson, I.G., J.A. Vickery and R.J. Fuller (2000*b*), "Summer bird abundance and distribution on set-aside fields on intensive arable farms in England", *Ecography* 23, pp. 50-59.

Holland, J.M., S. Southway, J.A. Ewald, T. Birkett and M. Begbie (2002), "Invertebrate chick food for farmland birds: spatial and temporal variation in different crops", *Aspects of Applied Biology* 67, pp. 27-34.

Kavanagh, B. (1990), "Bird communities of two short rotation forestry plantations on cutover peatland", *Irish Birds* 4, pp. 169-180.

Kennedy, C.E.J. and T.R.E. Southwood (1984), "The number of species of insects associated with British trees: a re-analysis", *Journal of Animal Ecology* 53, pp. 455-478.

Krebs, J.R., J.D. Wilson, R.B. Bradbury and G.M. Siriwardena (1999), "The second silent spring?", *Nature* 400, pp. 611-612.

Lewandowski, I., J.C. Clifton-Brown, J.M.O. Scurlock and W. Huisman (2000), "Miscanthus: European experience with a novel energy crop", *Biomass and Bioenergy* 19, pp. 209-227.

McCoy, T.D., M.R. Ryan, L.W. Burger and E.W. Kurzejeski (2001), "Grassland bird conservation: CP1 vs. CP2 plantings in Conservation Reserve Program fields in Missouri", *American Midland Naturalist* 145, pp. 1-17.

Mason, C.F. and S.M. Macdonald (2000), "Influence of landscape and land-use on the distribution of breeding birds in farmland in eastern England", *Journal of Zoology* 251, pp. 338-348.

Moorcroft, D., M.J. Whittingham, R.B. Bradbury and J.D. Wilson (2002), "The selection of stubble fields by wintering granivorous birds reflects vegetation cover and food abundance", *Journal of Applied Ecology* 39, pp. 535-547.

Moorcroft, D. and J.D. Wilson (2000), "The ecology of linnets *Carduelis cannabina* on lowland farmland" in *Ecology and Conservation of Lowland Farmland Birds* (Aebischer, N.J., A.D. Evans, P.V. Grice and J.A. Vickery, eds) British Ornithologists' Union, Tring, United Kingdom, pp. 173-181.

Moreby, S.J. and S.E. Southway (1999), "Influence of autumn applied herbicides on summer and autumn food available to birds in winter wheat fields in southern England", *Agriculture, Ecosystems and Environment* 72, pp. 285-297.

Mortimer, N.D., P. Cormack, M.A. Elasayed and R.E. Horne (2003), *Evaluation of the Comparative Energy, global warming and socio-economic costs and benefits of biodiesel*, Report for DEFRA, Contract No. CSA 5982/NFO0422, Sheffield Hallam University, Sheffield, United Kingdom: www.defra.gov.uk/farm/acu/research/reports/nf0422.pdf.

Nixon, P.M.I. (1997), "Does the common rustic moth *Mesapamea secalis* (L.) represent an economic threat to *Miscanthus*?", *Aspects of Applied Biology* 49, pp. 136-143.

Perkins, A.J. and G.Q.A. Anderson (2002), "Seed selection by tree sparrows *Passer montanus*: determining appropriate seeds for supplementary feeding on farmland", *Aspects of Applied Biology* 67, pp. 213-220.

Potter, L., M.J. Bingham, M.G. Baker and S.P. Long (1995), "The potential of 2 perennial C-4 grasses and a perennial C-4 sedge as lignocellulosic fuel crops in NW Europe – crop establishment and yields in E. England", *Annals of Botany* 76, pp. 513-520.

Reddersen, J. (2001), "SRC-willow (*Salix viminalis*) as a resource for flower-visiting insects", *Biomass and Bioenergy* 20, pp. 171-179.

Robertson, P.A. and N.W. Sotherton (1992), "Arable energy coppice as a wildlife habitat", *Wood Energy and the Environment* (Richards, G.E., ed.) Harwell Laboratories, Harwell, United Kingdom, pp. 143-148.

Robinson, R.A., J.D. Wilson and H.Q.P Crick (2001), "The importance of arable habitat for farmland birds in grassland landscapes", *Journal of Applied Ecology* 38, pp. 1 059-1 069.

Sage, R.B. (1995), "Factors affecting wild plant communities occupying short rotation coppice crops on farmland in the UK and EIRE", *Brighton Crop Protection Conference – Weeds*, pp. 985-990.

Sage, R. and T. Rich (2001), "Commercial SRC biomass plantations – will they still be good for farmland wildlife?" in *DTI Biofuels Seminar Series 2000/2001, Proceedings from the workshop on short rotation coppice* (Beale, N. and S. O'Brien, eds): www.dti.gov.uk/renewable/pdf/proceedings.pdf.

Sage, R.B. and P.A. Robertson (1996), "Factors affecting songbird communities using new short rotation coppice habitats in spring", *Bird Study* 43, pp. 201-213.

Sage, R.B. and P.A. Robertson (1994), "Wildlife and game potential of short rotation coppice in the UK", *Biomass and Bioenergy* 6, pp. 41-48.

Sage, R.B., P.A. Robertson and J.G. Poulson (1994), *Enhancing the conservation value of short rotation biomass coppice – Phase 1: the identification of wildlife conservation potential*, Report B/W5/00277/REP, Energy Technology Support Unit, Harwell, United Kingdom.

Sage, R.B. and K. Tucker (1998), "The distribution of *Phratora vulgatissima* (Coleoptera: Chrysomelidae) on cultivated willows in Britain and Ireland", *European Journal of Forest Pathology* 28, pp. 289-296.

Sage, R.B. and K. Tucker (1997), "Invertebrates in the canopy of willow and poplar short rotation coppices", *Aspects of Applied Biology* 49, pp. 105-111.

Steibel, H. (1997), "Habitat selection, habitat use and breeding success of yellow wagtails *Motacilla flava* in an agricultural landscape", *Vogelwelt* 118, pp. 257-268.

Stoate, C., S.J. Moreby and J. Szczur (1998), "Breeding ecology of farmland yellowhammers *Emberiza citrinella*", *Bird Study* 45, pp. 109-121.

Stoate, C. and D. Parish (2001), "Crops grown on set-aside land bring wild birds back to the fields - Monitoring is under way, and results so far are promising", *Nature* 414, pp. 687-687.

Tryjanowski, P. and R. Bajczyk (1999), "Population decline of the yellow wagtail *Motacilla flava* in intensively used farmland of western Poland", *Vogelwelt* 120, pp. 205-207.

Tucker, G.M. (1992), "Effects of agricultural practices on field use by invertebrate-feeding birds in winter", *Journal of Applied Ecology* 29, pp. 779-790.

Watson, A. and R. Rae (1998), "Use by birds of rape fields in east Scotland", *British Birds* 91, pp. 144-145.

Wilson, J.D., J. Evans, S.J. Browne and J.R. King (1997), "Territory distribution and breeding success of skylarks *Alauda arvensis* on organic and intensive farmland in southern England", *Journal of Applied Ecology* 34, pp. 1 462-1 478.

Wilson, J.D., B.E. Arroyo and S.C. Clark (1996*a*), *The diet of bird species of lowland farmland: a literature review*, Report to Department of the Environment and English Nature, University of Oxford, Oxford, United Kingdom.

Wilson, J.D., R. Taylor and L.B. Muirhead (1996*b*), "Field use by farmland birds in winter: an analysis of field type preferences using resampling methods", *Bird Study* 43, pp. 320-332.

Wise, I.L. and R.J. Lamb (1998), "Economic threshold for plant bugs, *Lygus* spp. (Heteroptera: Miridae), in canola", *Canadian Entomologist* 130, pp. 825-836.

POWERSWITCH!
THE ROLE OF BIOELECTRICITY IN THE FUTURE OF SUSTAINABLE ENERGY

Giulio Volpi[1] *and Thomas Cross*[2]

Abstract

To address climate change effectively and with the necessary sense of urgency, a major switch from polluting to clean fuels is needed. Practical steps to do this are clearly laid out in PowerSwitch!, a new campaign from the World Wide Fund for Nature that challenges power companies in industrialised countries to become CO_2-free by the middle of this century, and those in developing countries to make a major switch from coal to clean energy. Alongside significant improvements in energy efficiency, speedy deployment of renewable energies is another key means of reducing carbon dioxide emissions. (For the European Union, see Harmelink *et al.,* [2003] - even with a 27% reduction in power demand, energy from renewables needs to be able to cover 40-60% of electricity requirements by 2020.) Modern and carbon-neutral biomass fuels have the potential to become a vital source of electricity in the next twenty years. Research shows that the opportunity exists for OECD countries to generate up to 20% of their electricity requirements from sustainable biomass sources by 2020 (Bauen *et al.,* 2003). A number of appropriate regulations are therefore needed to ensure the continued sustainability of biomass energy systems. This paper focuses on modern bioenergy uses, *e.g.* conversion of biomass into electricity and heat, through an industrial process.

Bioelectricity today

Currently, bioelectricity represents about 1% of the electricity production capacity in OECD countries, with an installed capacity of about 18.4 Gigawatts (GW). Most bioelectricity production in these countries is associated with forestry and wood-processing industry activities. Most plants are of the combined heat and power type and are based on a variety of combustion technologies, where the heat produced is generally used for industrial process heat or district heating.

While a biomass industry base and a readily available biomass feedstock are strong factors behind the relatively more developed bioelectricity sector existing in certain countries, usually the development of bioelectricity has also been a result of regulations favouring its input into the grid and price-supporting policies. Therefore, a significant increase in bioelectricity use will require a strong policy commitment and needs to be accompanied by regulations and guidelines that ensure its environmental sustainability.

1. WWF Climate Change Programme, Brussels, Belgium.

2. XYLOWATT sa, Charleroi, Belgium.

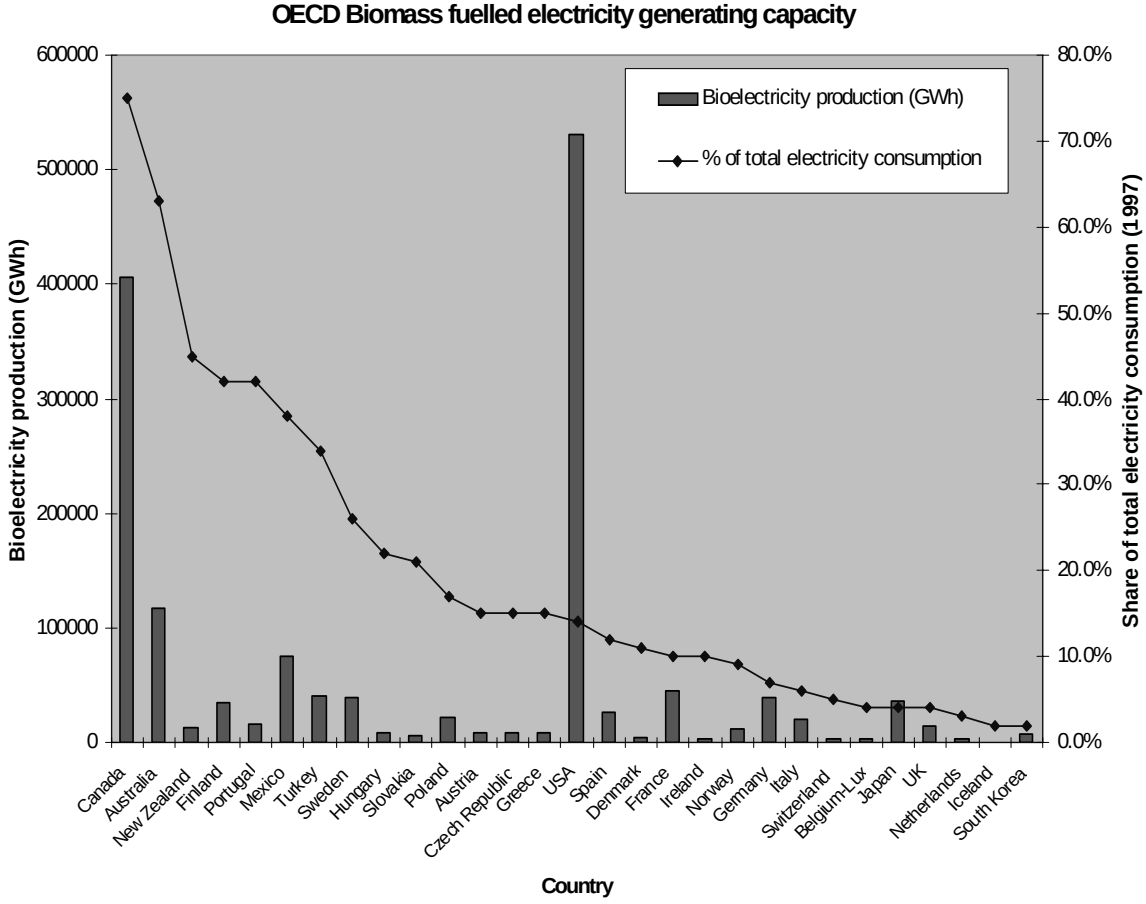
Technology status and prospects

Combustion technologies and co-firing with coal are commercial technologies on which the current bioelectricity industry is based. Gasification technologies are commercial in niche markets and for specific feedstocks (*e.g.* gasifiers are used in the pulp and paper industry to eliminate residue streams and the resulting product – gas – is used for heat and electricity generation). Gasification could lead to the more efficient and cleaner use of biomass for electricity production. Its demonstration and commercialisation using a wide range of biomass feedstocks are likely to be of great importance for economically viable and environmentally sustainable bioelectricity production. Furthermore, biomass gasification could lead to future biomass facilities being integrated with advanced conversion technologies such as fuel cells and co-producing products such as transport fuels, in addition to electricity.

Setting a target for bioelectricity in 2020

For OECD countries, an ambitious but realistically achievable target for bioelectricity production by the year 2020 could be the exploitation of 25% (6 Exajoules [EJ]) of the potentially harvestable residues (from agriculture, forestry and livestock) and the dedication of 5% of the crop, forest and woodland area to the cultivation of biomass for energy. Accomplishing this target over a 20-year period would require an average of 1.25 million ha of cropland per year to be converted to energy plantations.

Figure 1. Potential electricity production from biomass in OECD countries, 2020



Source: WWF (forthcoming).

A yield of 10 air-dry tonnes per hectare is considered to be an attainable average yield across the OECD region, and would provide 10 EJ from 5% of OECD countries' crop, forest and woodland area. Assuming that modern biomass conversion technologies can convert biomass to electricity at an average efficiency of 35%, the 16 EJ of the biomass resource exploited would represent about 19% of the OECD area's current electricity consumption, and 16% of the electricity demand estimated in the International Energy Agency's (IEA) reference scenario for 2020. The estimated electricity production from biomass would require an installed capacity of about 370 GW. Figure 1 provides an indication of the considerable potential for bioelectricity production in OECD countries.

Environmentally sustainable bioelectricity

Bioelectricity has a major role to play in an environmentally sustainable energy future. The World Wild Fund for Nature (WWF) believes that bioenergy can be developed without conflicting with – or indeed, competing with – food and fibre production. Nevertheless, national and regional governments should establish energy strategies that include local and regional planning guidelines to minimise potentially negative environmental impacts and enhance positive ones. Biomass is produced using widely varying strategies related to site-specific parameters, the scope of which makes the development of "one-size-fits-all" policies generally unsuitable. There are likely to be risks associated with bioelectricity production that need to be evaluated on a case-by-case and fuel-chain basis. Consequently, a number of appropriate regulations need to be designed to ensure the continued sustainability of biomass energy systems:

- The various sources of raw materials will need to be determined at a regional/landscape/ catchment level. They will include existing forest resources, dedicated forests and agricultural crops, short rotation coppice, and residues from forest and agricultural operations currently underway. Best-practice standards should be developed concerning each individual raw material source.

- Site-specific best methods of production need to be further developed, backed up by methodologies ensuring effective implementation and monitoring.

- There should be no conversion of High Conservation Value (HCV) habitats for energy production. HCVs should be maintained or enhanced. Production of biomass fuels should not result in net negative impacts on habitats and biodiversity.

Towards a blueprint for bioelectricity

The proposed target of about 16 EJ of bioelectricity in OECD countries by 2020 (equivalent to about 3 000 million tonnes of air-dry biomass) implies a more than twenty-fold increase in bioelectricity capacity over a period of about 20 years. Bioelectricity capacity would increase from approximately 18 GW to close to 370 GW and represent about 15% of installed capacity relative to the IEA reference case scenario for electricity capacity in 2020 (about 20% of 1997 installed capacity). The benefits could be multiple in terms of environmental damage averted through substitution of fossil fuels, rural development, improved energy security and, in general terms, a move to more sustainable electricity production. Stimulating the development of biomass power requires a cross-sectoral approach at government level, involving the Ministries of Agriculture, Environment, Trade and Industry, Transport, and Finance. Governments have a key role to play in promoting demand for biomass energy through a package of measures including, *inter alia:* preferential tariffs or quotas for biomass power, capital grants, public procurement, demonstration projects, building regulations and planning regulations.

In this context, WWF will:

- Promote biomass to consumers as a viable alternative and an environmentally sound source of energy.
- Work with the biomass industry and the power sector to endorse the use of biomass as a replacement for fossil fuels.
- Work with the agriculture and forestry sectors to promote sustainable supplies of biomass for power and heat generation.
- Work with national governments, intergovernmental organisations and other non-governmental organisations to develop biomass strategies and incentives to stimulate the supply of biomass for power generation.
- Advocate the development of best-practice standards for integrated pollution prevention and control in power generation plants.
- Develop guidelines for a code of good practice for the supply of raw materials.

BIBLIOGRAPHY

Bauen, Ausilio *et al.,* (2003), A Blueprint for Bioelectricity in the OECD, Imperial College London and E4tech for WWF, United Kingdom.

Harmelink, Mirjam *et al.,* (2003), *Low Carbon Electricity Systems: Methodology and Results for the EU,* Ecofys Report for WWF.

WWF (forthcoming), this paper is based on a forthcoming study prepared for WWF International by the Centre for Energy Policy and Technology, Imperial College London and E4tech (UK) Ltd., entitled *Bioelectricity Vision: Achieving 15% of Electricity from Biomass in OECD Countries by 2020.* For further information, see: www.panda.org/climate.

HARVESTING ENERGY WITH FERTILISERS

Christian Pallière[1]

Abstract

As the earth's natural energy resources decline, individuals, public bodies and industries are under pressure to reduce their consumption of fossil fuels. This pressure encourages the search for advanced technological solutions that maximise the efficient use of existing energy sources. It also makes the use of renewable energy sources a high priority, along with endeavours to find energy sources which do not increase the greenhouse gas problem, and can even contribute to binding some CO_2.

Agriculture produces energy

Energy is a central issue in agriculture. The very reason for the existence of the agriculture industry is to supply energy to mankind. It does this by making use of solar power to convert energy into biomass, which in turn supplies energy to human beings and animals in the form of nutrition.

The ability of the agriculture industry to supply energy in the form of biomass is greatly enhanced by the use of mineral fertilisers in agriculture, representing further efficiency in the capture of solar energy.

Energy consumption in Europe

Energy consumption for different economic sectors in Europe

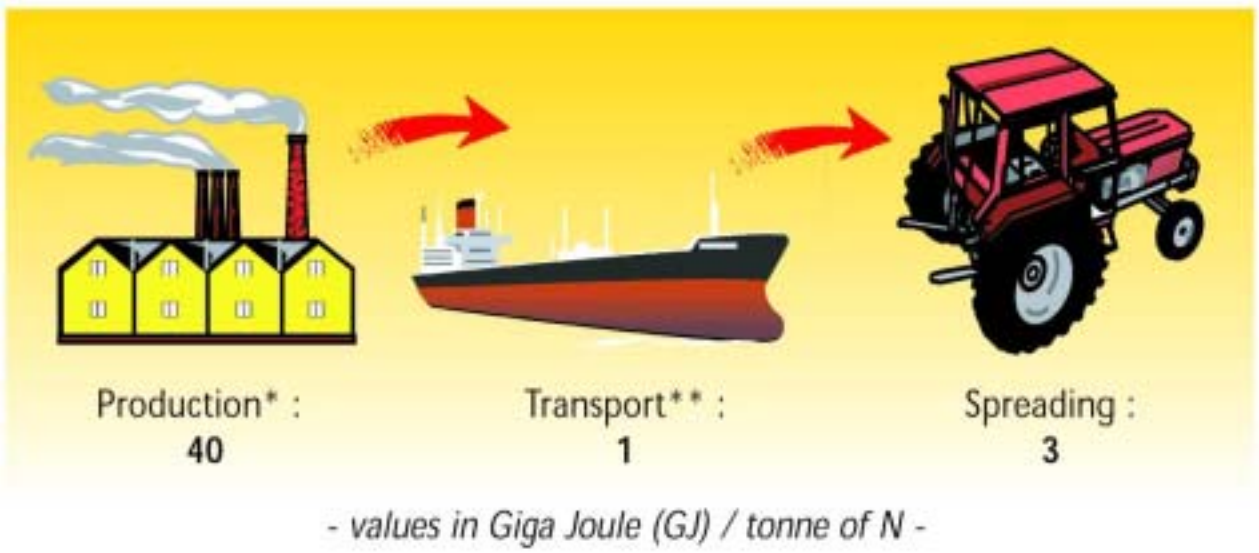
Food production accounts for 15% of total energy consumption in Europe, the remaining 85% being used by industry, traffic, private households and public services. Of this 15%, just 5% is consumed by agriculture, and this figure includes the energy used to produce mineral fertilisers.

Energy consumption in European agriculture

Of the total energy used to produce wheat in Europe, approximately 50% is needed to produce, transport and apply nitrogen fertilisers (Figure 1).

1. European Fertilizer Manufacturers Association (EFMA), Brussels, Belgium, representing the International Fertilizer Industry Association (IFA).

Figure 1. Energy consumption in the nitrogen fertiliser chain



Source*:* Hydro Agri Company.

Energy consumption in the nitrogen fertiliser chain

Most of this energy – around 90% – is required to produce mineral fertilisers, and it is therefore in this area that technologies have been developed to ensure that fertiliser manufacturing processes are as efficient as possible.

In fact, since the early 1900s, the efficiency of energy use in the production of nitrogen fertilisers has improved so dramatically that modern fertiliser factories are now close to the theoretical minimum of energy consumption.

Efforts continue to be made to improve energy use for transport, but it tends to be focused on the type of energy used.

Techniques used in applying Precision Farming principles are helping to decrease the level of energy used during fertiliser application.

Energy balance in crop production

Nitrogen application rate: the economic optimum

Efficiency of energy use is also a central issue on farms. Grain yields increase as more mineral nitrogen is applied, but there is an economic optimum which makes the most efficient use of the farmer's resources. For mineral nitrogen fertilisers, the economic optimum is an application rate of 170 kg nitrogen per hectare.

This economic optimum is also the level at which to have the best levering effect energy used/energy captured.

Energy balance in wheat production

At the above rate of application, wheat yields are approximately 8.2 tonnes per hectare, compared with 4.7 tonnes per hectare without nitrogen fertiliser. Expressed in terms of energy, this equates to 126 GJ (gigajoules) of solar energy captured on every hectare in the form of biomass when nitrogen is applied at the optimum rate, compared with 71 GJ per hectare without nitrogen fertiliser (Figure 2).

Compared to the 8 GJ used during the life cycle of a fertiliser, it means a levering effect of more than "x 6" when using a fertiliser.

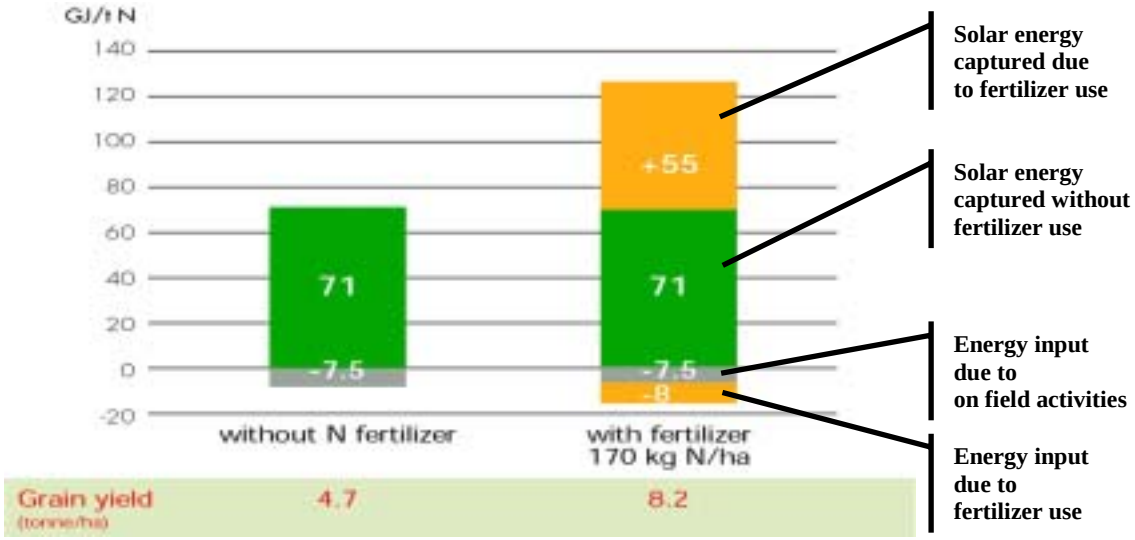
Fixing CO_2 with crop production

CO_2 binding and GHG balance in wheat production

At the same time, when plants capture solar energy to produce biomass, the carbon source to produce this biomass is taken from atmospheric CO_2. Taking again the same wheatfield, when producing 8.4 tonnes of wheat per hectare with nitrogen fertilisers, the volume of CO_2 taken from the atmosphere is 26 tonnes, compared to only 15 tonnes of CO_2 bound when 4.7 tonnes of wheat are produced per hectare without fertilisers (Figure 3).

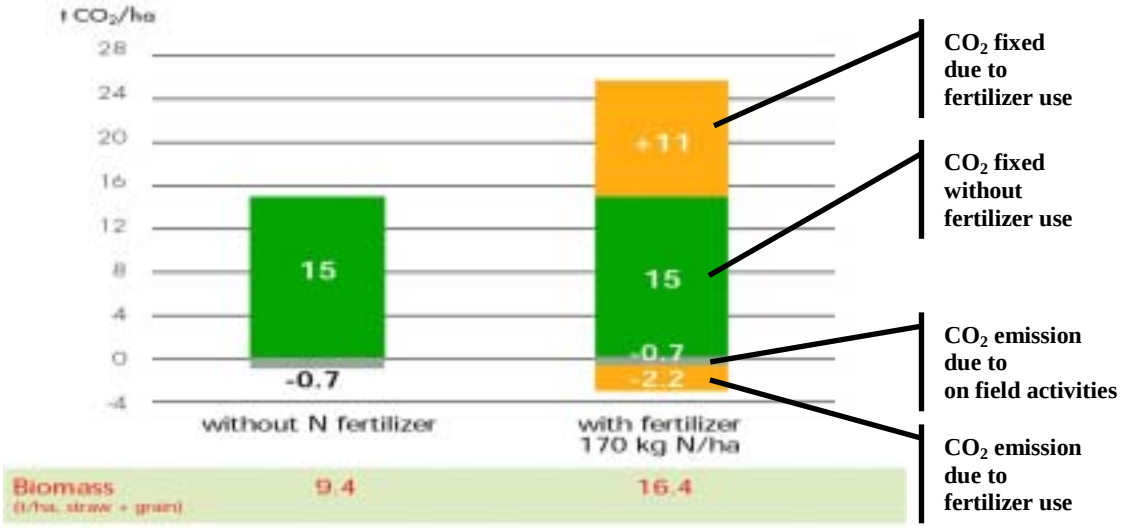
Thus, compared to CO_2 and other greenhouse gases (mainly NO_x) emitted during the life cycle of a fertiliser, from transporting raw materials to application in the field, the levering effect is in this case of a level of x 5 when using a fertiliser.

Figure 2. Energy produced on one hectare of wheat



Source: Kusters and Lammel, 1999.

Figure 3. CO_2 fixed from one hectare of wheat



Source: Kusters and Lammel, 1999.

The CO_2 binding is not permanent, but short to middle term, depending on the end use of the production (food, feed, industry). A more long-term binding of the CO_2 captured in the atmosphere is induced when part of the crop is ploughed in, increasing the soil organic content. But there can also be a general permanent fixing when total agricultural production increases, which is the case in a worldwide approach.

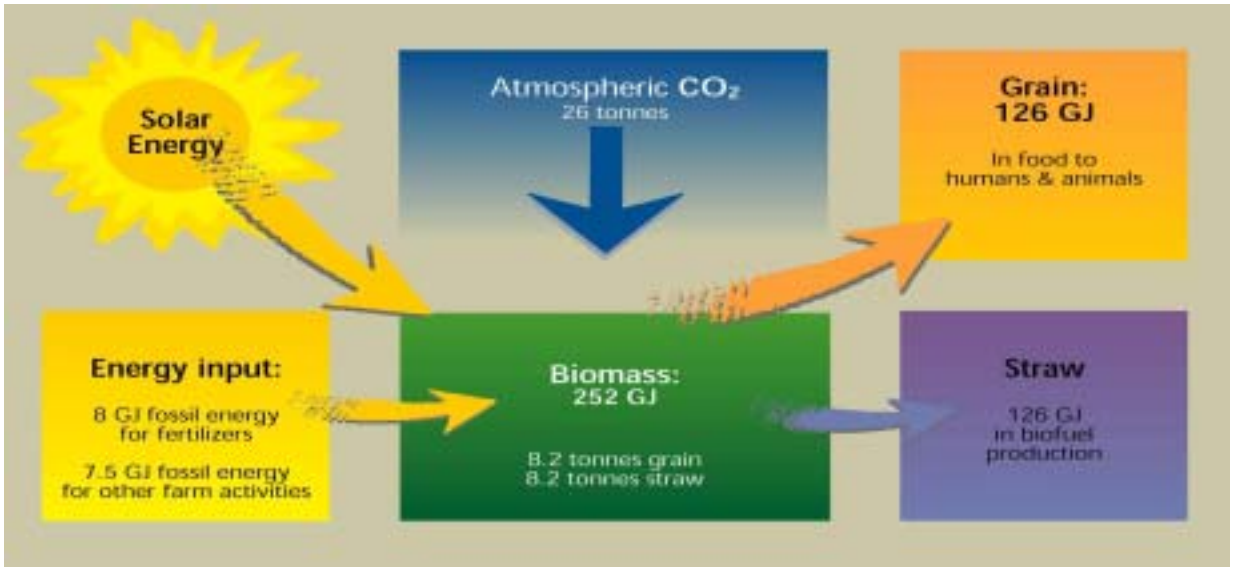
Producing biomass

The recycling of crop wastes in agriculture can also mean that part of the biomass produced represents a direct energy source (a type of biofuel) as well as producing food, which is itself a source of energy.

When using 15.5 GJ of fossil energy to produce fertilisers to be used on one hectare of wheat, 50% of the biomass produced generates an equivalent of 126 GJ of straw (Figure 4). If half this straw (4.1 tonnes) is used as a biofuel, it can replace 1.2 tonnes of oil, generating the same energy equivalent of 63 GJ, but avoiding the release of 4.4 tonnes of CO_2 from oil burning (in this case, the CO_2 binding through the use of the biomass is neutral, the CO_2 fixed during crop growth being released as the biofuel is used).

The potential effect is significant. Assuming that the whole area of wheat production in Western Europe (16.8 million ha) produces 4.1 tonnes of biofuel, Europe will "save" 3.5% of its total emissions of CO_2.

Figure 4. Energy production and CO_2 binding on one hectare of wheat



Source: European Fertilizer Manufacturers' Association.

Conclusions

The conclusions are clear.

First, the energy balance of crop production is positive because more energy is produced by mineral nitrogen fertilisers than is used in their production and application. This application of mineral nitrogen enables crops to produce more biomass, which in turn provides more energy for human and animal nutrition.

Second, the identification of the optimum nitrogen fertiliser application rate means that the highest energy yield is obtained. In short, agriculture is both an efficient user and a generous supplier of energy. In this respect, the use of mineral nitrogen fertilisers makes it easier to monitor nutrient application than is the case with other fertilisers.

Third, crop production using mineral nitrogen fertilisers helps to fix more greenhouse gas than is emitted during the entire production process of a fertiliser.

BIBLIOGRAPHY

Kusters, Juergen and Joachim Lammel, (1999), "Investigations of the Energy Efficiency of the Production of Winter Wheat and Sugar Beet in Europe", *European Journal of Agronomy*, No. 11, pp. 35-43.

POTENTIAL FOR AGRICULTURAL BIOMASS TO PRODUCE BIOENERGY IN THE CZECH REPUBLIC

Sergej Usťak and Marie Usťaková[1]

Abstract

Agriculture in the Czech Republic has some restrictive factors which significantly limit conventional agricultural production (approximately 60% of agricultural land belongs to the less-favoured area category; 8% is located in protected areas with specific environmental restrictions; and 13% is in mountain areas with highly unfavourable natural conditions). On the other hand, the common composition of agricultural areas is very suitable for alternative agricultural production, in particular biomass production, because the total area of unused, unfertilised soils is equal to one-fifth of the total agricultural area. Biomass is a very important renewable source of feedstock and energy. The wastes or by-products originating in conventional agriculture and forestry production, coupled with special industrial crops and short rotation forestry, are two main sources of biomass in the Czech Republic. Agricultural biomass production is a very important part of sustainable development and it solves a number of economic, social and environmental problems. The present share of renewable energies in total energy consumption in the Czech Republic is approximately 2.5%. Use of biomass as a renewable source of energy is currently about 68%. The potential share of renewable energies is estimated at about 5.6% of total energy consumption by 2010. Potential renewable energy use should increase by approximately 3.6 times, from 27 210 TJ/year in 2002, to 97 500 TJ/year in 2010. The main share of future renewable energy in the Czech Republic belongs to biomass (approximately 60-70%). At present, the total annual consumption of energy biomass is about 1.8 to 2 million tonnes. Current annual production of standardised biofuels (pellets and briquettes) is 140 to 160 000 tonnes, 80% of which is exported to EU countries.

The development of energetic biomass use in the Czech Republic began in the middle of the 1990s. At the outset, energetic biomass use was orientated mainly towards the waste and by-products of agricultural and forestry production. But the future main source of biomass will be the production and use of energetic plant species (wood and agricultural crops). Energetic biomass use is becoming increasingly orientated towards energetic plant species. Therefore, the selection and breeding of new energetic crops is the main condition for the successful development of energetic biomass production and an important target for agricultural research**.**

Long-term field experiments confirm that the sorrel of Uteush (hybrid *Rumex patientia L. x Rumex tianschanicus A. Los.*) is a highly productive energetic crop suited to temperate climatic conditions. This is a very adaptable plant with regard to the sowing period, agro-technical level, fertiliser requirements and soil conditions. Optimum growing conditions have been determined as follows: sowing rate – 6 kg/ha; latitude row – 15 to 30 cm; distance between individual plants – 6 to 8 cm. With only one annual harvest, this crop offers, on average, almost 14-16 tonnes of dry above-ground biomass, which exceeds the normal yield level of fast-growing woody plants. An advantage of the cultivation and harvesting of this crop is its high technological potential, coupled with the use of

1. Research Institute of Crop Production, Prague, Czech Republic.

ordinary agricultural cultivation methods. Moreover, the hybrid sorrel has considerable potential for the production of high-quality forage, specialised food products and biologically active food and feed additives because it has a high content of raw protein (20-40% dry matter), fat (3-6%), food fibres (10-30%), carbohydrates (30-40%), ash (5-10%), ascorbic acid (150-800 mg/kg) and carotene (20-60 mg/kg), depending on the age of the harvested plants. Younger plants usually have better food quality than older plants. Cultivation of this crop in the Czech Republic has increased, and it also has considerable potential for use in other countries in central and northern Europe.

Agricultural biomass production in the Czech Republic

The total area of the Czech Republic is approximately 79 000 km^2, with a population of 10.3 million. The total agricultural area is around 4.3 million ha, including nearly 3.1 million ha of arable soils, and the total area of forest is 2.6 million ha.

Of the total agricultural area:

1. Approximately 60% belongs to the less-favoured areas (LFA) category;

2. Approximately 8% is located in protected areas with specific environmental restrictions;

3. Approximately 13% (570 000 ha) of agricultural land is located in mountain areas with highly unfavourable natural conditions, *i.e.* elevation above sea-level of over 600 m, and 500-600 m sloping more than 7^o on at least 50% of the area.

These factors significantly limit conventional agricultural production in the Czech Republic. On the other hand, the common composition of agricultural areas (Table 1) is very suitable for alternative agricultural production, in particular biomass production, because the total area of unused, unfertilised soils, which are usually suitable for biomass production, is equal to 880 000 ha, or about one-fifth of the total agricultural area.

Biomass is a very important renewable source of feedstock and energy. There are two main sources of biomass: 1) ***waste*** or ***by-products*** originating from conventional agriculture and forestry production; and 2) special ***industrial crops*** and ***short rotation forestry***.

Table 1. Composition of the agricultural area in the Czech Republic

(hectares)

Type of use of agricultural area	Total agricultural area	Arable land	Grassland	Permanent cultures
Used fertilised soils	3 400 000	2 800 000	300 000	300 000
Unused unfertilised soils	880 000	280 000	600 000	0
Total agricultural area	**4 280 000**	**3 080 000**	**900 000**	**300 000**

Source: Ministry of Agriculture, Czech Republic; Czech Statistical Office.

According to the main pathways of biomass utilisation, all industrial crops are usually split into two groups: ***technical crops***, which are used for the production of fibre, technical oil, pharmaceutical and healthcare products etc., and ***energetic crops***, which are used for the production of biofuels and energy. Industrial crops are widely used in the production of ethanol, renewable diesel, pharmaceutical and healthcare products, textiles, paper, plastics, paints, adhesives, detergents, biochemicals, etc. Agricultural biomass production is a very important part of sustainable development and it solves a number of economic, social and environmental problems. The most important advantages of biomass production are:

i. substitution for fossil fuels and raw materials by renewable biofuels and biomaterials;

ii. decrease of carbon dioxide emissions and reduction of the greenhouse effect;

iii. sustainable use of soils;

iv. rural development and lowering of unemployment;

v. agricultural market innovation and expanding of market opportunities for agriculture; and

vi. increase of national energy security by using domestic energy supplies.

Potential for agricultural biomass production in the Czech Republic

In the European Union (EU) the largest proportion of biomass is used for energy production. Moreover, it is considered that biomass represents approximately 85% of future renewable energy resources in the EU. The situation is reflected in the Czech Republic (Table 2). Use of biomass as a renewable source of energy is currently about 68%, and its level of use is estimated to be approximately 63% by 2010. At the same time, the growth of energetic biomass production and use requires the lowest investment cost per unit of energy (only 12 EUR per gigajoule [GJ]).

Table 2. Present and potential (by 2010) production and use of renewable energy in the Czech Republic

Renewable source of energy	Actual use	Usable potential by 2010		Total capital costs	Investment costs
	TJ/ year	TJ/ year	% of total	million EUR	EUR/GJ
Biomass	18 650	61 770	3.53	536	12
Waste	1 520	3 560	0.30	822	402
Sun energy	140	11 500	0.66	2 915	257
Photovoltaic effect	0	80	<0.01	164	2 176
Thermal pump	30	6 670	0.38	688	104
Wind energy	30	3 710	0.21	607	165
Small hydroelectrics	2 340	5 660	0.32	524	158
Large hydroelectrics	4 500	4 500	0.26	0	0
TOTAL	**27 210**	**97 500**	**5.60**	**6 258**	**--**

Source: CZ BIOM, Czech Biomass Association; OZE, Association of Renewable Energy Sources.

Table 3. Estimation of potential biomass use for energy in the Czech Republic after 2010 and after 2020

Type of biomass	Source of biomass	After 2010		After 2020	
		Mt/year	PJ/year	Mt/year	PJ/year
Firewood	Waste of cut and manipulation	2.6	31.2	3.0	36.0
Cereal straw	25% of total yield	1.6	22.4	1.6	22.4
Straw of oil	100% of total yield	0.9	12.2	0.9	12.2
Grasses	Perennial growth	0.8	4.8	1.2	7.2
Used wood	Wood residues	0.6	8.1	0.9	12.2
Energetic crops	Plantation on devoted soil	0.8	8.8	4.0	44.0
Bio-diesel	Rape oil	0.1	4.2	0,2	8,4
ETBE/ethanol	Sugarbeet, cereals	--	--	0,1	4,1
Total biomass potential		**7.4**	**91.7**	**11.9**	**146.5**

Notes :
Mt: million tonnes; PJ: petajoules.

Source: CZ BIOM, Czech Biomass Association.

The present share of renewable energies in total energy consumption in the Czech Republic is about 2.5%. The potential share of renewable energies is estimated at about 5.6 % of total energy consumption by 2010. The potential renewable energy use should increase by approximately 3.6 times, from 27 210 terajoules (TJ)/year in 2002, to 97 500 TJ/year in 2010.

Table 3 shows the estimated results of potential biomass use for energy in the Czech Republic after 2010 and after 2020. The main potential share of energetic biomass after 2010 belongs to firewood (up to 35%) and cereal straw (22%), but after 2020 this changes to energetic crops (30%) and wood (25%). Table 4 shows known data on the present number of bioenergetic facilities in the Czech Republic. The total annual consumption of energy biomass is currently around 1.8 to 2 million tonnes. The annual production of standardised biofuels (pellets and briquettes) is currently 140 to 160 000 tonnes, 80% of which is exported to European Union (EU) countries.

The most extensive and developed kind of biofuel in the Czech Republic is rape oil methyl ester – biodiesel. The biodiesel programme was set up in 1991. Nowadays most fuel filling stations sell biodiesel to the general public. A summary of production, export, import and consumption of rape oil methyl ester is given in Table 5. Subtracting indirect taxes and adding government subsidies supports most bioenergy projects in the Czech Republic.

Table 4. The number of bioenergetic facilities in the Czech Republic in 2000

Type of facilities	Number
Small individual boilers with a capacity < 50 kW	40 000
Medium boilers with a capacity of 50-200 kW	430
Municipal boilers with a capacity of 200-500 kW	60
Municipal boilers with a capacity > 500 kW	17
Biogas plants	10

Source: Ministry of Environment of the Czech Republic; CZ BIOM, Czech Biomass Association.

Table 5. Summary of production, export, import and consumption of rape oil methyl ester in the Czech Republic

(thousand tonnes)

Year	1995	1996	1997	1998	1999	2000
Production	11.8	19.3	27.6	15.7	30.63	67.2
Import	2.4	3.2	1.5	0.08	0.03	0.072
Export	8.4	8.7	11.7	25.8	20.2	3.2
Consumption	17.8	24.8	37.5	41.4	50.77	70.4

Source: Ministry of Agriculture, Czech Republic; Czech Statistical Office.

Research results for bioenergy crop production in the Czech Republic

The development of energetic biomass use in the Czech Republic began in the middle of the 1990s. At the outset, energetic biomass use was orientated mainly towards the waste and by-products of agricultural and forestry production. There are many techniques and technologies for the conversion of agricultural biomass to energy. The most important are as follows: 1) direct combustion of biomass; 2) production and use of standardised solid biofuels (pellets and briquettes); 3) production and use of standardised liquid biofuels (such as biodiesel and ethanol); 4) biogas production; 5) pyrolisis, etc. At present, the most technically feasible and economically efficient method is direct combustion of agricultural and forestry wastes and by-products, but the future main source of biomass will be the production and use of energetic plants (wood and agricultural crops). Energetic biomass use is becoming increasingly orientated towards the energetic plant species. *Therefore, the selection and breeding of new energetic crops is the main condition for the successful development of energetic biomass production and the most important target for agricultural research.*

The Czech Research Institute of Crop Production (RICP) has been dealing with research into the cultivation and utilisation of industrial and energetic plant species since 1991. According to the RICP's long-term research, the potential energetic crops must meet the following criteria:

1. low cost, high yields;
2. simple and low-input agricultural technologies;
3. sowing is more preferable than planting;
4. perennial crops are more preferable than annual;
5. low input level of fertilising and plant protection;
6. possibilities to use common agricultural machines;
7. easy request conditions for harvesting;
8. sufficient quality of biomass for fuel production;
9. harmless to the environment.

The vast collection of energetic plants was tested, including short rotation coppices (about 30 clones of willows, 12 clones of poplars etc.) and energetic herb crops – about 60 species – for example, giant knotweed (*Polygonum sachalinensis),* hemp (*Cannabis sativa),* kenaf (*Hibiscus cannabinus),* linseed (*Linum usitatissimum),* miscanthus *(Miscanthus x giganteus),* rape *(Brassica napus),* reed canary grass (*Phalaris arundinacea.),* rosin weed *(Silphium perfoliatum),* Safflower (*Carthamus tinctorius),* Topinambur *(Helianthus tuberosus),* mallows *(Malva spp*.), different species of grass, etc.

Comparison of the cultivation of fast-growing, woody plants (usually species of poplars and willows) with energetic, non-woody plants shows that the cultivation of woody plants has certain advantages but, under current economic conditions in the Czech Republic, large-scale production is not possible, as the processing involved is particularly labour-intensive and there are no modern specialised facilities available in the country.

Careful consideration of the availability of suitable techniques for the cultivation and harvesting of energetic crops on a large scale reveals herbaceous (non-woody) energetic crops to be preferable, because common agricultural techniques can be employed. In our opinion, perennial crops definitely take priority over annual crops, because their cultivation and harvest are always financially and technically more simple and profitable.

Perennial crops usually involve high operation costs only during the first year, when perennial growth is being established. In following years costs are minimal, because the very expensive requirement for soil tillage falls off. Perennial crops usually require only minimal cultivation, some manure and regular harvesting. The costs of growing perennial energetic crops during the first year usually exceed by 1.5 to 3 times the analogical costs of annual plant-growing. It is at the initial stage of biomass production for energy, with no harvest taking place in the first year, that state subsidies are desirable. In subsequent years the production of biomass would cover overhead costs without recourse to subsidies.

It has been found that the sorrel of Uteush is one of the perennial energetic crops with the most potential, suitable for cultivation in the temperate climatic zone of Europe. The sorrel of Uteush (Figure 1) is a hybrid of the first generation received from the herb patience or English spinach (*Rumex patientia L.*), as a female line and Tien Shan sorrel (*Rumex tianschanicus A. Los.),* as a male line, which was bred with the method of long-term selection. There are two varieties of the sorrel of Uteush – the first variety was registered as “Rumex K-1” in the former USSR in 1988 and the second, newer, variety was registered as “Rumex OK-2” in the Ukraine in 2000. These varieties of sorrel were created as new fodder crops in the Central Botanical Gardens, named after Professor Grishko at the Ukrainian National Academy of Science (Uteush, 1991; Uteush and Lobac, 1996). These hybrids significantly exceed both the original plants and many traditional feed crops in terms of the quality of feed production and yields of above-ground biomass and seeds. The variety OK-2 is more efficient and earlier than the parent variety, K-1.

In the Czech Republic, the sorrel of Uteush has been grown experimentally since 1992 on the RICP’s trial field in Chomutov. The main aim of this trial research was to verify and quantify the possibility of cultivating hybrid sorrel as an energetic crop in temperate-climate conditions. Experiments included the complex tests of agricultural cultivation, including the sowing period, acceptable sowing rate, optimal application of fertilisers, and protection against pests and weeds.

Long-term trials confirmed that the sorrel of Uteush is one of the perennial energetic crops with the most potential, suitable for fuel biomass cultivation as a renewable source of energy in European temperate-climate conditions.

This crop excels from a technological perspective and requires only simple conditions for agricultural cultivation. The sorrel of Uteush is easily reproduced with seeds, unlike other highly productive energetic crops (*e.g.* miscanthus, bamboo, giant knotweed, giant reed), which is an advantage over other energetic crops grown in central and northern Europe. Moreover, it has a high reproductive coefficient, because the yield of seeds can reach 500 kg/ha on average, which, at a sowing rate of 5 kg/ha, is sufficient to sow approximately 100 ha.

Figure 1. The sorrel of Uteush



Source: Authors.

The sorrel seeds are easily harvested using a combine harvester adjusted to work at the lower speed required. The seeds must not be allowed to over-ripen, as this leads to high losses on yield. Otherwise, the sorrel seeds usually ripen fairly evenly and, at optimum ripeness, the harvest losses are minimal.

Research demonstrates that the sorrel of Uteush is a highly productive perennial crop, characterised by very high adaptability in respect to the sowing period, agricultural methods and soil conditions for cultivation. As a feed crop its main advantages are its extremely early ripening (the first mowing taking place in late April) and its high content of raw protein and vitamins during the early stages of growth.

Table 6 shows a long-term series of average yields of Uteush's sorrel from the trial foundation (1992) depending on different doses of mineral fertilisation. It was found that sorrel requires fertiliser only during the first two years – this is when differences among control (non-fertilised) and fertilised variants are greatest. In subsequent years the differences in yields among control and fertilised variants are reduced on average to 3.5 to 3.9 tonnes of dry matter of above-ground biomass per hectare. Moreover, practically no differences in yields are noted, whether doses of 60 or 120 kg NPK (nitrogen, phosphate, potash) are applied (long-term average of only approximately 0.4 tonnes/ha), which means that this crop requires low levels of fertiliser, apart from the first two years. In addition, this conclusion is strengthened by the fact that the trials were conducted on soil with low fertility. Under good soil conditions this crop could achieve significantly better results.

Table 6. Yields of total above-ground biomass[1] of the sorrel of Uteush

(tonnes per hectare of dry matter)

Fertiliser	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	1993-2001
Control	0.6	6.7	13.4	15.1	14.2	12.4	11.9	14.6	8.6	10.6	**11.9**
NPK-60	1.8	11.6	15.2	16.7	15.8	15.9	17.3	16.6	14.9	14.2	**15.4**
NPK-120	2.6	10.9	16.4	17.2	16.4	14.9	15.5	20.0	15.2	15.3	**15.8**
Average of variants	**1.7**	**9.7**	**15.0**	**16.3**	**15.5**	**14.4**	**14.9**	**17.1**	**12.9**	**13.4**	**14.4**

Note:

1. Energy biomass is cut only once per year in dry state.

Source: Authors' own results.

Table 7 represents results of chemical analyses on the content of essential nutrients and calculation of nutrient up-take at an average yield of 15 tonnes/ha. The high content and up-take of potassium and the increased up-take of nitrogen are immediately noticeable. Research reveals that the optimum fertiliser rate of NPK-60 is significantly lower than the values of comparable nutrient up-take calculated on the basis of yields and nitrogen and potassium content (except phosphorus). This may be explained by the very high accumulation of nutrients in the hybrid sorrel's roots: levels can reach 6-8% dry matter of nitrogen, 3-5% of phosphorus and 2-4% of potassium. At the same time, the values of combustion heat and power yield from one hectare are shown in Table 8. As a comparison, one rural household consumes 50-100 GJ of energy annually, which means that a hectare of sorrel can supply the energetic needs of approximately 3-5 rural households per year.

Results show that the sorrel of Uteush attains on average 220-260 cm in height and yields 14-16 tonnes of dry matter of above-ground biomass per hectare (in the case where only one cutting per year takes place in dry weight as energy biomass), whereas the sorrel achieves steady high yields as early as from the third year and can sustain this for many years. For instance, at the RICP the sorrel growth is 11 years old, and the author has sorrel that is 14 years old, which is in good condition.

Table 7. Chemical composition, annual nutrient up-take and energy content of the sorrel of Uteush

Parameter	Nitrogen total	Phosphorus	Potassium	Carbon	Magnesium	Combined Heat, MJ/kg	Energy yield GJ/ha[1]
% content	0.950	0.464	2.24	0.806	0.223	18.5	--
Up-take[1] kg/ha	143	69.6	336	121	33.5	--	278

Note:

1. Calculation of the up-take of nutrients is done at the average yield equal to 15 tonnes from 1 ha.

Source: Authors' own results.

Table 8. The results of comparison combustion tests of different biofuels

Biofuel	Temperature in chimney	Power capacity of boiler	Temperature of clinkering
Wood	230°C	1800 KW	--
Sorrel	225°C	1900 KW	1200°C
Cereal straw	180°C	1400 KW	800°C

Source: Authors' own results.

The great advantage of this crop is early ripening – as soon as July it is possible to harvest the hybrid sorrel as dry energetic biomass, and the farmer can easily choose a suitable period for mowing and air-drying the crop in the field and for the final harvesting and making into bales. The summer harvest is an advantage of the sorrel of Uteush in comparison with other energetic crops, which are mostly harvested as late as October-November, when the process is made difficult due to late-autumn weather conditions, sometimes resulting in postponement of the harvest until the spring, which can entail losses of 25-50%.

The hybrid sorrel is very tolerant of soil and site agro-ecological conditions, with the exception of very acid soils (<5.5 pH) and waterlogged soils with a high level of ground water (0-50 cm in depth). It can be successfully grown in many regions of Europe and around the world. It has no special requirements for soil fertility or nutrient content. In the case of sorrel used as a source of fuel from biomass its requirement for fertiliser is minimal and extends only over the first year, when it is necessary to apply 60-90 kg NPK per hectare. Some organic manure may also be applied at a rate of (40-80 tonnes/ha). If the sorrel is grown for food or feed purposes, it will require multiple mowing (usually 2-3 times per year), and its requirements for fertiliser will increase: it will be necessary to apply 30-60 kg NPK per hectare on a yearly basis (usually in the spring or after cutting).

The hybrid sorrel has a strong hollow stem that is very resistant. It can grow to a height of 120-160 cm on sandy and stony soils, and to 220-260 cm in highly fertile conditions. The leaves of the root rosette are 35-50 cm long, but the upper stem leaves are smaller. The small flowers are androgynous, the male flowers are purple-red and the female flowers are yellow-green, both borne in bunches. The fruit is a small, three-edged, glossy brown nut. 1 000-seed weight is 3 to 3.4 g.

For the successful establishment of sorrel cultivation it is necessary to prepare the soil very carefully. The main problem is weeds. The seedbed for sorrel can be prepared in the same manner as for spring cereals and technical crops: ploughing at the sowing depth in autumn or spring, 1-2 months before sowing; then harrowing and rolling with heavy rollers in spring, 2-3 days before sowing.

The sorrel seeds germinate 5-6 days after sowing, at 8-10°C. It has been found that optimal parameters for sorrel sowing are as follows: width of rows – 15-30 cm, depth of seeds – 1.5-2 cm; sowing rate – 5-6 kg/ha, or 1.7-2 million germinating seeds per hectare. Sorrel is a very adaptable plant with regard to the sowing period: it can be sown from April to July with the same results, the only condition being that the soil is sufficiently wet (*e.g.* after heavy rainfall). Sowing in autumn is inadvisable because the young plants are intolerant of winter frosts (established plants are unaffected). When the sorrel begins to grow, it is necessary to loosen the soil by weeding (usually 2-3 times during the first year). In the initial phases of growth the plants are generally over-run with weeds, although in

the later stages of development and in subsequent years the developing sorrel naturally inhibits the growth of most types of weed, making chemical treatments unnecessary. It is not recommended to mow sorrel in the first year of growth – this is very important for strengthening the young plants.

No diseases have yet been determined. The appearance of pests is observed relatively frequently (the goldsmith beetle and some others), but this occurs mostly in the later stage of growth, and will normally have no effect on the production of dry biomass. This is why sorrel does not require chemical treatment against pests when it is cultivated for energy biomass. Nevertheless, when the sorrel is cultivated for food or feed, or if the young sorrel is particularly badly attacked by pests, chemical protection will be necessary (especially during drought).

In addition to the use of the hybrid sorrel as an energetic crop, there are excellent possibilities for its use as a food or fodder crop, because it has a high content of valuable essential nutrients and vitamins (Table 9). Therefore the hybrid sorrel has much potential for the production of high-quality forage, specialised food products and biologically active food and feed additives. The feed (or food) quality varies considerably with the age of the plant: usually younger plants have the highest food quality. Table 9 represents the results of biochemistry analyses of the sorrel samples, depending on the various stages of growth. These results show that during the stage of leaf growth, the hybrid sorrel has the highest food characteristics, and these are lowest at the budding and blossoming stage, due to an increase of cellulose (food fibre) content and a decrease of raw protein. Likewise, the content of ascorbic acid decreases by more than four times. At the same time, the yields of total green biomass increase significantly. Average values of green biomass production can reach 2.5-3.0 tonnes/ha daily (starting from the third year).

High content of essential nutrients in the hybrid sorrel roots, in conjunction with high root yields (approximately 30-40 tonnes/ha from the third year), makes this crop highly suitable for processing. In addition, the roots of hybrid sorrel contain significant amounts of tanning agents (10-20%), which permit the creation of tanning additives used in leather production. Figure 2 shows the rapid increase of the hybrid sorrel cultivation in the Czech Republic for energy purposes.

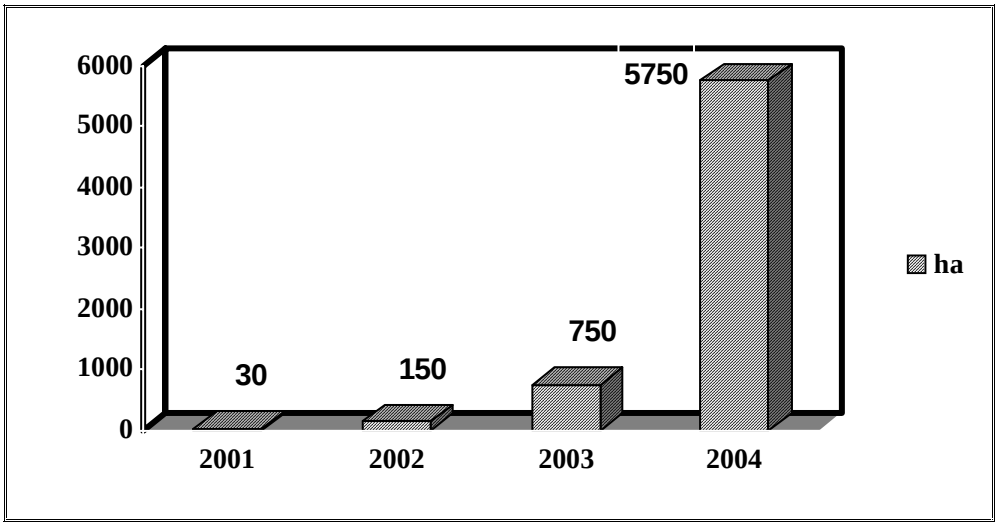
Table 9. Biochemical characteristics of green biomass of the hybrid sorrel, according to growing stages

Parameter	Leaves growing	Stem growing	Budding	Blossoming
Yield of green biomass, t/ha fm	18.6	32.4	82.8	98.4
Dry matter content v %	8.12	11.4	13.8	16.5
Raw protein, % dm	39.2	36.4	27.2	25.8
Nitrogen-free extractable matter, % dm	35.1	34.6	41.7	38.1
Fat, % dm	5.32	4.86	3.42	2.15
Food fibre, % dm	10.6	15.3	19.6	25.8
Raw ash, % dm	9.82	8.84	8.12	8.20
Ascorbic acid, mg/kg dm	620	565	326	124
Carotene, mg/kg dm	52.8	56.4	58.2	33.5

Notes:
fm: fresh matter; dm: dry matter.
Source: Authors.

Figure 2. Growth of the sorrel cultivation in the Czech Republic

(hectares)



Source: Authors.

Conclusions

Agricultural biomass production in the Czech Republic is a very important part of sustainable development and it solves a number of economic, social and environmental problems. At the outset, energetic biomass use was orientated mainly towards the waste and by-products of agricultural and forestry production. But in future the main source of biomass will be the production and use of energetic plants (wood and agricultural crops). Energetic biomass use is becoming increasingly orientated towards the energetic plant species. Therefore, the selection and breeding of new energetic crops is the main condition for the successful development of energetic biomass production and an important target for agricultural research**.** The selection and breeding of new biomass feedstock plant species is important for the successful development of bioenergy production and an important target for agricultural research. Long-term field experiments confirm that the sorrel of Uteush (hybrid *Rumex patientia L. x Rumex tianschanicus A. Los*.) is a highly productive energetic crop suited to temperate climatic conditions. This is a very adaptable plant with regard to the sowing period, agro-technical level, fertiliser requirements and soil conditions. An advantage of the cultivation and harvesting of this crop is the high technological potential and the possibility to use ordinary agricultural cultivation methods. Moreover, the hybrid sorrel has considerable potential for the production of high-quality forage, specialised food products and biologically active food and feed additives. The growth of this crop in the Czech Republic has increased, and there is also considerable potential for the crop in other countries in central and northern Europe.

BIBLIOGRAPHY

Uteush, Y.A. (1991), *New Potential Fodder Crops*, Ukraine, Kiyev, Naukova dumka, p. 192. (in Russian).

Uteush, Y.A. and M.G. Lobac (1996), *Fodder Recourse of Ukrainian Flora*, Ukraine, Kiyev, Naukova dumka, p. 220.

EMISSIONS FROM BIOGAS PLANTS IN AUSTRIA

Werner Pölz and Gerhard Zethner[1]

Abstract

In contrast to composting (where organic biomass disintegrates into carbon dioxide, water and compost by the action of atmospheric oxygen), digestive processes – without the presence of oxygen – produce methane and non-degraded substances (digested sludge), along with carbon dioxide. No energy is released with the production of biogas – but no energy input is needed either, provided there is optimum insulation against heat loss.

Being the major combustible component, methane has a considerable influence on the properties of biogas. Compared to natural gas, the limits of inflammability are higher, *i.e.* an inflammable mixture requires the presence of biogas in a range of between 7.7 and 23% volume in air (BIOGAS, 2001). Methane has a greenhouse gas potential 27 times higher than carbon dioxide (the cause of the greenhouse gas effect on earth [Dalemo, 2001]).

The average calorific value of biogas is about two-thirds of the calorific value of methane. With an energy content of about 6.5 kWh per Nm^3 of biogas, about 1.2 kWh of electrical energy can be produced using a block-type thermal power station (with an electrical efficiency of 25%) and about 2.5 kWh of heat from the cooling water of the engines at temperatures of about 80°C.

Furthermore, methane fermentation reduces the pathogenic bacteria contained in liquid manure and the germination of weed seeds. Biogas slurry is therefore an ideal fertiliser as it increases soil fertility, encourages a healthy soil life and thus healthy plant crops, as well as meadows rich in diversity. In most cases, the application of additional fertilisers, pesticides or herbicides is not necessary (Graf, 1998).

Which materials are suitable for the production of biogas?

In principle, all organic substances that occur naturally in the environment and disintegrate anaerobically are suitable for the production of biogas. The higher the lignin content, the smaller is the biogas yield, since the effective disintegration of lignin is an aerobic process requiring the action of white rot. The materials can be characterised according to the following areas of origin (Sedelmeier, 2000):

Faeces from animal husbandry (*e.g.* liquid manure from cows and pigs, poultry droppings, horse dung);

Agricultural remains (*e.g.* grass, silage, sugarbeet leaves, potato tops, remains from maize production);

Renewable raw materials (maize, common beet, grasses);

1. Federal Environment Agency Ltd., Vienna, Austria.

Waste from the agro-industry (*e.g.* brewer's grains, remains from vegetable processing, contents of rumen and intestines);

Waste from slaughterhouses*;*

Municipal waste (*e.g.* biowaste from the biowaste container, food scraps from restaurants, grease separator contents, cut grass);

Industrial waste (*e.g.* algae at power plants, water-alcohol mixtures from the pharmaceutical industry, glycerine from biodiesel production).

In Austria, faecal waste from agriculture, especially liquid manure from cows and pigs, is currently used mainly in the production of biogas. Co-fermentation (as described in the following section) has a considerable energetic potential, which to date has not been used in sizeable quantities.

Co-fermentation of solid and liquid substrates

The term "co-fermentation" refers to the fermentation of solid biowastes (*e.g.* food scraps from large canteens) together with liquid substrates, such as liquid manure. Suitable for co-fermentation are digesters in already existing sewage treatment plants and larger agricultural biogas facilities. Co-fermentation is an interesting option for the low-cost decentralised recovery of solid wastes and for producing energy from biomass.

Energy crops can be cultivated as main crops or as catch or succeeding crops, allowing for diverse crop rotations with high material and energy efficiency. Efficient methods are available for the cultivation, harvesting and conservation of energy crops.

Estimation of the potential for biogas production in Austria

In Austria an annual amount of about 40 million tonnes of biomass can be used for biogas production – 20 million tonnes of commercial fertiliser (solid and liquid manure) and 20 million tonnes of energy crops. From this amount, about 4 900 GWh (gigawatt-hours) of electricity can be produced per year as well as 6 700 GWh of heat, which corresponds to 10% of national electricity production and to the optimised demand for thermal energy of 448 000 one-family dwellings. To achieve this, 3 000-6 000 facilities will be necessary (Amon, 2001). Another study estimates the maximum technical potential (primary energy) for biogas at about 26 PJ (petajoules)/annum (Jungmeier, 1996). In the latter case about 6 400 TWh (terawatt-hours) per annum are derived from agriculture and 0.95 TWh per annum from industry and commerce and from organic household waste ("biowaste container").

Listed according to the federal provinces, the total primary energy potential for agricultural biogas facilities is estimated at about 14.5 PJ per annum (4 000 GWh), plus 1.5 PJ (400 GWh per annum) from municipal biowastes, kitchen and canteen scraps, as well as waste from slaughterhouses and meat-processing plants (Amon, 2001). Given an electrical efficiency of 28% and a thermal efficiency of 58% (about 50% of this heat is required for operating the fermenter), the potential amount of electricity is estimated at 1 100 GWh from agriculture and 96 GWh from the rest, with the potential amount of heat at 4.3 and 0.4 PJ (1 200 and 100 GWh). Although it is not the source of the highest energy potential, compared to other new/novel renewable energy sources in Austria, biogas does possess considerable final energy potential.

From an economic point of view, the national tariffs for electricity supply (valid since 1 January 2003) are relevant for the operation of a biogas plant (Table 1).

Table 1. National tariffs for the supply of electricity produced from biogas

Euro cent/kWh

	Biogas	Biogas with co-fermentation	Hybrid and multi-fuel installations
Bottleneck capacity up to and including 100 kW	16.5	12 375	Proportion according to amount of biogas used in relation to fuel-heat efficiency
Bottleneck capacity up to and including 100 kW to 500 kW	14.5	10 875	
Bottleneck capacity of more than 500 kW to 1 MW**	12.5	9 375	
Bottleneck capacity above 1 MW	10.3	7 725	

Notes:
*kW – kilowatt; **MW – megawatt.
Source: EVA, 2003.

Cost of electricity and heat production in biogas plants and of other new renewable energy sources in Austria

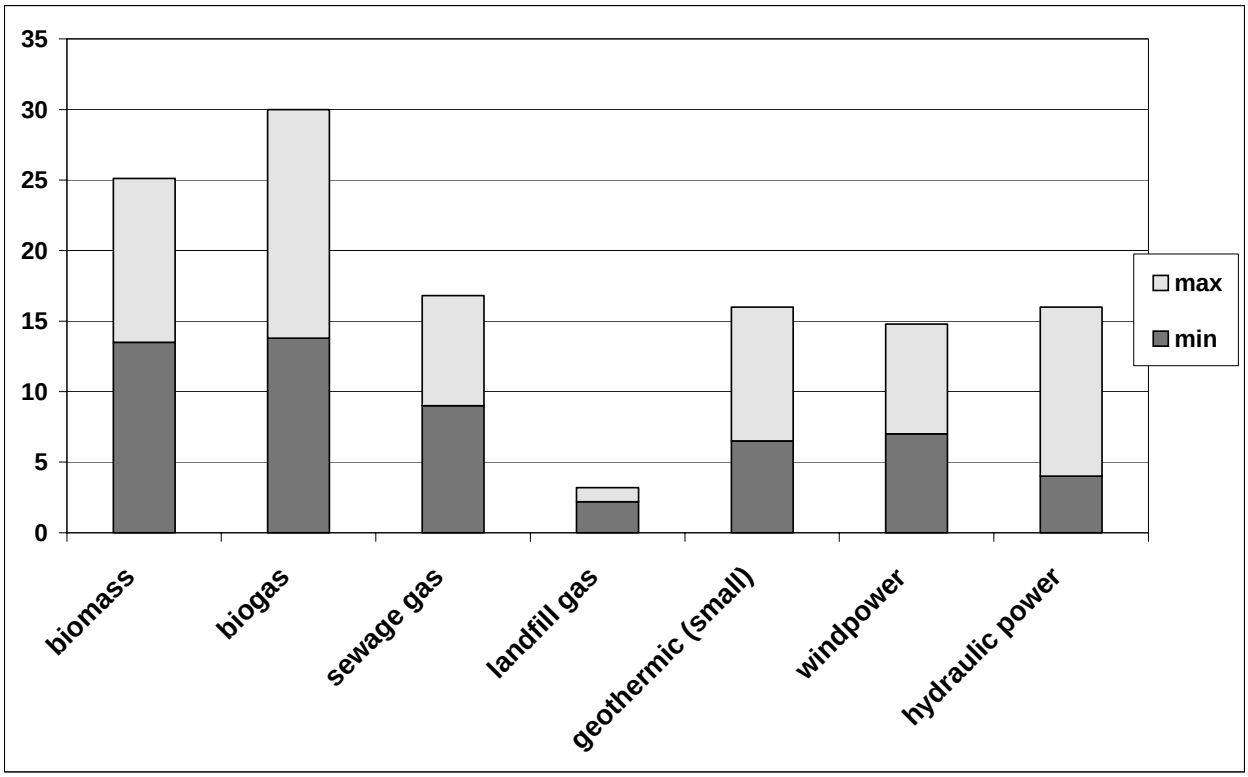
In the study entitled *Forcierung erneuerbarer Energieträger in Österreich* ("Promotion of Renewable Energy Sources in Austria") the potential and the cost of renewable energy sources are investigated (Haas *et al.*, 2001). The report estimates the primary energy potential (biogas, liquid biomass, solid biomass, geothermal energy, landfill and sewage gas) and the final energy potential (heat pumps, photovoltaics, mini hydropower, solar thermal energy and wind). In the field of electricity production, the current amount of 4.4 TWh (about 16 PJ) derived from new renewable energy sources (mini hydropower and biopower taken together) can be more than doubled in a more ambitious scenario, where electricity produced from new renewable energy sources amounts to 11.3 TWh (about 40 PJ).

Plant costs

Unlike other European countries, Austria has seen hardly any reductions in investment costs for agricultural biogas facilities in the last few years (Haas *et al.*, 2001). This may be due to the terms of subsidised investments – 30% up to 50%, leading to over-investment in the past. The total investment costs in Austria currently amount to about 11 630 EUR/kWel (kW power electricity) (including value-added tax [VAT]). It is not the block-type thermal power station (BHKW) that incurs the major part of the investment costs for agricultural biogas plants, but the area of gas production (the fermenter, pre-digester holding area, ultimate disposal place, etc.). The costs for "planning, mains connection and authorisation" account for about 3-6% of total investment costs. A falling trend can be observed here compared to facilities dating from 1997 mainly due to increasing competition between the electricity supply companies (EVU) (Figure 1).

The current electricity production costs (including VAT]) for biogas plants in Austria are between 13.80 and 29.79 EURc/kWhel; heat production costs (including VAT) between 6.54 and 14.53 EURc/kWhth (kilowatt thermal) (Figure 1).

Figure 1. Comparison of electricity production costs in EURc/kWh (including VAT) for technologies designed for using new renewables



Source: Haas *et al.*, 2001.

Cumulated energy demand for biogas production in Austria

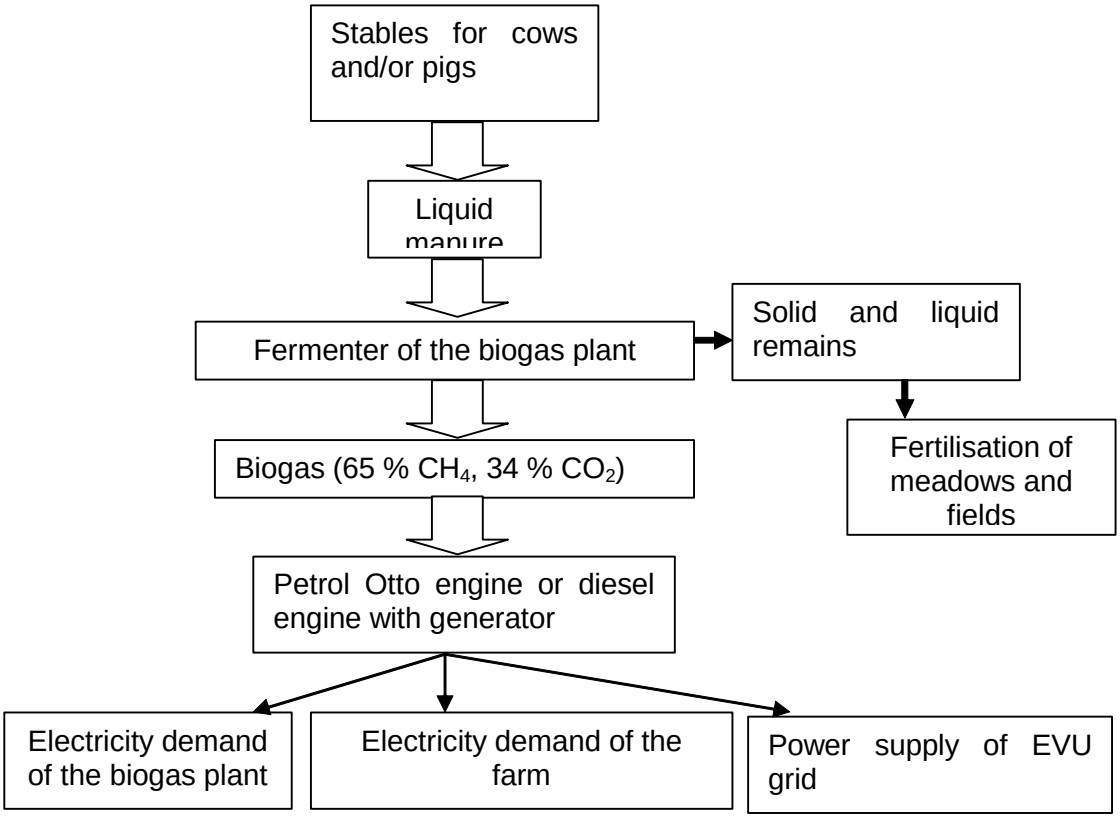
System boundaries

For a cumulated emission balance, system boundaries are necessary. All relevant energy inputs within the system boundaries are quantified and included in the emissions balance. Within the system boundaries the process stages (*e.g.* fermenter) are put together to build a process chain.

Figure 2 defines the system boundaries for biogas production on a farm with animal husbandry. Liquid and solid manure (occurring as animal waste) is fed into a fermenter. Due to the waste heat of the block-type thermal power plant, the fermenter has to be heated to about 35°C, depending on the temperature of the liquid manure. The energy necessary here is derived from the waste heat of the combustion engine. In a petrol Otto or diesel engine with a connected asynchronous generator, electricity is produced which can be used for meeting the electricity demands of the biogas plant (between 10 and 25%) and for supplying the farm with electricity (for the milking parlour, or to provide lighting, for example). Any remaining electricity is used to supply the local electricity supply companies with power. The balance also includes the disposal of liquid and solid remains on meadows and fields.

The system boundaries are extended for the production of biogas from energy crops (Figure 3). The balance includes the cultivation, harvest, transport and silage of energy crops. From the fermenter stage, the process chain is the same as that of a conventional biogas plant. In the present study, Sudan grass was the selected energy crop.

Figure 2. Biogas from a farm with animal husbandry (cows and pigs)



Source: Edelmann, 2000.

Raw materials

There are various raw materials available for the production of biogas within the system boundaries as described above. In the present study two energy sources (liquid manure and plant material) are investigated.

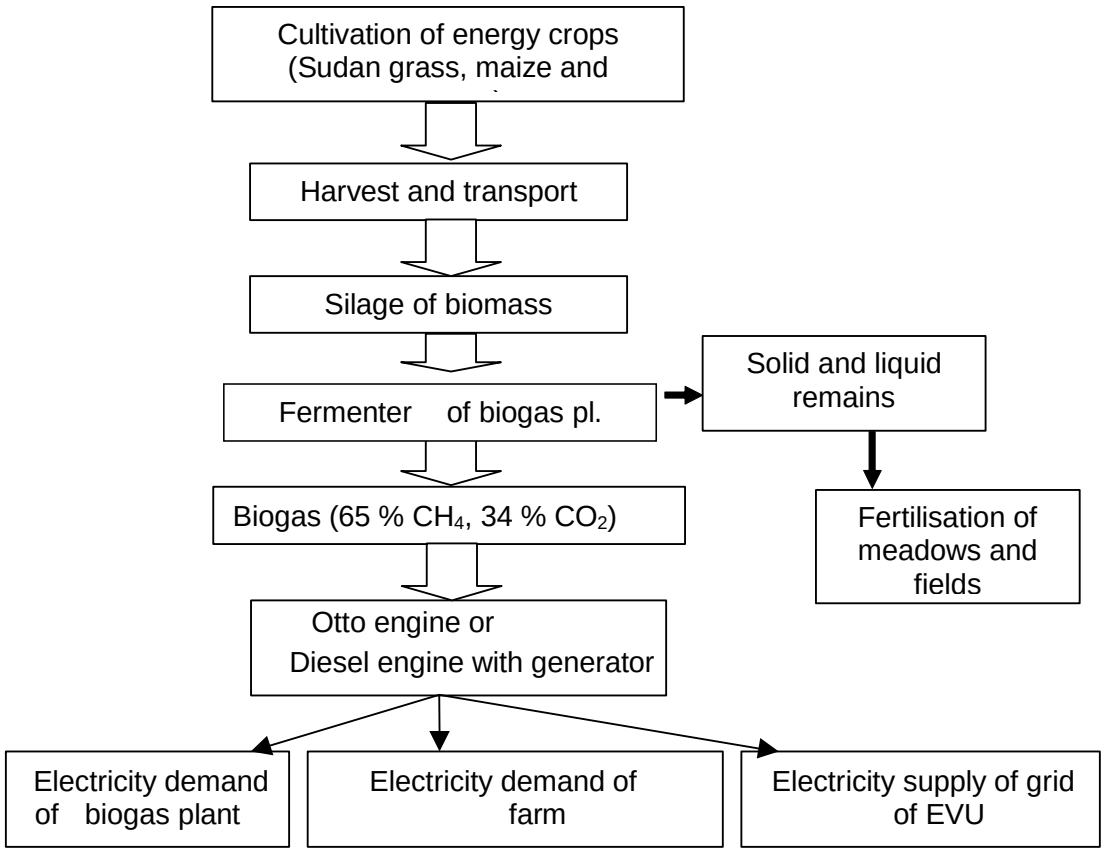
- Liquid manure

Liquid manure is considered a waste product, *i.e.* for its supply no energy input is included in the calculations.

- Sudan grass

Sudan grass is investigated as a potential energy crop. A power station in the Burgenland serves as an example under the category "grass power station" using this type of raw material. Sudan grass is a hardy annual similar to grain crops that can be cultivated as catch, succeeding or main crops. Due to its high biomass per hectare, Sudan grass (in the form of chopped straw) is highly suited for the production of biogas. The gross energy yield from one hectare of Sudan grass corresponds to about 10 000 m^3 of biogas per hectare (Priedl, 2001). For its supply, as shown in the system boundaries, the cultivation, harvest and silage of Sudan grass are included (Figure 3).

Figure 3. Biogas from the cultivation of energy crops on fallow land (key term "grass power station")



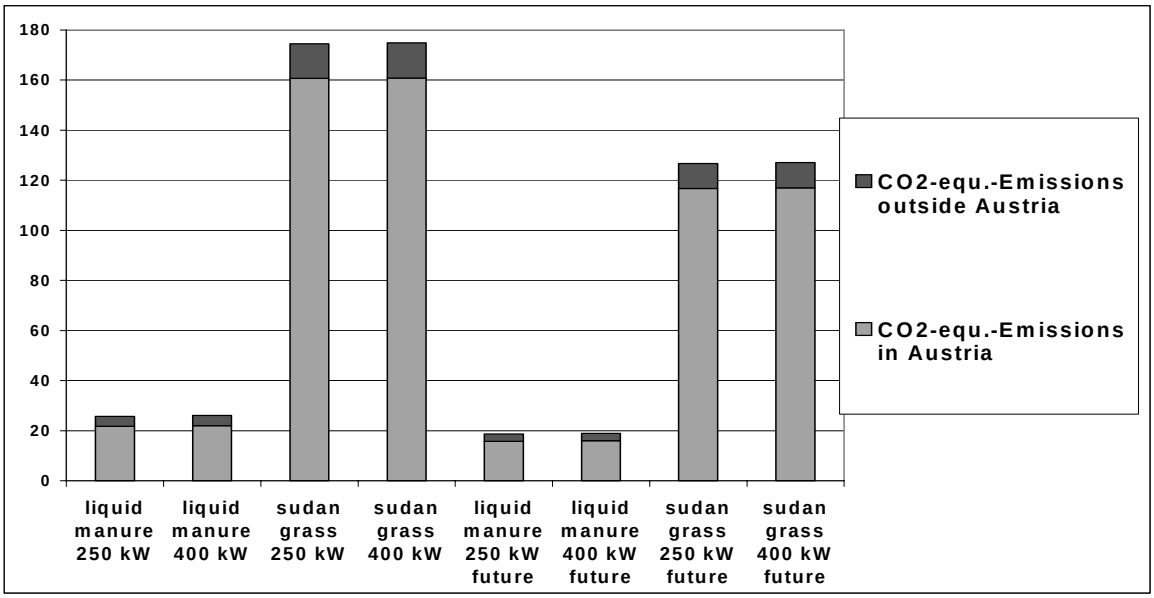
Source: Edelmann, 2000.

Cumulated emissions from electricity production in biogas plants

Figure 4 shows the total greenhouse gas emissions caused by the supply and combustion of biogas in agricultural biogas plants. Higher electrical efficiency reduces not only local emissions but, subsequently, also supply-related emissions. The cultivation and supply of Sudan grass for the production of biogas in a biogas plant causes about five times the amount of CO_2 equivalent emissions compared to biogas derived from liquid manure.

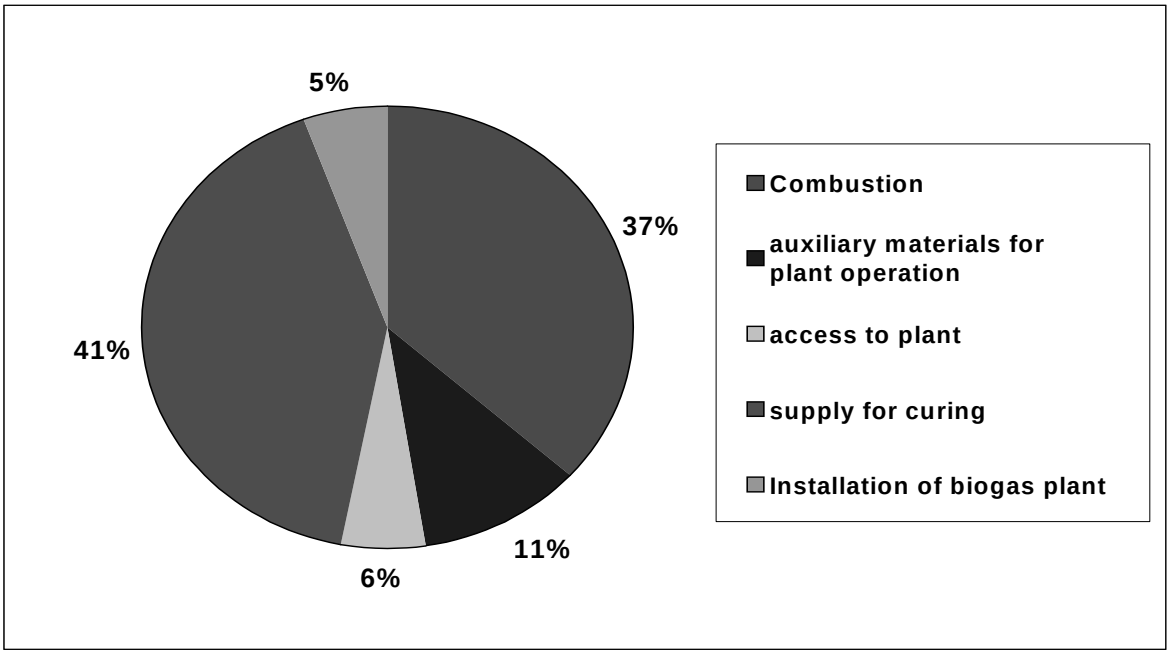
The supply for curing (emptying the fermenter and spreading fermented liquid manure on the field) causes the majority (41%) of the CO_2-equivalent emissions (Figure 5). Combustion causes CH_4 and N_2O emissions, which make up 37% of the CO_2-equivalent emissions.

Figure 4. CO_2-equivalent emissions in Austria and preceding emissions from the supply and combustion of biogas in grams for 1 kWh of final energy produced in investigated biogas plant types



Source: GEMIS 4.13, 2002.

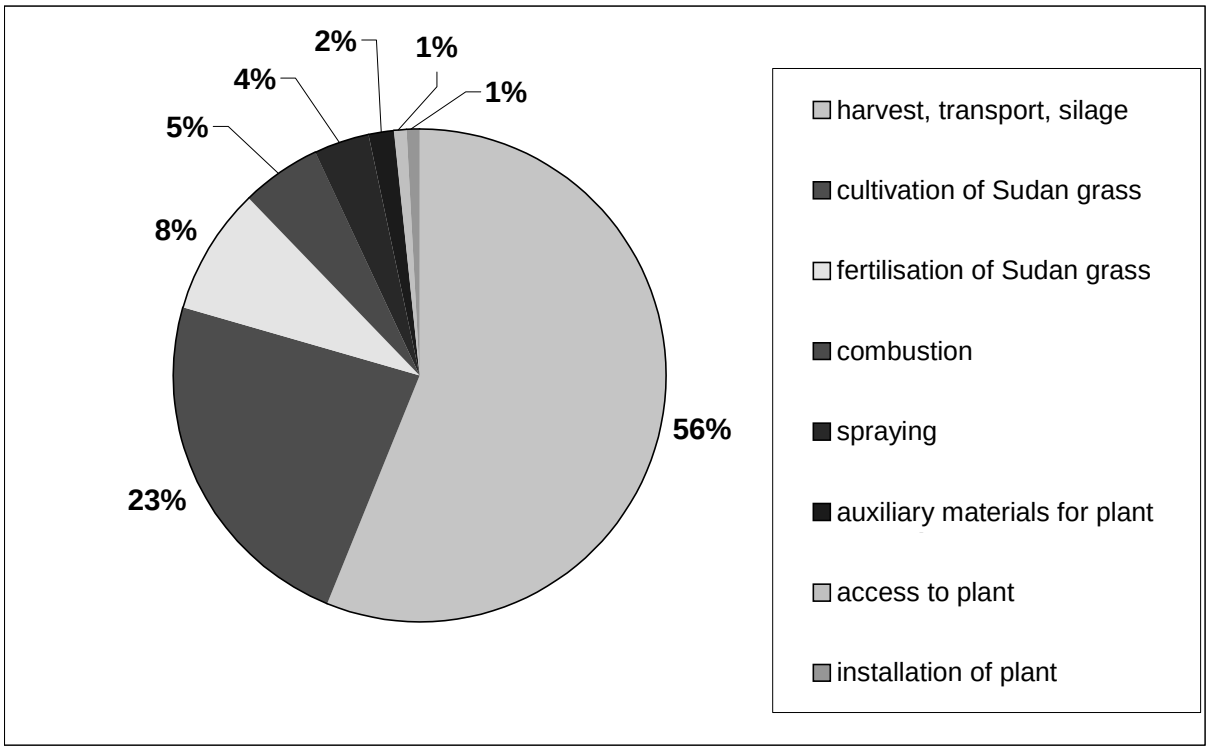
Figure 5. Distribution of total CO_2-equivalent emissions (including preceding processes) for the combustion and supply of biogas in an agricultural 250 kW biogas plant using liquid manure (current status)



Source: GEMIS 4.13, 2002.

The complete supply chain of Sudan grass – the cultivation of Sudan grass (23%); harvest; collection and transport from the field to the biogas plant and silage (56%); fertilisation of the field crop Sudan grass and assumed input of spraying substances (4%) – produce altogether about 90% of the total CO_2-equivalent emissions arising from electricity production in a biogas plant with the substrate Sudan grass (Figure 6).

Figure 6. Distribution of total CO_2- equivalent emissions (including preceding processes) for the combustion and supply of biogas in an agricultural 250 kW biogas plant using Sudan grass (current status)



Source: GEMIS 4.13, 2002.

BIBLIOGRAPHY

Amon, T. (2001), Artikelserie in TOP-AGRAR ab November 2001, Institut für Land-, Umwelt- und Energietechnik, Wien.

Baserga, U. (2000), Vergärung von Energiegras zur Biogasgewinnung, Ettenhausen.

BFL (2001), Fachbeirat für Bodenfruchtbarkeit und Bodenschutz; "Der Sachgerechte Einsatz von Bigasgülle und Gärrückständen im Acker- und Grünland, Wien.

BIOGAS (2001): www.biogas.org/info/bioland.html.

BLT (2001), Bundeslehranstalt Wieselburg, Betriebsmitteleinsatz für den Betrieb von Biogasanlagen homepage: www.blt.bmlf.gv.at/.

Braun, R. (2000), *Stand der Tecknik der Bioabfalbehandlung, Studie im Auftrag der Wiener Umweltanwaltschaft*, WUA, 1190 Wien Muthasse 62.

Dalemo, M. *et al.* (2001), *Environmental systems analysis of management systems for organic waste in Anaerobic Digestion 2001*, S. 235-240, Antwerpen.

ECOUNDCO (2001): www.ecoundco.at, Literaturhinweise.

Edelmann, W. *et al.* (2000), Publikation Gegenüberstellung der Ökobilanzen und ökonomischer Vergleich von Kompostierung, Vergärung und thermischer Behandlung von Abfällen, Baar, 2001.

Edelmann, W. *et al.* (2001), "Co-Vergärung von festen und flüssigen Substraten": www.biogas.ch/f+e/covede.htm, Baar 2000.

ENTEC (2001), Environment Technology: www.biogas.at.

ENTEC (2002), Telefonische Auskunft am 30, 1 (2002), zukünftige Entwicklung der elecktrischen Wirkungsgrade bei Biogasanlagen.

EVA (2003), Energieverwertungsagentur Wien, Einspeistarife für Biogas in den Bundesländern auf der homepage: www.eva.ac.at.

Fachverband Biogas e. V. (2000), *Biogasratgeber für Landwirte*, München.

GEMIS 4.13, Results from the computermprogramm "Global Emission Model for Integrated System", Umweltbundesamt, Vienna, 2002.

Graf, W. (1998), "Biogas für Österreich" S. 35-71, BM für Land- und Forstwirtschaft, Wien.

Graf, W. (2001), Gesprâchsnotiz und telefonische Auskunft am, 12 September.

Haas, R. *et al.* (2001), "Strategien zur weiteren Forcierung emeuerbarer Energieträger in Österreich," S. 80-114, TU Wien, Institut für Energiewirtschaft, Wien.

Hülsbergen, K.-J. (2000), Einsatz des Modellls REPRO zur Stoff-und Energiebilanzierung im Versuchsgut Scheyem, in Beiträge zur 6, Wissenschaftstagung zum Ökolgischen Landbau, S.67-72, Halle/Saale.

Jungmeier, G. (1996), Bewertung der Biogastechnik, Joanneum Research, Institut für Energieforschung, Graz.

Jungmeier *et al.* (1999), Joanneum Research, Treibhausgasbilanz der Bioenergie, Graz.

Kronos (2002), Produkt-info über Einsalze für die Schwefelreduktion in Biogas, Leverkusen.

LBA MÜNCHEN (1999), Landtechnik Beratung Bayem, Fließschema einer Biogasanlage, München.

Linde (2001), Betriebsunterlagen der Fa. Linde-KCA-Dresden, GMBH, Dresden.

Priedl (2001), Anlagenbetreiber der Biogasanlage “Graskraft” im Burgenland; Gesprächsnotiz vom Telefonat am, 20 October.

Ramharter, R., *et al.* (2000), Energiebilanzierung ausgewählter Feldfüchte des biologischen und konventionellen Landbaus im pannonischen Klimaraum in in Beiträge zur 6.

RETEC (2001), Regererative Energietechnik: www.biogas.de.

Schleiss *et al.* (2000), Stromproduktion aus der Fesstoff-Vergärung Seite 9, Ökobilanz im Auftrag des Biogasformum Schweiz.

Sedelmeier, J. (2000), Artikel “Nachwachsende Rohstoffe in Biogasanlagen”, Niederbayern.

Wellinger, A. *et al.* (1983), Biogas Handbuch S. 15-48, Verlag Wirz Aarau, Zürich.

Wissenschaftstagung zum Ökolgischen Landbau, S.365-340, Wien.

BIOGAS PRODUCTION FROM PIG SLURRY IN KOREA

Jong-sik Lee, Woo-kyun Park, Dong-gyu Im, and Mun-hwan Koh[1]

Abstract

Farm-scale biogas plants have been designed to process pig slurry of 10 m^3 day^{-1} under mesophilic conditions. The performance of pig slurry digestion was stable, based on the results of the process monitoring such as Volatile Solids reduction, pH and alkalinity variation, Chemical Oxygen Demand reduction and biogas production. The biogas yield varied from 0.52 m^3 to 0.72 m^3 per kg of added Volatile Solids. The biogas composition was similar throughout the operation period with 68-73% of methane and 25-30% of carbon dioxide. The produced biogas was used in a dual-fuel engine-generator to produce heat and electricity. Through the whole period of operation, the engine-generator offered 50-75% of the total electricity requirement for the system without operational failures. In this system, the biogas generation rate was 138 m^3 day^{-1}, with 230 kg of Volatile Solids addition. To produce the electricity, the amount of biogas consumed was 1.8 m^3 per kWh at 5-9 kW power load. This result showed that renewable energy production with 2 000 pigs was 216 000 kWh yr^{-1} – enough to meet the electricity demands of 100 rural households in Korea. During the anaerobic digestion of pig manure in biogas plants, an average 50% of VS reduction was consistently achieved. The digesters were efficient in reducing pathogens and offensive odours in wastewater. The numbers of *E-coli* and coliform bacteria were reduced by about 10^3 times.

The target for renewable energy use is 3% of electricity consumption by 2010. Therefore, there is a plan to establish the biogas plants over the three years from 2003-05. The funds for this plan will be supported partly by government. To develop the renewable energy production, several promoting measures are required such as special taxation measures, subsidies to help sell by-products in the form of liquid fertiliser and soil conditioner. In the future, it will be necessary to develop an integrated organic waste treatment system, including food waste and post-processing residues, as well as animal waste.

Renewable energy production is not well developed in Korea. However, the government has a plan to promote renewable energy production. As stated above, the target for renewable energy use is 3% of electricity consumption by 2010. Livestock farming has been increased, following a rise in meat consumption since the 1970s. Among the major categories of livestock, pigs produce the largest amounts of waste. Swine manure and wastewater from confined pig farms have a strong potential to contribute pollutants, such as organic matter, nutrients, pathogens and disgusting odours. However, when swine manure is effectively controlled, it is a valuable source of fertiliser and soil conditioner, and as an energy source (Angelidaki and Ahring, 2000; Bonmatí *et al*., 2001; van Lier *et al*., 2001).

1. National Institute of Agricultural Science and Technology, Korea.

Biogas production from organic wastes is one of the major research activities on biomass in Korea. The strong demand for renewable energy generation and a range of new and forthcoming environmental legislation, such as the Climate Change Levy and the Landfill Directive, may increase an interest in anaerobic digestion technology. Biogas production technology using pig slurry at farm scale has been developed in Korea.

Status of livestock farming in Korea

In Korea, pigs produce the largest amounts of waste among the major livestock with 13.4 million tonnes/year^{-1} in 2000. Those of beef cattle, dairy cattle and chicken were 7.5, 7.1 and 4.9 million onnes/year^{-1}, respectively. In addition to enlargement, another characteristic of livestock farming in Korea is its increasing scale. As shown in Table 1, the number of pigs raised was increased from 6.5 million in 1995, to 8.2 million in 2000. On the other hand, the number of farms decreased from 46 000 to 24 000 during the same period. This shows that the scale of livestock farming in Korea has enlarged.

Table 1. Annual changes in the number of pigs and of farms in Korea, 1995-2000

(thousands)

Year	1995	1996	1997	1998	1999	2000
Number of head	6 461	6 516	7 096	7 544	7 864	8 214
Number of farms	46	33	27	27	24	24

Source: Ministry of Agriculture and Forestry, 2001.

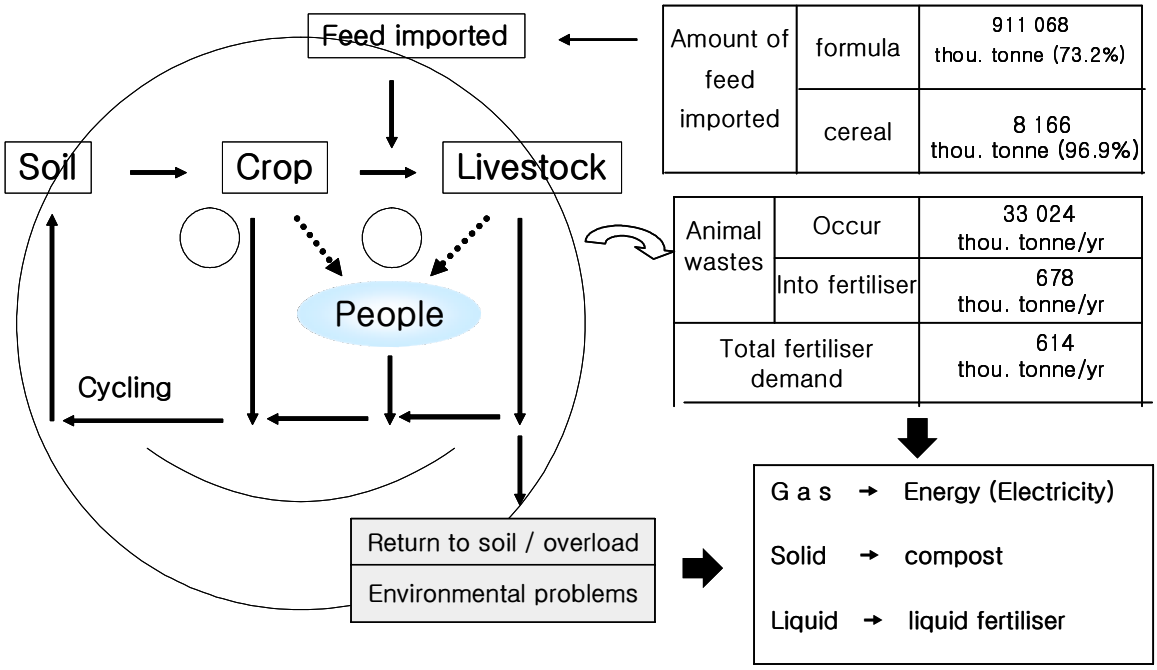
The third characteristic is import of high amounts of animal feed. Figure 1 shows the biomass cycle of livestock in Korea. Korea imports formula and cereal as animal feed. Those amounts are 911.1 million and 8.2 million tonnes/year^{-1}, which are 73.2% and 96.9% of total amounts of animal feed, respectively. Livestock animals produce animal wastes of 33.0 million tonnes/year^{-1}. This amount corresponds to 678 000 tonnes of chemical fertiliser. When animal wastes are effectively controlled, it is a valuable resource as a fertiliser, soil conditioner and as an energy source (Angelidaki and Ahring, 2000; Bonmatí *et al*., 2001; van Lier *et al*., 2001). However, it has a strong potential to release global-warming gases such as methane and nitrogen oxides, offensive odour and water contamination, because of its high concentration of organic matter, nutrients and pathogens.

Research on biogas production in Korea

Major research activities on biomass utilisation in Korea include: hydrogen production from organic wastes; biogas production from organic wastes (such as food residues, manure, sludge) by anaerobic digestion; bioethanol production from lignocellulosic biomass; biodiesel production from waste cooking oil; biological CO_2 fixation and utilisation of microalgae; and thermal conversion of biomass for biofuel production. In Korea, research on the biogas production began in the early 1970s. During the early stage, from the 1970s-80s, the plant was small scale, required large amounts of manpower and had a low energy supply (Figure 2).

In 1999, the integrated biogas energy system (IBES) was developed (Figure 3). It is an anaerobic digester of 200 m^3, which is a farm-scale biogas plant for generating energy from manure from about 2 000 pigs. This system consists of three parts: an anaerobic digester for reduction of organic matter and the production of biogas; an electricity generator for collecting energy; and electrochemical oxidation process for waste water treatment containing biorefractory pollutants.

Figure 1. Biomass cycle of livestock in the Korean agro-ecosystem



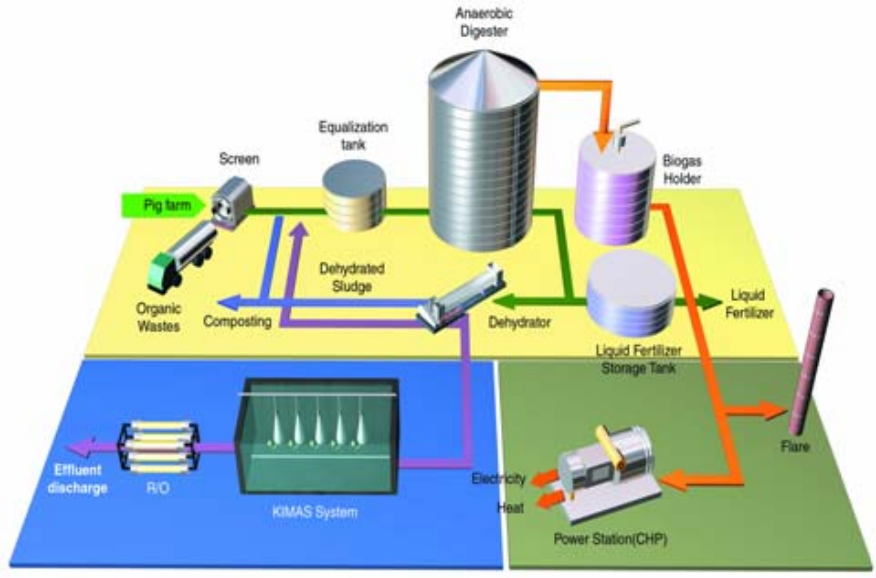
Source: Authors.

Figure 2. Biogas production plant in the 1970s



Source: Authors.

Figure 3. Diagram of an integrated biogas energy system



Source: Chae *et al.*, 2001*b*.

Digester

Digestion takes place in a semi-continuous, single-stage, continuously stirring anaerobic digester, under 35°C of mesophilic temperature. As swine manure contains insufficient methane bacteria for the initiation of the biological anaerobic digestion, the reactor was inoculated with fouled sewage sludge and animal manure to initiate a rapid start-up. The empty reactor was filled to 20% of total net volume with sewage sludge and 5% of animal manure. This was heated to 25°C, then feeding was started with 20% of the designed quantity, with a 1°C-per day temperature increase until a temperature of 35°C was reached. The digester was constructed as a cylindrical flat-bottomed tank with a depth/width ratio close to 1, instead of the conical bottoms of most early anaerobic digesters. In order to achieve proper mixing performance, a gas recirculation with draught tube and a supplementary external recirculation pump were used together. The major advantage of this mixing system is the complete absence of any mechanical part inside the reactor. The operation of this plant is fully automated.

Dual fuel engine-generator

An electricity generator may be a more suitable way to use energy even if it adds capital costs. Consequently, in this plant, a dual-fuel engine-generator was used to supply all energy demands on the plant, and the surplus of electricity and heat was planned to be fed into the pig-breeding farms. The biogas produced by the digester was collected, and sent to a dual-fuel engine-generator. The electricity generator was rated at continuous 33 kW (kilowatt), 380/220 volt, 3-phase, 0.8 power factor, and 60 hertz. The engine allowed for up to 80-92% substitution of biogas for diesel fuel. The heat was recovered from the engine's coolants and exhaust heat exchanger systems.

Electrochemical oxidation process

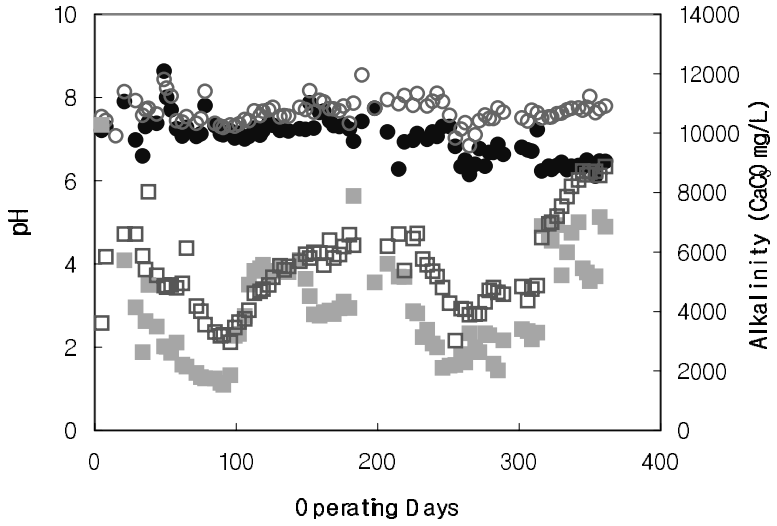
The effluent of the swine manure digester was treated for the simultaneous removal of both the Chemical Oxygen Demand (COD) and nitrogen in an electrochemical oxidation batch reactor. The basic form of an electrochemical process requires two electrodes (an anode and a cathode), an

electrolyte, and a source of current. The electrolyte cell used in this study consisted of a 6 -cubic litre tank, and four plate dimensionally stable anodes (DSA) (Pt/Nb/Sn-Ti) as anodes (5x6 cm) and 5 titanium cathodes with the inter-electrode gap maintained at 10 mm. The supply voltage was 7-8V DC and the current varied from 8A to 30A depending on the experimental purpose. During the electro-oxidation process the solution was continuously re-circulated, and vigorously agitated by a magnetic stirrer. Samples for analysis were taken at regular intervals. Sodium chloride was added as a support electrolyte. Previous researchers have reported many parameters that affect electrochemical reactions, such as current density, electrolyte types and its concentration, anode material, etc. (Vaze *et al*., 1998; Polcaro *et al*., 1999). However, this test was not intended to examine all of these parameters, only the economical and technical aspects of using electrochemical oxidation as a post treatment method of digested effluent, based on the electricity demand.

Performance of anaerobic digester

Swine manure contains significant quantities of ammonia, which is the main inhibitor of anaerobic digestion (Angelidaki and Ahring, 1994; Hansen *et al*., 1998). Free-ammonia (NH_3) is strongly dependent on the pH. The pH of the digester was maintained at 6.3 and 8.5, a healthy environment for the methane-forming bacteria. Alkalinity was maintained in the range of 2 966 to 6 606 mg L^{-1} as $CaCO_3$, which was sufficient to keep a stable pH (Figure 4).

Figure 4. Variation of pH and alkalinity in the digester



Source: Chae *et al.*, 2001*a*.

Because of the temperature sensitivity of the methanogen, the temperature inside the digester ranged between 34.5 and 35.8°C, with a 0.8°C maximum deviation per day from 35°C. In the digestion of swine manure, not only an imbalanced biological process but also a physical hindrance, such as sedimentation and scum formation, should be very carefully monitored in order to avoid process failures. According to the solids profile, the solids concentration deviated from the average value in the digester by no more than 10% over the entire digester depth. The temperature at the top of

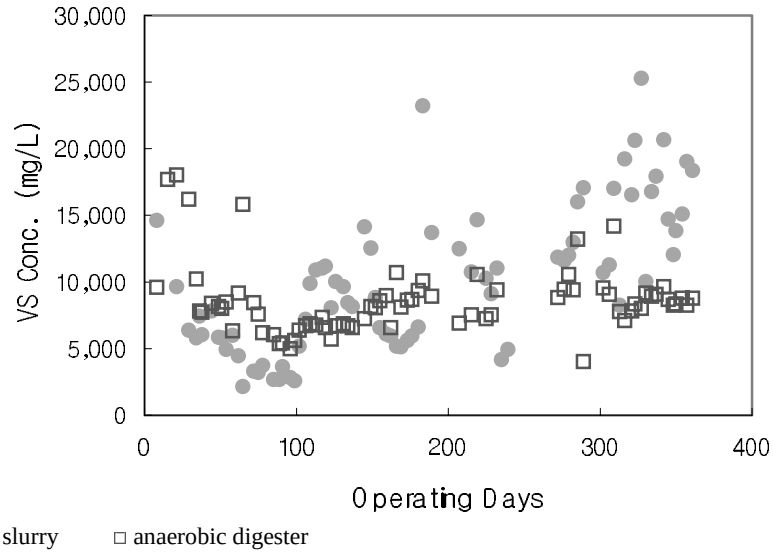
the digester was only 0.5°C higher than the bottom. This result indicates that adequate mixing within the digester was achieved. Figure 5 shows the Volatile Solids (VS) variation of influent pig slurry and digester effluent with operating periods. The average VS concentration of influent and effluent were 11 600 and 8 450 mg L^{-1}, respectively. In this system, VS/TS (Total Solids) ratio of the digester sludge, which is an excellent indicator for determining the accumulation of inorganic matter inside the digester, averaged 0.56 for the entire run.

Production of biogas and electricity

During anaerobic digestion of pig manure in the biogas plant, a 50% reduction (on average) of VS was consistently achieved (Figure 6). However, no further VS reduction occurred, due to the presence of inherent materials such as lignin, cellulose and hemicellulose, which are mostly non-biodegradable. The varying input VS amount resulted in significant fluctuations in biogas production. The biogas yield varied from 0.52 to 0.72 m^3 per kg of added VS. The biogas composition was relatively constant throughout the operating period with the 68-73 vol. % of methane and 25-30 vol. % of carbon dioxide.

In this system, biogas generation rate was 138 m^3 day^{-1}, with 230 kg of added VS. To produce the electricity, the amount of biogas consumed was 1.8 m3 per kWh (kilowatt-hour) at 5-9 kW power load. This result showed that renewable energy production with 2 000 pigs was 216 000 kWh/$year^{-1}$, which can supply the electricity needs of 100 households in Korean rural areas.

Figure 5. The changes of VS concentrations with anaerobic digester operating periods



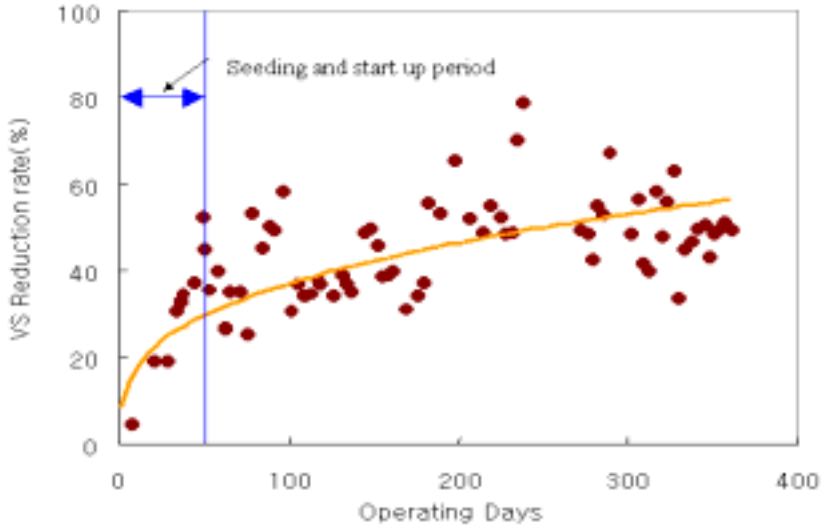
Source: Chae *et al.*, 2001*a*.

Purification of waste water

The performance characteristics of the biogas plant were monitored. As shown in Figure 7, the COD in the influent was reduced by 50%, from 33 172 to 16 279 mg L^{-1}. In particular, concentration of Soluble Chemical Oxygen Demand (SCOD) was decreased by 79%, from 15 199 to 3 183 mg L^{-1}. The effluent was measured after 30 minutes of settling. The digester showed efficiency in reducing pathogens in wastewater. Numbers of *E-coli* were decreased from $1.73x10^5$ in raw pig slurry, to

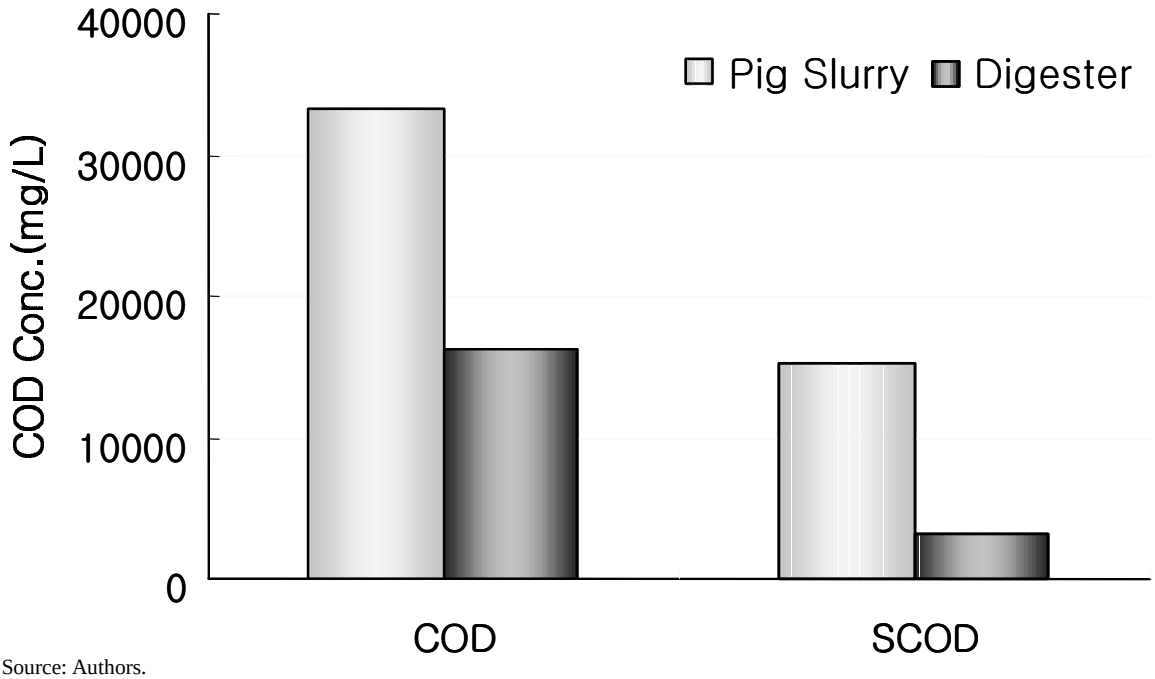
$2.31x10^2$ in digester effluent. Those of coliform were reduced about 10^3 times, from $2.54x10^5$ in raw pig slurry to $3.24x10^2$ in digester effluent. Offensive odours also decreased: untreated pig slurry was rated at 4-5 (indicating a serious nuisance), whereas digester effluent was rated at only 1-2 (indicating little awareness of a problem).

Figure 6. VS reduction rate in biogas plants with operating periods



Source: Chae *et al.*, 2001*a*.

Figure 7. COD concentration of raw pig slurry and digester effluent



Source: Authors.

Effects of biogas production from pig slurry

Biogas plants are suitable for the treatment of highly concentrated organic wastes such as pig slurry. In technical terms, they have developed a system for the production of biogas. In environmental terms, they improve water quality, by reducing organic matter; decrease the odour nuisance; lower the emission of greenhouse gases, such as methane and nitrogen oxides; and diminish the level of pathogens in wastewater. In economic terms, they produce renewable energy, methane. Table 2 shows the potential amounts of biogas from animal waste. Pig slurry produced in Korea has potential methane generation of 422 329x$10^3$$m^3$. This corresponds to 206 941 kl of diesel, or 105 582m^2 of propane. Also, it can reduce the cost of wastewater treatment and utilise the by-product. After biogas production, liquid matter can be used as liquid fertiliser, which has high N efficiency. Solid matter can be a good soil conditioner.

Table 2. Potential amounts of biogas from animal waste

	Potential amounts of methane ($x 10^3 m^3$)	Conversion amounts	
		Diesel (kl)	Propane (m^3)
Pig slurry	422 329	206 941	105 582
Livestock manure	1 450 216	650 207	362 554

Source: Authors.

Prospects for a biogas plant system

Korea has a plan to promote renewable energy production. The target for renewable energy use is 3% of electricity consumption by 2010. For this, the government has made an effort to develop a Korean-style biogas plant system. There is a plan to establish the biogas plant for the three years from 2003-05. The total cost of this plan will be approximately USD 466 700, with funds of 50% coming from central government.

At present, methods of renewable energy production in Korea are not well advanced. In order to bring about development, several promoting measures are needed, including special taxation measures, such as a price policy favouring renewable energy, and subsidies to help sell by-products as liquid fertiliser and soil conditioner. In the future, the development of an integrated organic waste treatment system, including food waste and residues from processed products, as well as animal waste is needed.

Conclusion

Biogas production with pig slurry has beneficial effects in several fields. In technical terms, it can be helpful in developing the technology for biogas production, suitable to the Korean condition. In environmental terms, the treatment of pig slurry by anaerobic digestion, can remove water pollutants which consequently protects water quality. It also reduces the problems posed by odours, and pathogens. Biogas generating systems convert methane (one of the major greenhouse gases) into carbon dioxide, which has the effect of reducing greenhouse gas emissions, as carbon dioxide has 21-times less greenhouse effect than methane. In economic terms, renewable energy and by-products in the form of liquid fertiliser and soil conditioner are produced.

The Korean government has the target of 3% of electricity consumption from renewable energy by 2010. One part of the plan is the establishment of biogas production systems over the three years 2003-05.

For the practical use of renewable energy, some initiatives are required. These include special taxation policies, such as a price measure favouring renewable energy; permission to sell by-products; and the development of integrated organic waste treatment systems, etc. Integrated organic waste treatment systems can utilise animal waste, food waste and residues from agricultural processing as energy production resources.

These are the recommendations for using biomass:

- It is important in the context of the reduction of environmental contamination to manage organic wastes including animal wastes and crop residues.
- Organic wastes or crop residues could be actively used in energy production in more efficient ways, through the development of technologies such as biogas production technology, rather than simple recycling.
- Consider developing an indicator relating the production or utilisation of biomass to energy use or its use-efficiency, energy production or recycling of organic materials produced in the agricultural sector.

BIBLIOGRAPHY

Angelidaki, I. and B.K. Ahring (1994), "Anaerobic thermophilic digestion of manure at different ammonia loads: effect of temperature", *Wat. Res.*, 28 (3), pp. 727-731.

Angelidaki, I. and B.K. Ahring (2000), "Methods for increasing the biogas potential from the recalcitrant organic matter contained in manure", *Wat. Sci. Tech.*, 41 (3), pp. 189-194.

Bonmatí, A., X. Flotats, L. Mateu and E. Campos (2001), "Study of thermal hydrolysis as a pretreatment to mesophilic anaerobic digestion of pig slurry", *Wat. Sci. Tech.*, 44 (4), pp. 109-116.

Chae, K.J., S.K. Lim, K.H. Choi, W.K. Park and D.K. Lim (2001*a*), "Anaerobic Digestion of Pig Slurry and Biogas Utilization Technology" (in Korean), *10th Korea/Japan Symposium in Water Environment 2001*, pp. 95-102.

Chae, K. J., S.K. Lim, K.H. Choi, W.K. Park and D.K. Lim (2001*b*), "Treatment of Pig Slurry and Biogas Production" (in Korean), *Journal of the Korea Organic Waste Recycling Council*, 9 (3), pp. 19-26.

Hansen, K. H., I. Angelidaki and B.K. Ahring (1998), "Anaerobic digestion of swine manure: Inhibition by ammonia", *Wat. Res.*, 32 (1), pp. 5-12.

Ministry of Agriculture and Forestry, Republic of Korea (2001), *Agricultural and Forestry Statistical Yearbook* (in Korean), pp. 96-131.

Polcaro, A.M., S. Palmas, F. Renoldi and M. Mascia (1999), "On the performance of Ti/SnO_2 and Ti/PbO_2 anodes in electrochemical degradation of 2-chlorophenol for wastewater treatment", *Journal of Appl. Electrochem.*, 29, pp. 147-151.

van Lier, J.B., A. Tilche, B.K. Ahring, H. Macarie, R. Moletta, M. Dohanyos, L.W. Hulshoff Pol, P. Lens and W. Werstraete (2001), "New perspectives in anaerobic digestion", *Wat. Sci. Tech.*, 43 (1), pp. 1-18.

Vaze, A.S., S.B. Sawant and V.G. Pangarkar (1998), "Electrochemical oxidation of *p-t*-butyltoluene to *p-t*-butylbenzaldhyde", *Journal of Appl. Electrochem.*, 28, pp. 623-626.

3. Social Dimension

Page

Integrated Renewable Energy Farms for Sustainable Development in Rural Communities
Nasir El Bassam, Integrated Research Center for Renewable Energy (IFEED), Germany *263*

Small-sized Commercial Bioenergy Technologies as an Instrument of Rural Development
Giuliano Grassi, European Biomass Industry Association (EUBIA), Belgium; Gianluca Tondi, ETA Renewable Energies, Italy; and Peter Helm, WIP-Munich, Germany *277*

A Global Bioenergy Network and its Impact on OECD Countries
Rainer Janssen, WIP-Renewable Energies/(LAMNET), Germany; Peter Helm, WIP-Munich, Germany; Angela Grassi, ETA Renewable Energies, Italy; Giuliano Grassi, European Biomass Industry Association (EUBIA), Belgium; J.R. Moreira, Centro National de Referência em Biomassa (CENBIO), Brazil; and O. Masera, Universidad Nacional Autonóma de México, Mexico *289*

Agriculture and Renewable Resource Chains in Wallonia, Belgium
Didier Marchal, ValBiom, Belgium; and Yves Schenkel, Centre de recherches agronomiques de Gembloux (CRA), Belgium *301*

Key Factors for the Successful Market Development of Bioenergy – Experiences from Austria
Christian Rakos, Austrian Environment Agency, Austria *307*

INTEGRATED RENEWABLE ENERGY FARMS FOR SUSTAINABLE DEVELOPMENT IN RURAL COMMUNITIES

N. El Bassam[1]

Abstract

Current approaches to energy are unsustainable and non-renewable. Implementing sustainable energy strategies is one of the most important levers humankind has for creating a sustainable world. Future energy policies should put more emphasis on developing the potential of energy sources, which should form the foundation of future global energy structure. The United Nations, in support of the Sustainable Rural Environment and Energy Network (SREN, FAO), is developing a concept for the optimisation, evaluation and implementation of integrated renewable energy sources for rural communities.

Introduction

Current approaches to energy are unsustainable and non-renewable. Furthermore, energy is directly related to the most critical social issues which affect sustainable development: poverty, jobs, income levels, access to social services, gender disparity, population growth, agricultural production, climate change and environmental quality and economic and security issues. Without adequate attention to the critical importance of energy to all these aspects, the global social, economical and environmental goals of sustainability cannot be achieved. Indeed, the magnitude of change needed is immense, fundamental and directly related to the energy produced and consumed nationally and internationally (El Bassam, 1998a).

The key challenge to realizing these targets is to overcome the lack of commitment and to develop the political will to protect people and the natural resource base. Failure to take action will lead to continuing degradation of natural resources, increasing conflicts over scarce resources and widening gaps between rich and poor. We must act while we still have choices. Implementing sustainable energy strategies is one of the most important levers humankind has for creating a sustainable world. More than two billion people, mostly living in rural areas, have no access to modern energy sources. Food and fodder availability is very closely related to energy availability (Chiaramonti *et al.*, 1998).

More than two billion worldwide currently have no access to grid electricity or other efficient energy supplies. That is one-third of humanity.

1. International Research Centre for Renewable Energy (IFEED), Germany.

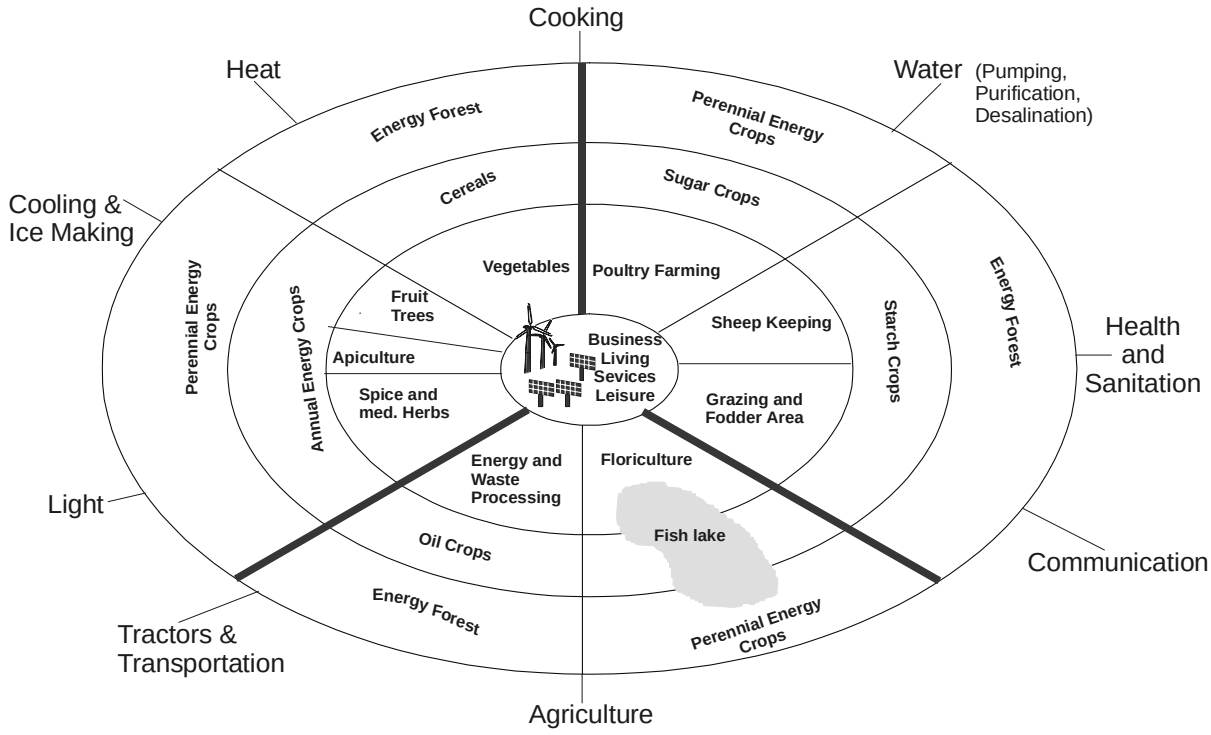
In order to meet challenges, future energy policies should put more emphasis on developing the potential of energy sources, which should form the foundation of future global energy structure. In this context, the FAO is supporting the SREN in developing a concept for the optimisation, evaluation and implementation of integrated renewable energy sources for rural communities.

The Integrated Renewable Energy Farm

Concept

The concept of an Integrated Renewable Energy Farm (IREF) is a farming system model with an optimal energetic autonomy including food production and, if possible, energy exports (El Bassam, 1998). Energy production and consumption at the IREF has to be environmentally friendly, sustainable and ultimately based mainly on renewable energy sources. It includes a combination of different possibilities for non-polluting energy production, such as modern wind and solar electricity production, as well as the production of energy from biomass (Figure 1).

Figure 1. Basic energy requirements for rural communities



Source: El Bassam, 2001.

The IREF concept includes a decentralised living area from which the daily necessities (food and energy) can be produced directly on-site with minimal external energy inputs. The land of an IREF may be divided up into compartments to be used for growing food crops, fruit trees, annual and perennial energy crops and short-rotation forests, along with wind and solar energy units within the farm.

An IREF system based largely on renewable energy sources would seek to optimise energetic autonomy and an ecologically semi-closed system, while also providing socio-economic viability and giving due consideration to the newest concept of landscape and bio-diversity management. Ideally, it will promote the integration of different renewable energies, promote rural development and contribute to the reduction of greenhouse gas emissions (Figure 1).

The objectives

The project is an activity of the SREN of the European System of Cooperative Research Networks in Agriculture (ESCORENA). Under the leadership of FAL and the SREN working group on Biomass Production and Conversion of Energy, a group of SREN member scientists and others will collaborate to:

- develop the conceptual framework of the IREF model;
- gather the required information;
- elaborate the results into a functional model;
- publish the results; and
- prepare a project proposal for experimental verification of the model.

The overall objective is that the IREF concept be successfully introduced into agricultural production systems which have to be completely sustainable.

As a contribution to the above, this project seeks to:

- Develop a workable scientific model for estimating the requirements and feasibility of an IREF ready for experimental verification or demonstration in Europe; and
- Prepare a project proposal for experimental verification (demonstration farms) of the model under various conditions.

The IREFs will also offer possibilities for demonstration and education. Data collection and model development will take place in close collaboration with the Sustainable Development Department Group of the regional office for Europe (REUS) and the Environment and Natural Resources Services of the Sustainable Development Department (SDRN) and other technical departments of FAO in order to assure the adaptability of the model to non-European regions and exchanges of mutual benefit between this project and two on-going FAO programmes (*e.g.* the World Food Summit Action Plan; Strategy 2000) and future FAO initiatives such as “Energizing the Food Chain” and developments in organic farming.

Results

Global approach

Basic data should be available for the verification of an IREF. Various climatic constraints, water availability, soil conditions, infrastructure, availability of skills and technology, population structure, flora and fauna, common agricultural practices and economic and administrative facilities in the region should be taken into consideration.

Renewable energy technologies are available from different natural resources: biomass, geothermal, hydropower, ocean power, solar (photovoltaic and solar thermal), wind and hydrogen.

Climatic conditions prevailing in a particular region are the major determinants of agricultural production. In addition to that, other factors like local and regional needs, availability of resources and other infrastructure facilities also determine the size and the product spectrum of the farmland. The same requisites also apply to an IREF. The climate fundamentally determines the selection of plant species and their cultivation intensity for energy production on the farm. Moreover, climate also influences the production of energy-mix (consisting of biomass, wind and solar energies) essentially at a given location; and the type of technology that can be installed also depends decisively on the climatic conditions of the locality in question. For example, cultivation of biomass for power generation is not advisable in arid areas. Instead a larger share can be allocated to solar energy techniques in such areas. Likewise, coastal regions are ideal for wind power installations.

Taking these circumstances into account, a scenario was made for an energy farm of 100 ha in the different climatic regions of Northern and Central Europe, Southern Europe, Northern Africa and the Sahara and Equatorial regions (Table 1). It was presumed that one unit of this size needs about 200 mega-watt-hours (MWh) heat and 100 MWh power per annum for its successful operation. A need for fuel of approximately 8 000 litres per annum has to be calculated. The possible shares of different renewable energies are presented in Table 1.

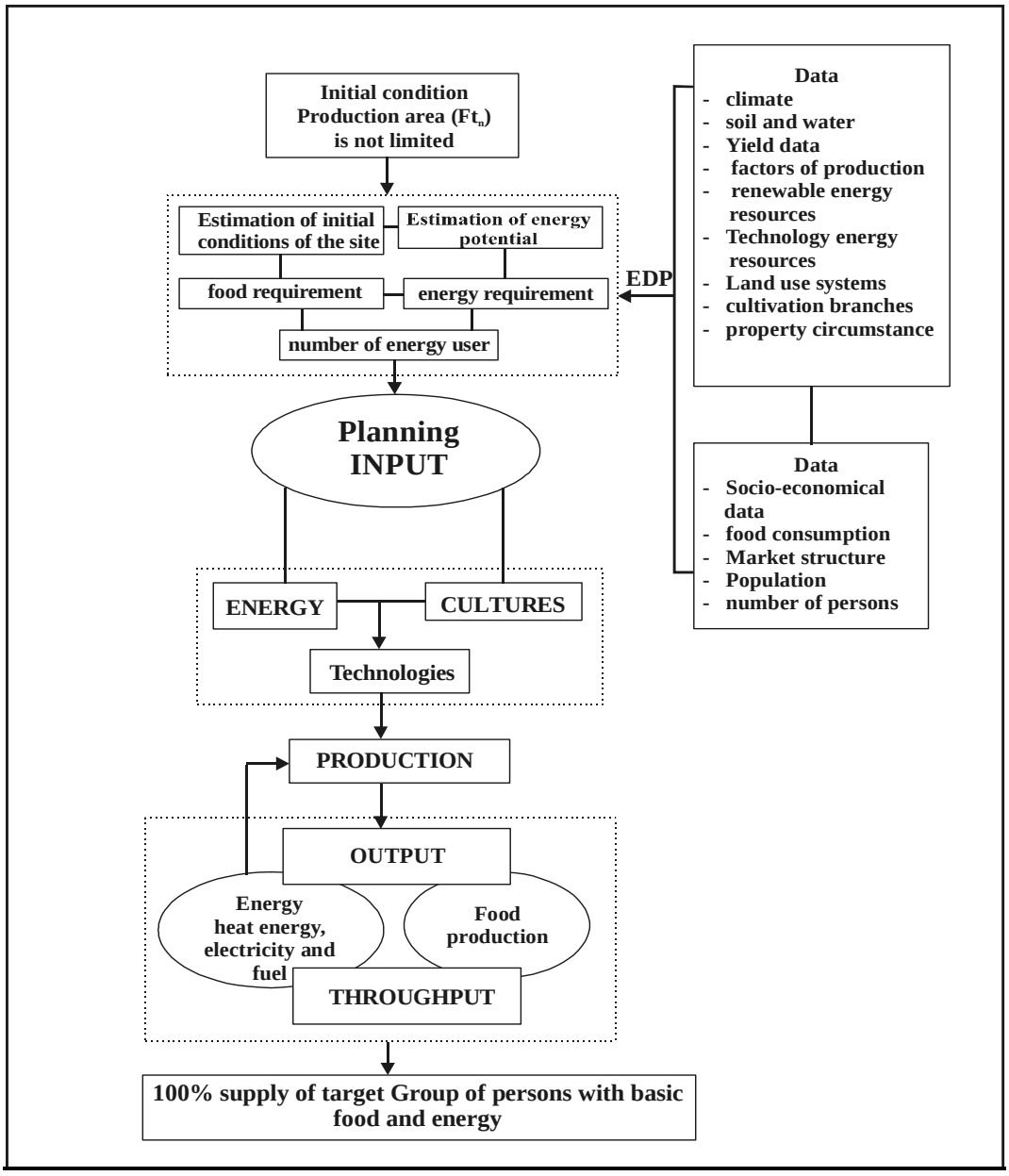
Table 1. The possible share of different renewable energy sources in diverse climatic zones produced on an energy farm of 100 ha

Climate region	**Energy source**	**Power production** (% of total need)	**Heat production** (% of total need)	**Biomass need** (t/a)	**Biomass area** (% of total area)
Northern and Central Europe	Solar	7	15	60	12
	Wind	80	-		
	Biomass	60	100		
Southern Europe	Solar	100	100	36	4.8
	Wind	80	-		
	Biomass	40	65		
North Africa Sahara	Solar	100	100	14	1.2
	Wind	100	-		
	Biomass	20	25		
Equatorial region	Solar	100	100	45	10
	Wind	45	-		
	Biomass	70	100		

Source: Author.

It is evident that throughout Europe, wind and biomass energies contribute the major share to the energy-mix, while in North Africa and the Sahara the main emphasis obviously lies with solar and wind energies. Equatorial regions offer great possibilities for solar as well as biomass energies and little share is expected from the wind source of energy in these regions. Under these assumptions, in Southern Europe, the Equatorial regions and North and Central Europe, a farm area of 4.8, 10 and 12 ha, respectively, would be needed for the cultivation of biomass for energy purposes. This would correspond to annual production of 36, 45 and 60 tonnes for the respective regions. In North Africa and Sahara regions, in addition to wind and solar energy, 14 tonnes of biomass from 1.2% of the total area would be necessary for energy provisions. Projection steps are illustrated in Figure 2.

Figure 2. Projection steps



Source: El Bassam, 1999.

Moving ahead, in order to broaden the scope and seek the practical feasibility of such farms, the dependence of local inhabitants (end users) is to be integrated in this system. Roughly 500 persons (125 households) can be integrated in one farm unit. They have to be provided with food as well as energy. As a consequence, the estimated extra requirement of 1 900 MWh of heat and 600 MWh of power has to be supplied from alternative sources. Under the assumption that the share of wind and solar energy in the complete energy provision remains at the same level , the production of 450 tonnes of dry biomass is needed to fulfil the demands of such farm units. For the production of this quantity of biomass, 20% of farm area needs to be dedicated for cultivation. In Southern Europe and the Equator, 15% of the land area should be made available for the provision of additional biomass.

More than 200 plant species have been identified in different regions of the world to serve as sources for biofuels. A summary of energy plant species which can be grown under various climatic conditions is documented in Tables 2-4.

Table 2. Representative energy plant species for different climate regions (temperate climate)

- Cordgrass (*Spartina spp.*)
- Fibre sorghum (*Sorghum bicolor*)
- Giant knotweed (*Polygonum sachalinensis)*
- Hemp (*Cannabis sativa)*
- Kenaf (*Hibiscus cannabinus)*
- Linseed (*Linum usitatissimum)*
- Miscanthus *(Miscanthus x giganteus)*
- Poplar *(Populus spp.)*
- Rape *(Brassica napus)*
- Reed Canary Grass (*Phalaris arundinacea.*)
- Rosin weed (*Silphium perfoliatum*)
- Safflower (*Carthamus tinctorius*)
- Soybean (*Glycine max*)
- Sugar beet (*Beta vulgaris*)
- Sunflower (*Helianthus annuus*)
- Switchgrass (*Panicum virgatum*)
- Topinambur (*Helianthus tuberosus*)
- Willow (*Salix spp.*)

Source: El Bassam, 1996 and 1998b.

Table 3. Representative energy plant species for different climate regions (arid and semi-arid climate)

- Argan tree (*Argania spinosa*)
- Broom (Ginestra) (*Spartium junceum*)
- Cardoon (*Cynara cardunculus*)
- Date palm (*Phoenix dactylifera*)
- Eucalyptus (*Eucalyptus spp.*)
- Giant reed (*Arundo donax*)
- Groundnut (*Arachis hypogaea*)
- Jojoba (*Simmondsia chinensis*)
- Olive (*Olea europaea.*)
- Poplar (*Populus spp.*)
- Rape (*Brassica napus*)
- Safflower (*Carthamus tinctorius*)
- Salicornia (*Salicornia bigelovii*)
- Sesbania (*Sesbania spp.*)
- Soybean (*Glycine max*)
- Sweet sorghum (*Sorghum bicolor*)

Source: El Bassam, 1996 and 1998*b*.

Table 4. Representative energy plant species for different climate regions (tropical and sub-tropical climate)

- Aleman Grass (*Echinochloa polystachya*)
- Babassu palm (*Orbignya oleifera*)
- Bamboo (*Bambusa spp.)*
- Banana (*Musa x paradisiaca*)
- Black locust (*Robinia pseudoacacia*)
- Brown beetle gras (*Leptochloa fusca*)
- Cassava (*Manihot esculenta*)
- Castor oil plant (*Ricinus communis*)
- Coconut palm (*Cocos nucifera*)
- Eucalyptus (*Eucalyptus spp.*)
- Jatropha (*Jatropha curcas.*)
- Jute (*Crocorus spp.*)
- Leucaena (*Leucaena leucoceohala*)
- Neem tree (*Azadirachta indica*)
- Oil palm (*Elaeis guineensis*)
- Papaya (*Carica papaya.*)
- Rubber tree (*Acacia senegal*)
- Sisal (*Agave sisalana*)
- Sorghum (*Sorghum bicolor*)
- Soybean (*Glycine max*)
- Sugar cane (*Saccharum officinarum*)

Source*:* El Bassam, 1996 and 1998*b*.

Layout of an IREF

The concept of the IREFs includes 4 pathways:

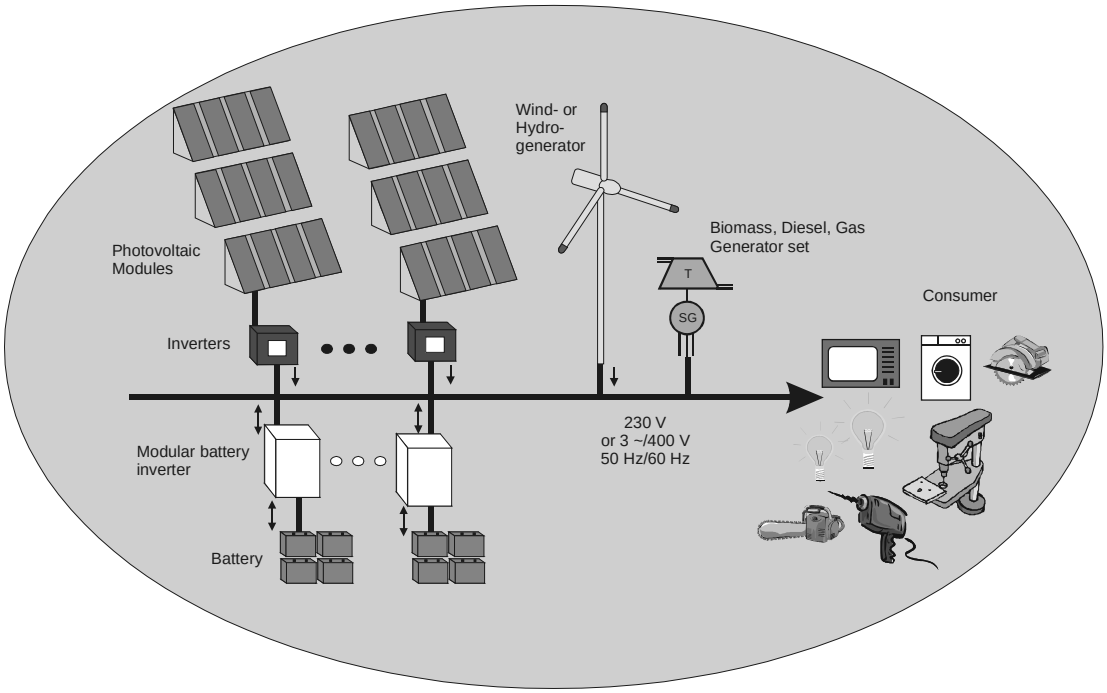
1. Economic and social pathway;
2. Energy pathway;
3. Food pathway; and
4. Environmental pathway.

In order to generate its maximum output, it is necessary to determine the most appropriate equipment and facilities to be located on the farm. These would probably include:

- Windmills;
- Solar collectors (thermal);
- Solar cells (PV);
- Briquetting and pelleting machines for biomass;
- Bio-gas production units;
- Power generators (bio-fuels, wind and PV-operated);
- Bio-oil extraction and purifying equipment;
- Fermentation and distillation facilities for ethanol production;
- A pyrolysis unit;
- Sterling motors;
- A water pump (solar, wind and bio-fuel operated);
- Vehicles (solar, bio-fuel-operated or draught vehicles);
- A Monitoring system; and
- Cooking stoves.

The configuration of technologies depends on the sources of a given region (Figure 3).

Figure 3. Enegy system integration



Source: El Bassam, 2001.

The overall objective is to promote a complete sustainable farming system. Depending upon this objective, the verification of demonstration farms in various regions of the world have to be prepared, taking into account the following influential factors:

- Impact, influence and needs of climate, soil and crops;
- Ratio of required food/bio-fuel production;
- Input requirement for cultivation, energy balance and output: input ratio;
- Equipment choices (wind, solar and biomass generation and conversion technology);
- The information so collected from different regions would provide information on the optimal farm size, its regional adaptation and solve other related constraints.

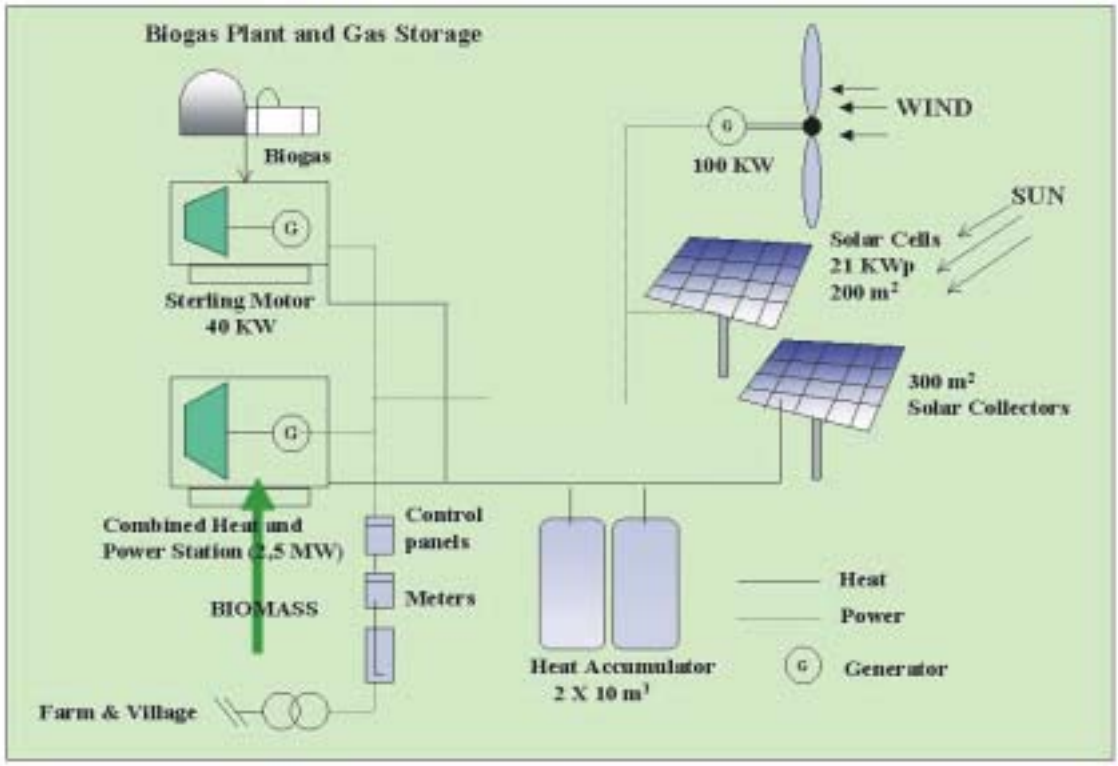
Regional implementation

Verifying the implementation of the IREF in a practical sense at regional level, taking into consideration the climatic and soil conditions, planning work has been started at Dedelstorf (Northern Germany). An area of 280 ha has been earmarked for this farm, which would satisfy the food and energy demands of the 700 participants in the project. For the settlement purposes, old military buildings are being renovated. It is expected to take a period of 3 years to complete the project. The main elements of heat and power generation will be: solar generators and collectors, a wind generator, a biomass combined heat and power generator, a sterling motor and bio-gas plant.

The total energy to be provided amounts to 8 000 MWh heat and 2 000 MWh power energy. The cultivation of food and energy crops will be according to ecological guidelines. The energy plant species foreseen are: short-rotation coppice, willow and poplar, miscanthus, polygonum, sweet and fibre sorghum, switch grass and reed canary grass and bamboo. Adequate food and fodder crops as well as animal husbandry is under implementation according to the needs of people and specific environmental conditions of the site. A research, training and demonstration centre will accompany this project.

In northern Germany a site near Hanover has been already identified for the implementation of an “Integrated Renewable Energy Farm” (90% biomass, 7% wind, 3% solar) and as a research centre for renewable energies – solar, wind and energy from biomass as well as their configuration. Special emphasis is dedicated to optimisation of energetic autonomy in decentralised living areas and to promote regional resource management. The centre undertakes the responsibility in the field of research, education, transfer of technology and co-operation with national and international organisations. It also offers trade and industry the opportunity to introduce, demonstrate and commercialise their products. The co-operation with developing countries on the issues of sustainable energy and food production is also one of the prime objectives of the research centre (Figures 4 and 5).

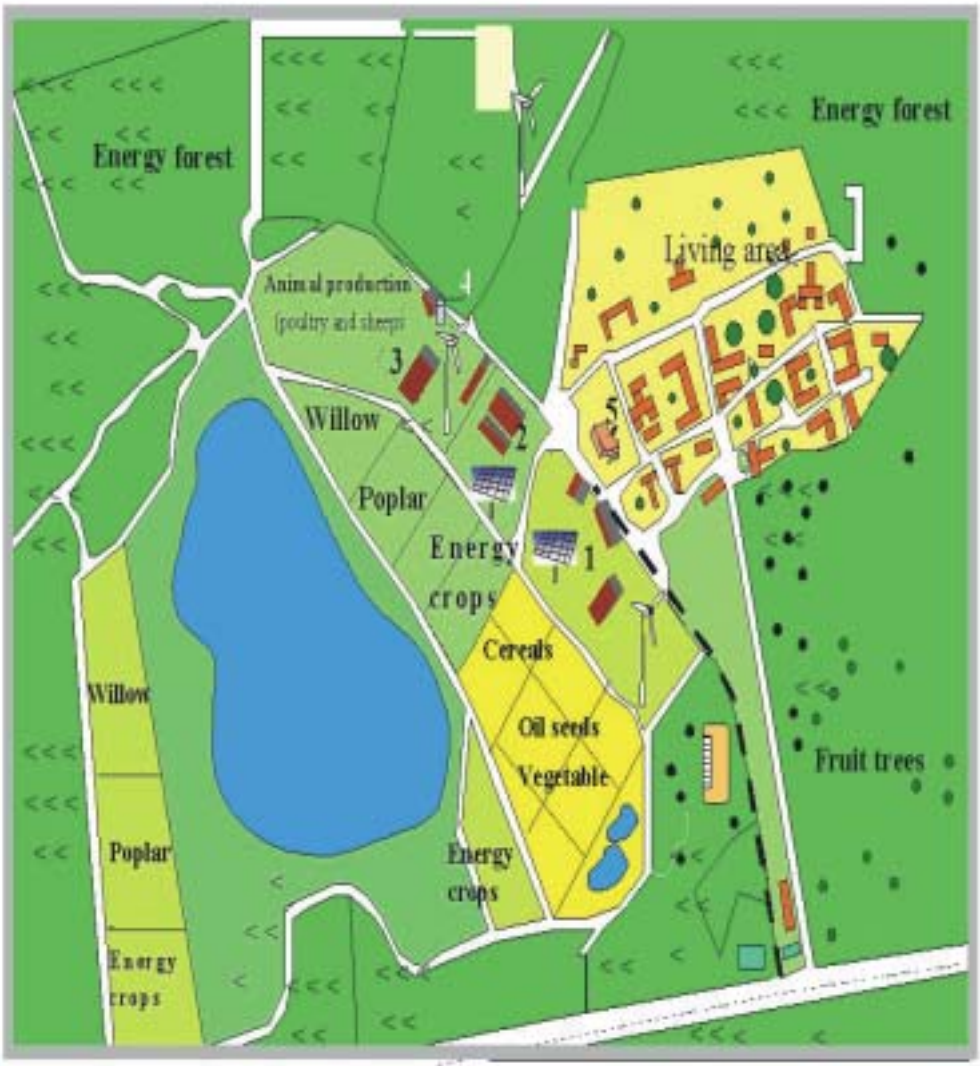
Figure 4. Technologies for heat and power production on Integrated Renewable Energy Farms



Technologies for heat and power production on Integrated Renewable Energy Farms

Source: El Bassam, 1999.

Figure 5. Integrated Renewable Energy Farm, Dedelstorf, Germany



1 Thermal and Power unit (Biomass, Wind, Solar) 2 Pelleting, Oil mill, Ethanol unit
3 Animal husbandry 4 Biogas unit 5 Administration

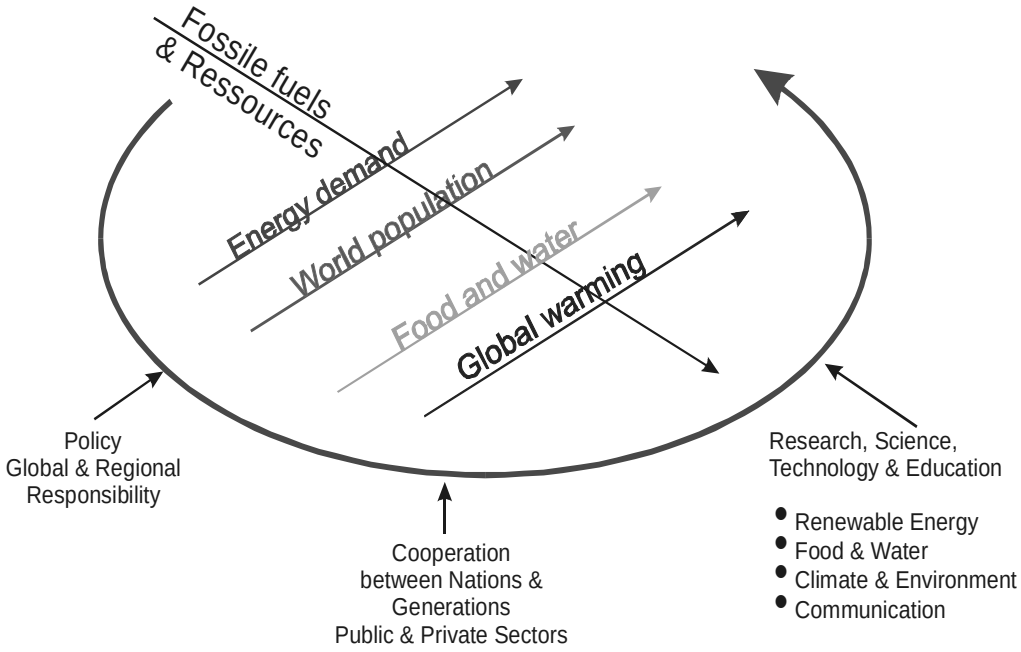
Integrated Renewable Energy Farm, Dedelstorf, Germany

Source: El Bassam, 1999.

The world still continues to seek energy to satisfy its needs without giving due consideration to the consequent social, environmental, economic and security impacts. It is now clear that current approaches to energy are unsustainable. It is the responsibility of political institutions to ensure that the research and the development of technologies supporting sustainable systems be transferred to the end users. Scientists must bear the responsibility of understanding the earth as an integrated whole and must recognise the impact of our actions on the global environment, in order to ensure sustainability and avoid disorder in the natural life cycle.

Sustainability in a regional and global context requires that demands are satisfied and risks overcome (Figure 6).

Figure 6. Sustainability in regional and global context demands, risks and measures



Source: El Bassam, 1999.

The International Research Centre for Renewable Energy (IFEED), Germany (www.ifeed.de) offers:

1. Verifying the possibilities of introducing renewable energy technologies;
2. Planning and implementing of projects;
3. Training and follow-up;
4. Co-operation and the organisation of seminars, workshops and conferences.

BIBLIOGRAPHY

Chiaramonti, D., P. Grimm, M. Cendagorta and N. El Bassam (1998), Small energy farm scheme implementation for rescuing deserting land in small Mediterranean islands, coastal areas, having water and agricultural land constraints, Feasibility study, in *Proceedings of the 10th International Conference "Biomass for Energy and Industry"*, Würzburg, 1259-62.

El Bassam, N. (1996), *Renewable energy - potential energy crops for Europe and the Mediterranean region*, REU Technical Series 46, Food and Agriculture Organization of the United Nations (FAO), 200 S, Rome.

El Bassam, N. (1998*a*), "Biological Life Support Systems Under Controlled Environments"in El Bassam, N. *et al.* (eds.), *Sustainable Agriculture for Food, Energy and Industry*, James & James Science Publishers, Volume 2, pp. 1214-1216, London.

El Bassam, N. (1998*b*), *Energy Plant Species – Their Use And Impact on Environment And Development*, James & James Science Publishers, ISBN 1-873936-70-2, 321 pp, London.

El Bassam, N. (2001), "Renewable Energy for Rural Communities", *Renewable Energy* 24 (2001), 401-408.

El Bassam, N. (1999), Integrated Energy Farm Feasibility Study, SREN-FAO.

SMALL-SIZED COMMERCIAL BIOENERGY TECHNOLOGIES AS AN INSTRUMENT OF RURAL DEVELOPMENT

Giuliano Grassi[1], *Gianluca Tondi*[2] *and Peter Helm*[3]

Abstract

The sustainable development of large areas of the world is one of today's greatest challenges. The standard of living of a large part of the world's population is significantly affected by the availability of energy, together with food and water. As most developing countries have limited indigenous fossil fuel resources, imports of energy are required to bridge the increasing gap between demand and production. Consequently, there exist today substantial motivation and a growing interest in the development of renewable sources of energy, such as energy systems based on biomass and, in particular, energy crops.

In the present work, one possible scheme (the Bioenergy Rural Village Complex), based on a sweet sorghum crop and aimed at providing rural villages in developing countries with sufficient energy, fuel, food and feed, will be presented.

The Bioenergy Rural Village Complex

The **Bioenergy Rural Village Complex** is based on the premise that bioenergy can support the basic needs of rural populations on a village scale. In fact, these populations require not only energy, but also a set of other products essential to life, such as food, animal feed, etc. The proposed Bioenergy Complex, based on a sweet sorghum crop, aims at satisfying these needs, which is essential for the sustainable development of rural areas throughout the world. The approach is therefore based on the simultaneous production of a large number of biomass-based products by means of an integrated system. The technologies used will therefore be deeply inter-connected: the scheme makes use of all parts of the biomass resource (sweet sorghum), thus reducing to a minimum the amount of waste produced. These various co-products will allow a significant improvement in the economics of the overall system, and the integration of food, feed and energy production will be obtained in a sustainable way.

1. EUBIA (European Biomass Industry Association), Brussels, Belgium.

2. ETA Renewable Energies, Florence, Italy.

3. WIP, Munich, Germany.

A biomass integrated complex for a population of approximately 3 000 is constituted by several sub-systems, such as:

- A sweet sorghum plantation;
- A biomass pre-treatment unit;
- A co-generation unit;
- A bioethanol micro-distillery;
- Food products (cereals, milk, meat, sugar);
- A village energy network connection (power, cooking fuel, bioethanol for agricultural machinery).

The bioenergy complex is based on a plantation of about 400 ha (harvested twice a year in tropical regions) of a dedicated herbaceous, very versatile, sugar-starch-lignocellulosic crop (a specific variety of sweet sorghum). The integrated bioenergy complex, through the production of several different co-products, will be able to provide a sufficient amount of:

1. Electric power for the village;
2. Heat for biomass drying; for internal needs (sugar juice extraction and concentration, for ethanol distillation) and for other uses such as heating greenhouses, fisheries, etc.;
3. Ethanol for numerous village uses (cooking, tractors, lighting) and for sale;
4. Food (cereals, liquid sugar, milk, meat) for 3 000 inhabitants;
5. Animal feed for cows, pigs, chickens, fish, etc.;
6. Other co-products (organic fertilisers, bagasse, etc.);
7. Other industrial biomass-derived products – if needed – such as pulp for paper, charcoal, activated charcoal for drinking-water purification, etc.

Moreover, the proposed system will also provide numerous diversified jobs to the village inhabitants. Sweet sorghum has been selected as the main biomass resource for the following main reasons:

- It has a very high yield (up to 80 tonnes/ha of fresh matter) in terms of starch, sugar, lignocellulosic component, and today can be considered the most versatile and promising energy crop;
- It can be grown in a wide range of latitudes (tropical, sub-tropical, or temperate zones) as well as on poor-quality soil. It can be grown in soils with pH = 5-8.5. Areas suitable for growing grain sorghum and corn are also suitable for sweet sorghum.
- The required N_2 inputs are rather low (approximately 100 to 200 kg/ha per year, depending on agronomic practices), reducing the risk of water contamination. Where land availability is a problem, rotations with leguminous crops could eliminate the need for nitrogen inputs such as fertilisers.

- It requires very low fertiliser and water input. The water requirement for growing sweet sorghum is one of the lowest (≅ 200 kg of water per kg of biomass) – about half of the requirement for corn and about one-third of the requirement for sugarcane;

- In 1995, worldwide, sweet sorghum plantations extended over 45 million ha (producing 75 million tonnes/year of grains, and representing the 4th world cereal). There are ≅ 4 000 varieties of sweet sorghum throughout the world and significant future genetic improvements are expected. Sweet sorghum can be cultivated in any continent (North and South America, Africa, Europe, Asia) and even in cold regions (*i.e.* Inner Mongolia, Central Europe, etc.), provided that the total accumulated daily temperature during the 120 to 150-day cycle reaches 2 600 to 4 500°C.

The sweet sorghum plantation is the basis of the integrated bioenergy complex (Figure 1). Other configurations of bioenergy complexes can be designed and optimised on the basis of different types of biomass feedstock (agro-forestry residues, agro-industrial wastes, dedicated crops, etc.) but these complexes generally will not be able to supply such a wide range of products as a sweet sorghum-based complex. Sweet sorghum, unlike other types of biomass feedstock, has a major diversity of fundamental components such as starch, sugar and lignocellulosics.

The integrated bioenergy complex, based on the exploitation of sweet sorghum for the production of bioethanol and other energy/industrial commodities, has been demonstrated in terms of its economic viability and offers a new sustainable path for the decentralised production of bioethanol, which is considered a strategic fuel for the transport sector. Such a project could be implemented in developing countries, like China, on a large scale, as past studies have shown high yields of this crop in terms of grains, sugar and bagasse in several different climatic belts (*i.e*. Inner Mongolia, South China).

This integrated project, once implemented on a large scale, or with numerous small-scale projects, can have important impacts on the economics of such complexes in terms of reducing the production costs of ethanol. Utilisation of particular varieties of sweet sorghum as dedicated energy crops is, in this respect, of great importance because the process "integration" comes from the opportunity of converting the several components of the plant: starch, sugar and lignocellulosic material. This very important feature distinguishes sweet sorghum from other grain crops (corn, wheat, barley) currently utilised for bio-ethanol production in other climatic areas. In fact, well-known bioethanol crops (*i.e.* sugarbeet; corn; sugarcane) are cultivated only in order to produce alcohol. Sweet sorghum plants, however, can provide not only sugar and grains for bioethanol production, but also large amounts of bagasse, as fuel to generate steam; electricity necessary for the bio-ethanol production process, syngas, hydrogen, etc., thus providing an energetic surplus for sale.

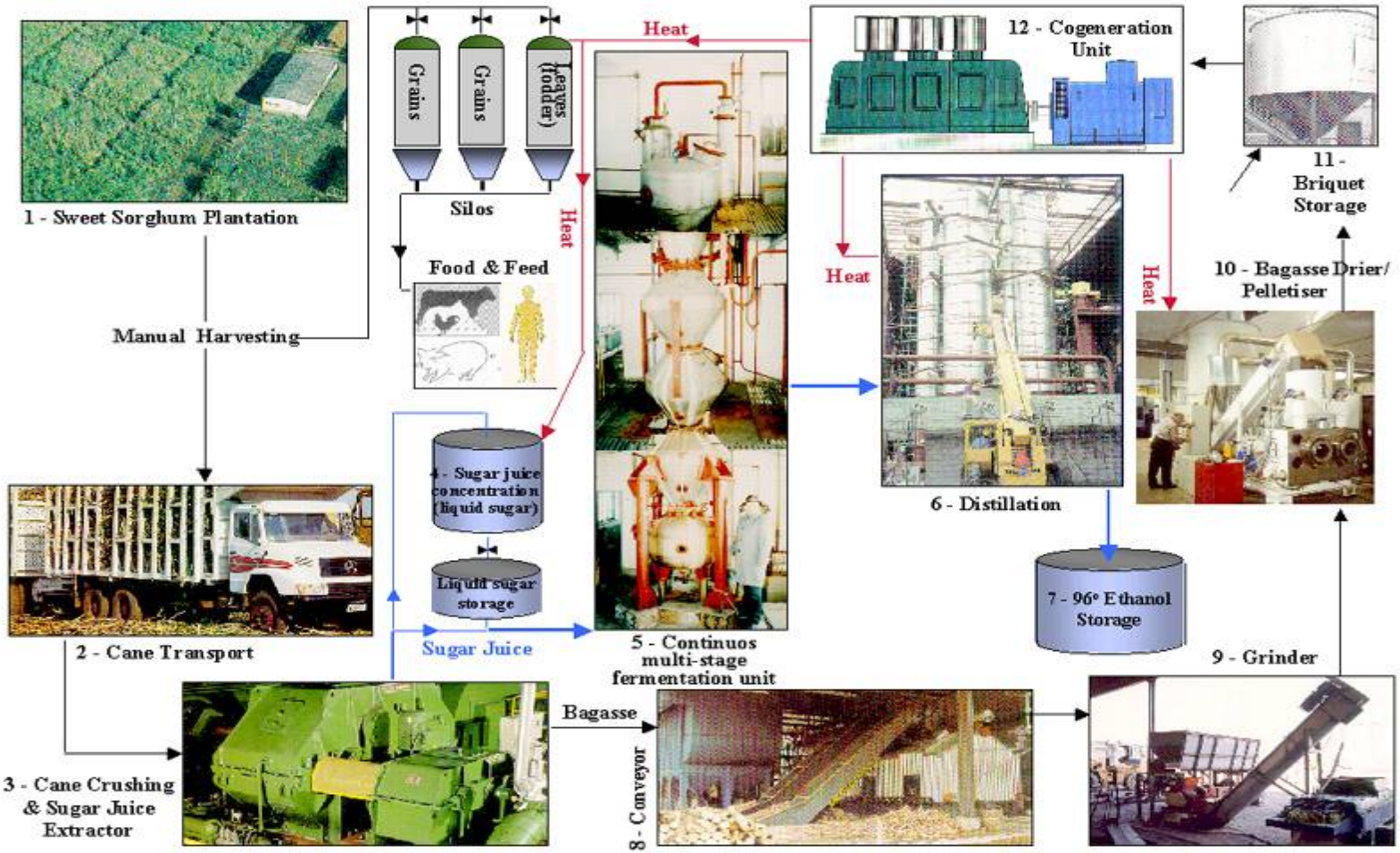
General characteristics of sweet sorghum

As already mentioned, the complex is based on sweet sorghum, given its manifold advantages. The most important data concerning this energy crop are the following:

- Number of varieties available: ≅ 4 000 (probably originating in China);

- Geographic areas cultivating this crop: Canada, United States, Brazil, Russia, China, South-East Asia, Africa.

Figure 1. Scheme of the Integrated Bioenergy Complex



Source: EUBIA Archives.

- Yearly world sorghum grains production: ≅ 70 million tonnes/year (in the EU only 1 million tonnes/year) from ≅ 40 million ha;
- Present utilisation: feed, food (from grain/sugar juice); ethanol from sugar;
- Required seeds: ≅ 15 kg/ha;
- Plantation: 6-25 plants/m^2;
- Cultivation areas: sweet sorghum can be grown in tropical/sub-tropical/temperate zones where the accumulated temperature during the growing season (assuming a daytime temperature of above 10°C) reaches 2 600 to 4 500°C;
- Vegetative period: 90-150 days (2 cuts are possible in some areas);
- Required soil characteristics: 4.5-8.5 pH;
- Productivity (typical), depending on the climatic, soil, water input conditions: grains: 1.2-7.0 tonnes/ha per year; sugar: 5-14 tonnes/ha per year; lignocellulosic (bagasse): 12-40 dry tonnes/ha per year; leaves (forage): 1.9 tonnes/ha per year;
- Biomass weight distribution: cane: ≅ 75%; leaves: ≅ 10-15%; roots: ≅ 10%; grains: up to 5%;
- Sugar juice (≅ 70% total weight) is composed of:
  - cellulose, polymer $(C_6H_{10}O_5)_\eta$ 15-25% of total weight;
  - hemicellolose, polymer $(C_5H_{10}O_5)_\eta$: 35-50% of total weight;
  - lignin: 20-30% of total weight depending on the crop variety;
  - calorific value: 4 125 kcal/kg (dry and ash free) (Table 1).

Table 1. Heat value of crops

Biomass	Heat value		Ash content	Ultimate analysis	Weender analysis
	(bomb calorimeter) (kJ/kg)		wt %	Relative to bomb calorimeter (dry, ash-free)	
	Dry and ash-free biomass (daf)	Dry biomass	Ash content (DIN 51715)	(DIN 51900)	
Sweet sorghum	18 268	17 328	8.8	96.6	96.6
Ryegrass, 30 cm	18 889	16 622	11.2	99.9	99.0
Maize-silage	17 864	16 881	5.0	98.5	98.9
Wheat straw	17 181	16 322	4.6	92.4	102.5

Note:
The ash content and the net calorific value have been measured following the methodology as specified in DIN 51715 and DIN 51900.
Source: 7th EC Conference, "Biomass for Energy and Industry", Florence, Italy, 1992.

The chemical composition of bagasse and ash is the following:

- Chemical composition of bagasse:

Fixed carbon	16.6%
Carbon	35.5%
Hydrogen	6.7%
Nitrogen	0.98%
Sulphur	0.11%
Chlorine	5 400 ppm
Ashes	7%
Volatile matter	65.5%

Source: ENEL.

- Composition of ash:

CaO	18.37%
MgO	4.66%
Na_2O	1.13%
K_2O	19.35%
SiO_2	34.50%
Ti_2O	1.4%
Cl	4%
P_2O_5	8.9%

Source: ENEL.

Sweet sorghum can be defined as an "admirable high-energy crop" for the following reasons:

- It has two times the photosynthetic efficiency of sugarbeet, soybeans, wheat etc. (its photorespiration can almost not be measured);
- It can be grown in all locations going from tropical to very northern regions (such as Inner Mongolia);
- The quantity of water needed by sweet sorghum is only one-third of that needed by sugarcane (less than 200 kg of water per kg of biomass);
- It is very resistant to droughts (it is also known as the "camel crop"); to flooding, to salinity- and alkaline conditions;
- In particular situations and with the use of optimised hybrids it can produce up to 5-6 m^3 ETOH/ha;
- The growing period of sweet sorghum is short (4-5 months) in comparison with sugarcane (8-24 months);
- Sowing requires only a small amount of seeds: ≅10/15 kg/ha (corn ≅ 40 kg/ha);
- Sweet sorghum must be considered possibly the most promising "food-feed-energy" crop for the 21st century due to its high yield of grain, sugar and lignocellulosic material;
- It also contributes towards reducing CO_2 emissions.

Considering the large number of known varieties of this plant (more than 4 500) and therefore the significant potential for its further future improvement, we can assume the following (prudent) average productivity (extrapolated from data obtained in Mediterranean regions of the EU and from recently developed hybrids in China – also tested in Italy and Germany – where sorghum plantations are well established on a total of ≅ 0.2 million ha):

Grains	5 tonnes/ha
Sugar	7 tonnes/ha
Lignocellulosic material	15 tonnes/ha
Leaves (forage)	1.80 tonnes/ha

Technologies

The proposed scheme makes use of several different technologies for biomass collection, treatment and conversion into energy and liquid biofuel. The most important are:

- Harvesting;
- Biomass pre-treatment (grain separation, cane crushing, sugar juice extraction, pelletisation);
- Co-generation (small scale) and carbonisation;
- Bioethanol production (fermentation and distillation);

Each different area requires some technological improvement to reach full commercial availability and performance guarantees. For instance, development has yet to be completed in the sectors concerning harvesting; on-field grain separation and collection; and sugar juice extraction.

The following section describes the several items/technologies that constitute the complex.

Sweet sorghum plantation

The complex is based on a plantation of 400 ha, to be harvested twice per year (see Figure 2, a typical plantation). The following productivity (average) value can be considered:

- Bagasse (dry): 15 tonnes/ha
- Grains: 5 tonnes/ha
- Sugar: 7 tonnes/ha
- Leaves: 1.88 tonnes/ha.

Figure 2. Large-scale plantation



Source: EUBIA Archives.

Cane crushing and sugar juice extraction

The fresh cane will be processed in a cane-crushing and sugar juice mechanical extraction unit for conversion into bioethanol (Figure 3). After this operation, about 45 000 tonnes/year of sugar juice (5 600 tonnes of sugar) and about 24 000 tonnes/year of bagasse (50% humidity) will be available. Part of the sugar juice may be utilised as liquid sugar (high concentration), the remaining part going to ethanol production.

Figure 3. Cane crushing and sugar juice extraction



Source: ILLOVO Co. Ltd, South Africa.

Pelletisation technology

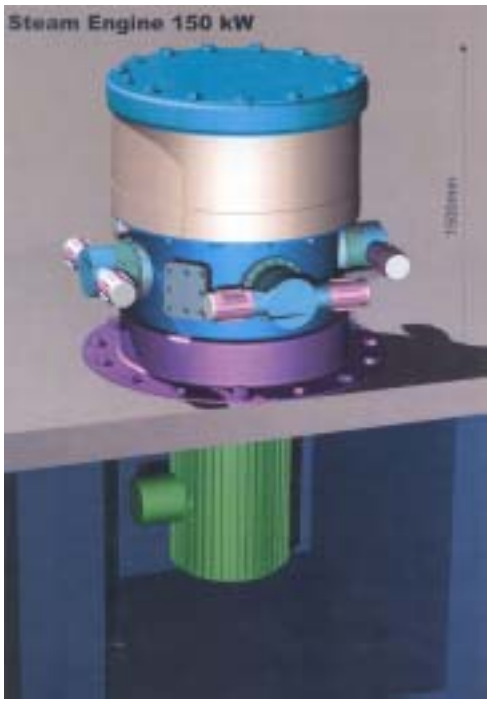
New generation units have been developed recently and made available for commercialisation. Typical pellet dimensions are in the range of 6-12 mm diameter and 10-40 mm length. These machines proved efficient in treating various types of feedstock, not only sawdust and woodchips, but also agricultural residues, wastes, energy crops, etc. Pelletisation represents a key technology in the above-mentioned bioenergy scheme, since it allows a significant reduction in storage costs as well as ensuring good quality fuel. Moreover, some interesting options are possible, such as mixing the biomass with limited amounts of other feedstock, such as organic wastes, etc.

Co-generation plants

The biomass pellets are burned in a combustion chamber (Figure 4) to produce steam at a temperature of 350°C (25 bar or higher) the steam then expands in a reciprocating engine coupled with an alternator powering the electricity grid. With a maximum operating time of 8 000 hours/year, it is possible to obtain:

- gross electric net energy production: about 800 000 kWh_{el}/year;
- net thermal energy production: about 1 850 000 kWh_{th}/year.

Figure 2. Typical steam engine generator (150 kWe), Sweden



Source: EUBIA Archives.

Carbonisation

Bagasse pellets submitted to a clean efficient carbonisation process are converted directly into charcoal pellets (for cooking/heating) without the use of any binder-agglomerating compound. Furthermore, charcoal pellets can also eventually be converted into activated charcoal (medium quality). One hectare can produce 2 tonnes of activated charcoal, which is sufficient to purify the drinking water for 10 000 people all year round.

Bioethanol production

This technology offers the fast conversion of sweet sorghum sucrose into ethanol. It is based on a fixed-yeast fluidised bed reactor, where gelatinous particles having uniform diameter and good mechanical properties support the yeast for the fermentation. This technology could significantly reduce the time necessary for fermenting the sweet sorghum juice and, therefore, the investment costs. The co-generation unit provides the heat necessary for distillation (Figure 5). Bioethanol production is divided into two main stages:

Fermentation: The fermentation unit is completed with one mash buffer tank, two small yeast propagation tanks, two fermentation tanks and ancillaries. In this plant a side stream of mash is fed into the yeast propagation tank and mixed with fresh yeast available on the market, nutrients, and processed water, to produce sufficient yeast cells to balance process losses. The enriched yeast suspension is then pumped into the fermentation tanks.

Distillation: The beer is fed into the distillation unit to strip and concentrate the alcohol to the required level. The distillation unit is complete with one column and with all ancillaries. This process uses a special technique to recover most of the residual ethanol remaining in the distilling system when it leaves the column as waste, which prevents valuable ethanol from being either blown into the atmosphere as polluting volatile organic compounds (VOCs) or discharged in the water.

Figure 5. Distillation units





Source: TM srl, Siena, Italy.

Conclusions

The elaboration of a strategy for rural villages is a key issue at policy level, and the proposed scheme fits with the situation in the rural areas of many developing countries. The bioenergy complex based on sweet sorghum would be capable of satisfying a large part of the energy demands, thus improving living conditions in the concerned areas and giving impetus to their socio-economic development, whilst also providing great additional benefits for the environment.

The potential benefit of adopting this biomass-integrated complex on a worldwide scale (the system having some inherent flexibility with regard to size and configuration) justifies the significant effort necessary for its optimisation and for reducing the investment cost. The respect of strict and sound environmental rules for the biomass production (*i.e.* soil fertility conservation, erosion control, pesticide control, biodiversity plantation, architecture, good quality water for irrigation, etc.) and for its conversion (low noxious emission, good waste management, etc.) will provide sound conditions for sustainable, significant socio-economic development in large rural areas on several continents.

It is now possible to supply modern bioenergy complexes for rural villages based on sweet sorghum plantations. Cultivation of this crop, apart from satisfying the essential needs of the population (food, animal feed, energy), also creates the potential for an economic, sustainable activity.

The proposed Integrated Complex could provide a vital contribution towards general rural socio-economic development and could increase considerably the Human Index of Development of the village inhabitants.

However, there is a limited choice of commercially sound technologies available for these types of small bioenergy complexes. Economics are still penalised by the relatively high cost of technology manufacture in small series. Transfer of good modern technologies is vital for accelerating their penetration in rural districts of developing countries. The comprehensive utilisation and processing of the biomass resource in integrated complexes with the simultaneous production of several high-value commodities is essential for the improvement of the economics and large-scale deployment of this type of activity.

Significant effort for management, technical assistance and for education and training must be envisaged as a vital accompanying measure to ensure the viable and durable operation of the complex.

BIBLIOGRAPHY

ENEL - CRT (Pisa), Lab. results on sweet sorghum chemical analysis.

Grassi, G., D. Chiaramonti, G. Tondi, E. Lutter, P. Helm, T. Fjällström, M. Wang and W. Dong (2000), "Bioenergy Village Strategy For Sustainable Development", Proceedings of the "First World Conference on Biomass for Energy and Industry", Seville, Spain, 5-9 June.

Grassi, G., Z. Qiong, A. Grassi, T. Fjällström and P. Helm (2002), "Small-scale modern autonomous bioenergy complexes: development instrument for fighting poverty and social exclusion in rural villages", Proceedings of the 12th European Conference on Biomass for Energy, Industry and Climate Change, Amsterdam, the Netherlands, 17-21 June.

A GLOBAL BIOENERGY NETWORK AND ITS IMPACT ON OECD COUNTRIES

R. Janssen,[1] P. Helm,[1] A. Grassi,[2] G. Grassi,[3] J.R. Moreira[4] and O. Masera[5]

Abstract

A global network on bioenergy involving 48 expert institutions (Knowledge Centres and Small and Medium-size Enterprises) from 24 countries has been established in order to promote the sustainable use of biomass in Latin America, Europe, China and Africa. This network supports the elaboration of recommendations for the development and implementation of policy options for the promotion of biomass and bioenergy as well as the identification of commercially available and reliable biomass technologies worldwide. In the field of bioenergy technologies a variety of opportunities for international co-operation, technology transfer and joint-ventures between OECD and non-OECD countries have been identified, and the network actively supports the establishment of initial business contacts. Additionally, members of the global network on bioenergy are involved in the preparation and setting up of national and international bioenergy policy programmes and initiatives aiming at increasing the share of bioenergy and other renewable energies in the global energy supply structure.

Introduction

Good management of resources, alleviating poverty and improving the socio-economic conditions of living as well as the identification of sustainable technical and economical schemes are key objectives for research and development (R&D) efforts in emerging countries and successful partnerships of OECD countries with non-OECD countries from Latin America, Asia and Africa. Projects focussing on scientific co-operation and policy research in general, and especially in the field of renewable energies, are of great importance today, as the creation of suitable policy frameworks is required prior to the development of more advanced technologies in order to tackle the main challenges of sustainable development.

Therefore, scientific co-operation and the linkage of scientists, decision makers and entrepreneurs in thematic networks is expected to gain ever-increasing importance in the relation between OECD

1. WIP-Munich, Munich, Germany. The project “Latin America Thematic Network on Bioenergy - LAMNET is funded by the European Commission in the framework of the specific research and technological development programme “Confirming the International Role of Community Research” under the contract ICA4-CT-2001-10106.

2. ETA-Florence, Florence, Italy.

3. European Biomass Industry Association – EUBIA, Brussels, Belgium.

4. Centro National de Referência em Biomassa – CENBIO, São Paolo, Brazil.

5. Universidad Nacional Autonóma de México, Mexico.

countries and countries in Latin America, Asia and Africa. In order to contribute to these objectives the project "Latin America Thematic Network on Bioenergy – LAMNET" is funded by the European Commission in the framework of the specific research and technological development programme "Confirming the International Role of Community Research".

LAMNET – a Global Network on Bioenergy

The project LAMNET project succeeded in setting up a trans-national forum for the promotion of the sustainable use of biomass in Latin America, Europe, China and Africa. Currently, the global network LAMNET consists of 48 institutions (Knowledge Centres and SMEs) from 24 countries worldwide, thereby involving a large number of members with excellent expertise in the field of biomass (Janssen *et al.*, 2002).

LAMNET supports the elaboration of recommendations for the development and implementation of policy options for the promotion of biomass and bioenergy as well as the identification of commercially available and reliable biomass technologies worldwide.

The website of this global network on bioenergy was established early in 2002 under www.bioenergy-lamnet.org. It provides detailed information on the objectives, activities and scientific publications of this trans-national forum as well as the contact details of all network members. Additionally, links are provided to other organisations and companies engaged in the field of bioenergy.

Further dissemination activities of the LAMNET project include the publication of a periodic newsletter (two issues per year), a project database providing information on the energy demand and resources in Latin America and other emerging economies as well as the organisation of several bioenergy workshops.

One week prior to the World Summit on Sustainable Development (WSSD) in Johannesburg, a workshop on "Biomass, Rural Energy and the Environment" was organised in Durban as a joint event of the three thematic networks CARENSA, SPARKNET and LAMNET, which are funded by the European Commission Fifth Framework Programme for Research. This workshop aimed at strengthening synergies and initiating future co-operation of the three multi-stakeholder networks in order to promote sustainable energy for development by assessing energy demand and resources, expanding the institutional knowledge base, and by creating a broad-based discussion forum to evaluate innovative policy options.

The 3rd LAMNET project workshop in São Paulo and Brasilia, 2-4 December 2002, on "Bioenergy Policies and Innovative Bioenergy Technologies" included a session on ethanol-based fuel cells and a technical tour to the Copersucar Technology Center (CTC), one of the world's most advanced R&D centres in the sugar and ethanol sector (Figure 1).

Figure 1. Visit at the Copersucar Technology Center



Source: Authors.

In 2003, the LAMNET network is continuing all activities in order to strengthen this trans-national forum for the promotion of biomass and bioenergy in Latin America, Europe, Africa and China. It will thereby contribute to the establishment of modern energy supply systems which are fully in line with today's crucial goals of poverty eradication and sustainable development.

The next LAMNET project workshop will take place in Beijing, P.R. China in the framework of an International Conference on Bioenergy and Liquid Fuel Development (20-23 April 2004). This conference is co-organised by the LAMNET project, the China Association of Rural Energy Industry (CAREI), the Chinese Academy of Agricultural Engineering and the Chinese Ministry of Agriculture as well as the Ministry of Science and Technology.

International co-operation on bioenergy technologies

Within the framework of the LAMNET project it is one of the main objectives to identify currently available, efficient, cost-competitive and reliable bioenergy technologies which provide opportunities for the conversion of biomass to energy services in Latin America, Europe, Africa and China. Relevant technologies and systems are selected on the basis of maturity of the technology, cost-effectiveness, simplicity of maintenance, social acceptability and the impact on development. Moreover, opportunities for international co-operation, technology transfer and joint-ventures between OECD and non-OECD countries in the field of bioenergy technologies are identified and promoted by the LAMNET network. Within the framework of the LAMNET project the establishment of initial business contacts is supported through advice and recommendations by expert network members.

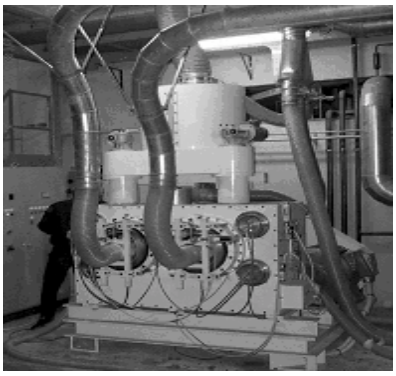
The LAMNET project is particularly focused on the promotion of small-scale, decentralised bioenergy technologies as their penetration is expected to be much easier in terms of the supply of biomass resources and the investment level (Grassi *et al.*, 2002*a*). Information documents describing bioenergy projects and technologies, which include a detailed technological and economical analysis, are elaborated by the European Biomass Industry Association (EUBIA) in the framework of the LAMNET project. Currently, information documents are available on biomass pellets and briquettes, micro-distilleries for ethanol production and modern bioenergy village complexes.

Pelleting technology for the South African sugar industry

On the occasion of the 2nd LAMNET project workshop on biomass, rural energy and the environment, organised by WIP-Munich and Illovo Sugar Ltd. in Durban, South Africa, the Managing Director of network member Illovo Sugar, Mr Don Macleod, stated that the production of energy from both sugarcane bagasse and molasses is a known technology and therefore sugar by-products can contribute to the global movement towards sustainable "green energy" whilst also improving the return to producers of sugar. Mr Macleod showed strong interest in new technologies providing opportunities to improve the energy generation capacity. The pelletising technology for a variety of biomass feedstocks is an important step in providing energy from bagasse on a year-round basis and the workshop contributions on this subject are of specific interest to the Illovo group.

Within the framework of the LAMNET project, a co-operation agreement between Illovo Sugar and a European manufacturer of innovative pelleting technology (Figure 2) has been initiated and samples of South African sugarcane bagasse have been compacted at the European pelleting facility. Currently, the produced bagasse pellets are being scientifically investigated at Illovo Sugar in order to verify the future potential of this biomass technology for the south African region.

Figure 2. Pelletiser machine, Italy



Source: Authors.

Bioenergy technologies for the Cuban sugar industry

The Cuban LAMNET members, Dr Paulino Lopez Guzmán, Bioenergy Development Programme, Ministry of Sugar and Julio Torres Martinez, Cuban Observatory for Science and Technology, reported that the bioenergy sector in Cuba is almost entirely focussing on bagasse as a residue of the sugarcane processing industry and that 80% of the available agricultural land in Cuba is cultivated with sugarcane. This constitutes an enormous resource of biomass, but unfortunately Cuba has so far not exploited this enormous potential in an efficient way. Therefore, international co-operation on innovative bioenergy technologies for an efficient exploitation of sugarcane bagasse, such as High Pressure Steam Turbines, Biomass Integrated Gasification Combined Cycle (BIGCC) and Bagasse Pelleting Technologies, are of great strategic benefit for the Cuban sugarcane industry.

A strategic alliance between the Cuban network members and the European Biomass Industry Association has been accomplished and a technology co-operation agreement including the installation of pilot pellet production facilities between the Cuban Ministry of Sugar and a European manufacturer of pelleting equipment has been initiated.

Ethanol based fuel cell technologies for Brazil

On the occasion of the 3rd LAMNET project workshop in Brazil, a session was organised on the two basic principles for the realization of ethanol-based fuel cells, *i.e.* the direct electrochemical conversion (Iwasita, 2002) of ethanol and the reforming of ethanol to hydrogen (Rampe *et al.*, 2000). Renowned international experts in the field of fuel cells discussed the future potential of this promising technology, especially for countries in Latin America.

It was agreed that fuel cells will contribute to the world's future cleaner energy supply by exploiting their high efficiency and low pollution levels. Thereby, the introduction of bio-ethanol-based fuel cells will have to take advantage of the existing bio-ethanol infrastructure in Brazil providing a suitable fuel supply with a low level of contaminants. Nevertheless, extended research on the micro-contaminants in bio-ethanol has to be performed to ensure safe operation of the fuel cells. Furthermore, ethanol fuel cells, both direct conversion or via reforming, are currently still in the R&D stage. In particular, the charge transfer in direct ethanol fuel cells still needs to be optimised and further research is required in order to find a suitable catalyst. Although commercialisation of ethanol-based fuel cells is therefore not expected in the very near future, there is a great opportunity for co-operation between countries developing innovative fuel cell technologies and Brazil, with its long-term experience in the production and processing of bio-ethanol (Figure 3).

Figure 3. Fuel cell vehicle, Germany



Source: Authors.

Bioenergy technologies for rural development in China

Bioenergy has an essential strategic and practical significance for China, as the exploitation of biomass resources involves rural development, energy development, environmental protection, resource conservation and the ecological balance. Therefore, China is striving to obtain support from international organisations, foreign governments and scientists, and shows strong interest in co-operation to promote technological progress.

Within the framework of the LAMNET project a strategic alliance between the network members from China and the European Biomass Industry Association, as well as other bioenergy experts from Europe and Latin America, has been established in order to identify opportunities for technology transfer and joint-ventures in the field of modern bioenergy technologies (Grassi *et al.* [2002]), Grimm *et al.* (2002).

Co-operation on bio-fuels production: Latin America – Europe

The European Commission has recently adopted an action plan and Directives to foster the use of alternative fuels for transport, starting with the regulatory and fiscal promotion of biofuels. The Commission considers that the use of biofuels (such as ethanol) derived from agricultural sources is the technology with the greatest potential in the short to medium term. This action plan outlines a strategy to achieve a 20% substitution of diesel and gasoline by alternative fuels in the road sector by 2020.

In order to take advantage of these policies supporting the large-scale introduction of biofuels in Europe, a co-operation agreement has been initiated between representatives of the German and the Brazilian sugar industry sector on the occasion of the 3rd LAMNET project workshop in Brazil. Thereby, it is envisaged that the long-term experience of the Brazilian network members in the field of ethanol production from sugar crops (Correa Carvalho, 2002) will serve to stimulate and benefit the potential set-up of bio-ethanol production facilities and the distribution infrastructure in European regions.

Policy options for the promotion of bioenergy

In order to identify opportunities for co-operation activities between OECD countries and countries from Latin America and Africa in the field of bioenergy, the LAMNET project monitors the development of national energy policy frameworks, as well as the preparation and set-up of bioenergy policy programmes and initiatives in selected countries. In the following, recent national policy initiatives promoting the sustainable use of biomass are presented which facilitate the involvement of companies and multilateral organisations from OECD countries:

Brazilian energy initiative to the World Summit on Sustainable Development

An ambitious proposal for a revolution in the planet's energy matrix was brought to the Johannesburg Summit on Sustainable Development by Brazil. The Brazilian Energy Initiative, conceived by Professor José Goldemberg, São Paulo State Secretary of the Environment, calls for extended use of alternative sources like solar, wind, geothermal, tidal, biomass and small hydroelectric facilities (Goldemberg, 2002). Its goal is to raise the share of these sources from 2.2% today to 10% by 2010.

The LAMNET co-ordination partner, Professor José Roberto Moreira from the Brazilian Biomass Reference Centre (CENBIO) was involved in the elaboration of the technical background document on biomass (Moreira, 2002). These technical papers served to quantify the world capacity to obtain significant amounts of energy by the year 2010 from new and renewable energy sources. It is shown that through the use of 300 million ha of land it is possible to fulfil the total global energy demand by using the most advanced agricultural and industrial technologies. The document concludes with a list of practical actions promoted by the Brazilian Energy Initiative that, if implemented, would allow most of the 102 sugarcane-growing countries to rely on energy from sugarcane in the short term and would initiate the creation of a large-scale global bio-ethanol market with significant impact on several OECD countries:

Figure 4. Distillation column



Source: Authors.

- Immediate increase of the ethanol production by reducing the export of molasses and its use as feedstock for animal feeding (Figure 4).

This action can be applied in about 150 sugar-producing countries. The production of 100 kg sugar generates molasses for the production of at least 15 litres of ethanol. From the production of 120 million tonnes sugar from sugarcane and sugarbeet it would therefore be possible to produce 18 million m^3/year of ethanol, an amount sufficient to replace 0.7% of the total fuel consumption in the world within a few years.

- Immediate conversion of a share of the sugarcane production from food to fuel.

This action can be carried out in 102 countries. The present world sugar production from sugarcane is around 100 million tonnes/year, while the international market turns out to be approximately 30 million tonnes/year. Additionally, several sugar producers have large stocks that are not being commercialised due to the risk of a further price reduction. Therefore, a reasonable decision would be to divert 10% of the sugarcane to ethanol production: this means 10 million tonnes of sugar, yielding 7 million m^3/year of ethanol, one or two years after the decision is taken. This is the

maximum time required to install industrial facilities, whereas blending a few per cent of ethanol in gasoline is an easy task and can be initiated in a few months. The equivalent of around 6 million m^3/year of gasoline (representing 0.3% of global fuel consumption) can be replaced by this practical action.

Brazil: PROINFA programme

The major objective of the PROINFA programme (Program to Foster Alternative Sources of Electric Power) is to raise the share of electric power generated by independent producers in the Brazilian market. The programme's first phase calls for the central utility Electrobras to sign electricity purchase contracts for the construction of 3 300 MW (megawatts) new capacity (wind, Small Hydro Power [SHP], biomass) by 2006. These contracts will ensure the purchase of electricity from alternative sources over a 15-year period and this commitment is a way of guaranteeing subsidies that will cover the competitive differential of small producers. PROINFA will assure subsidies to producers of electric power from alternative sources until they can supply 10% of the national energy matrix. From that point on it is foreseen that these producers will have sufficient know-how and effective market share to compete in an open market.

The PROINFA programme, which is an integral part of the Brazilian Law 10438 already signed by the Brazilian president, is scheduled to be implemented in 2003. It will create opportunities for foreign investors planning to engage in the construction and operation of renewable energy-based electric power generation facilities.

P.R. China: Bioenergy focus of the 10th Five-Year-Plan Programme

On the occasion of the second project workshop in South Africa, Professor Wang Mengjie, China Association of Rural Energy Industry, pointed out the vast potential of biomass resources in China (straw: 720 million tonnes/year; firewood: 127 million tonnes/year; livestock waste: 130 million tonnes/year; urban waste: 120 million tonnes/year) which, to date, are not utilised efficiently (Wang, 2002). The Chinese government emphasised the importance of the bioenergy, and the Ministry of Science and Technology regards the development of biomass utilisation technologies as key and preferable research projects. The focus of the current Five-Year-Plan Programme will therefore be on the solution of technological difficulties and the demonstration of applicable technologies, including biomass gasification and electricity generation systems, ethanol from cellulose wastes, ethanol from sweet sorghum juice and biomass fast pyrolysis.

In order to realise the ambitious goal to significantly increase the application of innovative bioenergy technologies, China is striving to obtain support from international organisations, foreign governments and scientists, and shows strong interest in co-operation to promote technological progress. Within the framework of the LAMNET project, close collaboration links are established with the Chinese LAMNET members from the Ministry of Agriculture and the Ministry of Science and Technology.

Colombia: National Alcohol Program for Colombian gasolines

Recently, a promising initiative for the promotion of bioenergy was launched by the Colombian government. On 19 June 2001 the Congress of the Republic of Colombia approved a new law, which mandates the use of bio-ethanol from sugarcane in Colombian gasoline and diesel fuel oil in order to improve the quality of these fuels and decrease emission levels. This Law follows the example set by the Brazilian Proalcool programme (Figure 5) and it is an example to the world of how a congress of a developing country can take an advanced initiative to promote the use of renewable fuels for the development of a new agro-industrial industry, leading to the creation of a significant number of new employment opportunities.

Figure 5. Bioethanol-gasoline blend sold at Brazilian gas station



Source: Authors.

The new law will allow private industry (national and international) to start production of bio-ethanol to be blended with gasoline (10% volume) in the year 2006, thereby saving 6 million tonnes of CO_2 per year. The LAMNET member CORPODIB (Corporation for the Industrial Development of Biotechnology and Clean Technology) has been actively working on this project during the last seven years. It has elaborated the feasibility study and the implementation plan, and will follow the project during its implementation stage (Echeverri, 2002).

For the implementation of this National Alcohol Program in Colombia private investors are invited to participate in the production of fuel ethanol in an open market. In order to guarantee attractiveness for foreign investors, the Colombian government grants tax exemption for bio-ethanol, and the discount cash flow rate of return for investors is estimated to exceed 20%.

Costa Rica: Bioenergy focus of the National Plan for Development

Within the framework of the LAMNET project, the potential for ethanol production and utilisation in Costa Rica was investigated. Due to the fact that the Costa Rican economy has been strongly affected by external shocks on the international oil market in the past, the government is very interested in the exploitation of ethanol and other biofuels. The recent Costa Rican President Mandate in the National Plan for Development (2002-06) includes the substitution of methyl tertiary butyl ether (MTBE) in gasoline by ethanol, or similar options for the utilisation of biofuels.

For the implementation of this mandate, the public authorities have organised a group of representatives from the Ministry of Agriculture, RECOPE, the Ministry of Environment and major interest groups. Currently, the terms of reference for a pioneer study are being developed and the LAMNET member CINPE is joining the group as part of the University Academic Consortium (Vargas, 2002). The major aim of this study is the quantification of the potential substitution of MTBE by bio-ethanol, as well as the investigation of the technical and economic implication of this substitution process.

Cuba: Energy Development Program – Cuban Ministry of Sugar

The large energy potential of sugarcane biomass can be taken advantage of in Cuba as well as most of the Caribbean countries, if modern technologies are used for the production of electricity and alcohol. For this, a profound technological change is required affecting not only the sugar factories, but also agricultural and harvesting practices. The production of electric energy and alcohol from sugarcane can help to alleviate the dependence of Caribbean countries on imported oil and contribute

to the mitigation of greenhouse gas (GHG) emissions. But the persistent lack of funds in these developing countries has, until now, proved to be an obstacle to the introduction of modern technologies. Therefore, regional or local production of the required equipment is necessary in order to reduce the cost of the technological change.

When the Cuban Development Program for National Energy Sources was formulated in 1993, the importance of the sugar agro-industry for the development of the National Electroenergetic System (NES) was analysed. Currently, the Cuban Observatory for Science and Technology, in partnership with the LAMNET members, Centre for World Economy Studies (CIEM) and the Cuban Ministry of sugar (MINAZ), is investigating the main implications concerned with the transformation of the sugar agro-industry into a modern, flexible and more decentralised NES, which is able to satisfy Cuban electricity needs while avoiding or reducing GHG emissions. The study, which is supported by the LAMNET project, entails an analysis of technical, economic and social problems related to the introduction of the profound technological changes turning the sugarcane agro-industry into a reliable, competitive and environmentally friendly source of electricity and liquid fuel (Torres, 2002).

Senegal: regional strategy for sustainable cooking fuels

Traditional energies such as firewood, charcoal and agro-forestry residues dominate the national energy balance in the Sahelian countries. Thereby, wood is mainly used in rural areas, whereas charcoal and petroleum are almost exclusively used in urban areas (Fall, 2002). Today, this non-sustainable energy supply poses serious threats to forest ecosystems as well as to the food supply for the Sahelian population.

Within the LAMNET project it is envisaged to establish co-operation schemes between scientists, decision makers and entrepreneurs from Sahelian and OECD countries in the field of bioenergy applications in order to alleviate major health, social and environmental problems currently afflicting the region, such as the deforestation of vast areas of land and respiratory diseases caused by indoor charcoal use.

Republic of South Africa: White Paper on Renewable Energy and Clean Energy Development

Honourable Narend Singh, KwaZulu-Natal Minister of Agriculture and Environmental Affairs, acknowledged the role of the 2nd LAMNET workshop as an input to the United Nations World Summit on Sustainable Development in Johannesburg, intending to turn the world away from a self-destructive course in which the economic and other activities of humankind threaten to deplete natural resources and destroy the basis of human existence. He stated that South Africa represents a microcosm of the challenges to be addressed by the WSSD, as it is unique in having a developed industrial economy, with all its challenges of sustainability caused by over-consumption of vast quantities of the planet's natural resources such as oil, gas, timber and metals, virtually side-by-side with an under-developed rural economy with all the evils of erosion, contamination of water resources, destruction of natural foliage, over-stocking and exhaustion of the soil's fertility through unscientific cropping.

For sustainable development a balance is required between environmental-conservation, economic and social interests, adjusted appropriately to suit every particular circumstance, and it is generally the role of government to serve as a catalyst and regulator, in partnership with the private sector wherever possible. With respect to the supply of green energy in the province of KwaZulu-Natal, Honourable Singh pointed out the opportunity provided by the sugar and timber industry as well as the production of alcohol fuel and bio-diesel from biomass resources such as sugarcane, sunflower seeds and the Jatropha plant. In conclusion, he stated that the near future may well be bright for energy

from biomass as the demand for electricity generation in South Africa will exceed current capacity within three to five years, and decisions will have to be made about new generation, while a *White Paper on Renewable Energy and Clean Energy Development* requires a 5% increase in the use of green electricity by 2012.

This *White Paper* supplements the government's policy on energy which pledges "Government support for the development, demonstration and implementation of renewable energy sources for both small and large-scale applications". The *White Paper* sets out the government's vision, policy principles, strategic goals and objectives for promoting and implementing renewable energy in South Africa.

The 10-year target for renewable energy laid out in the South African *White Paper* aims at "An additional 10 000 GWh renewable energy contribution to final energy consumption by 2012, to be produced mainly by biomass, wind, solar and small hydro". The South African authorities acknowledge that the financial resources for the realisation of this ambitious target will have to come from a combination of South African and international resources. International co-operation, technology transfer and joint-ventures are therefore strongly encouraged by the South African government.

Conclusions

Within the framework of the global bioenergy network LAMNET, a variety of opportunities for international co-operation, technology transfer and joint-ventures between OECD and non-OECD countries have been identified in the field of bioenergy technologies. These opportunities include the application of innovative bioenergy technologies (*i.e.* biomass pelleting, BIGCC, ethanol production from alternative sources, fast pyrolysis and bio-ethanol-based fuel cells) in the Brazilian, South African and Cuban sugarcane industries as well as in the P.R. of China, to aid rural development. Additionally, the long-term experience of the Brazilian network members in the field of ethanol production and infrastructure can be exploited to achieve the goals of an action plan recently adopted by the European Commission, aiming at a 20% substitution of diesel and gasoline by alternative fuels in the European road sector by 2020.

Further opportunities for co-operation activities between OECD countries and countries from Latin America and Africa in the field of bioenergy are identified by the LAMNET project through the direct involvement of LAMNET members in the development of national energy policy frameworks as well as the preparation and setting-up of bioenergy policy programmes and initiatives. Recent programmes to promote the sustainable use of bioenergy are implemented in Brazil (PROINFA programme), Colombia (National Alcohol Program), Costa Rica (National Plan for Development), Cuba (Energy Development Program), the Republic of South Africa (*White Paper on Renewable Energy and Clean Energy Development*) and the P.R. of China (bioenergy focus of the 10th Five-Year-Plan).

BIBLIOGRAPHY

Correa Carvalho (2002), *Liquid biofuels in Brazil*, Proceedings of the 12th European Conference on Biomass for Energy, Industry and Climate Protection, 17-21 June, Amsterdam, the Netherlands.

Echeverri (2002), Colombia paving the way in renewable fuels for transport, *LAMNET Newsletter*, Issue 2, 10, December.

Fall (2002), "Traditional Energy Use in the Sahel", *ESI Africa*, Issue 4, 41.

Goldemberg (2002), "The Brazilian Energy Initiative", *LAMNET Newsletter*, Issue 2, 3, December.

Grassi *et al.* (2002*a*), *Small-scale modern autonomous bioenergy complexes*, Proceedings of the 12th European Conference on Biomass for Energy, Industry and Climate Protection, 17-21 June, Amsterdam, the Netherlands, 1 460.

Grassi *et al.* (2002*b*), *EU-China Joint-venture on ECO-FLY project*, Proc. 12th European Conference on Biomass for Energy, Industry and Climate Protection, 17-21 June, Amsterdam, the Netherlands, 1 178.

Grimm *et al.* (2002), *European bioenergy technology for the exploitation of the huge agro-forestry residues potential in China*, Proceedings of the 12th European Conference on Biomass for Energy, Industry and Climate Protection, 17-21 June, Amsterdam, the Netherlands, 1 445.

Iwasita (2002), *The electrocatalysis of ethanol oxidation*, Proceedings of the 3rd LAMNET Project Workshop, 2-4 December, Brasilia, Brazil, 76.

Janssen *et al.* (2002), "A global network on bioenergy - objectives, strategies and first results", *International Sugar Journal*, Vol. 104, June, No. 1 242, 274.

Moreira (2002), "Technical Document on Biomass supporting the Brazilian Energy Initiative", *LAMNET Newsletter*, Issue 2, 7, December.

Rampe *et al.* (2000), *Hydrogen Generation from Ethanol by Allothermal Reforming*, Proceedings of the 1st World Conference on Biomass for Energy and Industry, Seville, Spain, 5-9 June, 1 889.

Torres (2002), "Energetic Diversification of the Caribbean Sugar Agroindustry", *LAMNET Newsletter*, Issue 2, 11, December.

Vargas (2002), *Ethanol Potential in Costa Rica*, Proceedings of the 3rd LAMNET Project Workshop, 2-4 December, Brasilia, Brazil, 49.

Wang (2002), *Biomass Energy and the Technology Development in China*, Proceedings of the 2nd Joint LAMNET Project Workshop, 19-21 August, Durban, Republic of South Africa, 33.

AGRICULTURE AND RENEWABLE RESOURCE CHAINS IN WALLONIA, BELGIUM

Didier Marchal[1] *and Yves Schenkel*[2]

Abstract

Agriculture plays an essential role in food production. In addition, agriculture is also a producer of renewable resources for non-food processes.

The development of non-food agricultural chains generates new opportunities of income for farmers. Furthermore, it emphasises the multifunctional role of agriculture. In order to develop non-food agricultural chains in Wallonia, Belgium, ValBiom, (the Biomass Valorization Association) has implemented the FARR-Wal project.

The FARR-Wal project aims to improve the income of Walloon farmers and the rural dynamics by consolidation of the non-food chain.

Three objectives have been identified:

- To increase and diversify Walloon farmers' activities, through the use of biomass and the development of non-food crops;
- To raise GDP in Wallonia, by developing economic activities in the field of processing, distribution and non-food use of agricultural products and biomass; and to
- Establish the sustainable strengthening of the socio-economic network in rural environments by creating local activities in processing and biomass use.

The main activities developed by the FARR-Wal project are:

- Disseminating information about potential developments (active surveillance of technological changes);
- Highlighting awareness of chain actors (farmers, traders, industries, municipalities, consumers, researchers, etc.);
- Establishing a connection between supply and demand of the various actors, co-ordination of actions and chains;
- Setting up demonstration projects (*e.g.* supply of wood boilers) and initiation of research and development projects (oil production at the farm).

1. ValBiom, Gembloux, Belgium.

2. Centre de recherches agronomiques de Gembloux (CRA), Belgium.

Context

During the period 1977-96, the number of people working in agriculture decreased from 64 800 to 37 100 (1 500 jobs lost per year) in Wallonia. Furthermore, Walloon farmers are confined to production of four basic commodities (sugar, grain, milk and bovine meat) and therefore suffer particularly from globalisation.

Diversification towards new opportunities is one of the solutions to these problems. The areas of energy and industrial biomass use are non-food alternatives which make this diversification possible. They depend on policies concerning: the development of renewable energy development, environmental pressure on fossil energies and raw materials and recycling, etc.

In addition to its role in food production, agriculture has to provide new services to the population.

As one example, energy crops preserve the appearance of the landscape, decrease CO_2 emissions, protect ground water and, in some cases, make waste recycling possible. On the other hand, agricultural products can provide certain raw materials which, when substituted for fossil fuels, contribute not only towards conservation of fossil fuel resources, but also to the development of new, more environmentally friendly products, such as biolubricants, bioplastics, biomaterials, vegetable ink and paint, and fibres in general. The use of vegetable products instead of fossil resources protects the atmosphere (by mitigating CO_2 emission) and contributes to sustainable development (renewable resources use).

In Wallonia, some initiatives to promote use of renewable resources have already been established, such as the support made available to the BELBIOM and VALONAL associations, or specific projects dedicated to non-food applications (miscanthus, hemp, short rotation coppice, rapeseed, vegetable chemistry, etc.) and the use of manure in biomethanation. This support has led to some practical implementations: non-food rapeseed chain, demonstration projects for short rotation coppice, demonstration of biolubricants in forest harvesting, agriculture and construction.

Furthermore, the recent Wood Energy Plan (co-funded by the Walloon Ministry of Agriculture and the Walloon Ministry of Energy) aims to implement about 10 wood heating systems in rural areas in Wallonia.

In 1997 the European Commission published the *White Paper* "Energy for the Future: Renewable Source of Energy". The objective is to double the use of renewable energies from 6% in 1997, to 12% of energy consumption in 2010. Biomass remains the principal source of renewable energy. According to the objectives of the *White Paper*, energy crops should produce 45 Mtoe (million tonnes of oil equivalent) on a surface of about 10 million hectares. Faced with this, each member state and the European regions will have to make a substantial effort towards achieving this degree of renewable energy use. The Walloon Region, with its agriculture, has an important role to play to offer new opportunities to this sector.

On the other hand, the *Green Paper* "Towards a European strategy for the Security of Energy Supply", published by the Commission in 2001, encourages European countries to adopt a secure, affordable and ecological energy supply.

At the present time, renewable energies represent about 1% of total energy consumption in Belgium, nothing being derived from agriculture. Nevertheless, some opportunities appear today because the potential exists and the socio-economic conditions seem to be favourable.

The support policy to agriculture is mainly directed to assistance for production. It is important to emphasise that this support is justified by the resulting environmental advantages derived by society. Non-food uses of agricultural crops in the field of oil substitution present a new advantage to agriculture: lowering of CO_2 emissions. In the framework of the Kyoto Protocol, Belgium undertook to reduce CO_2 emissions from 7.5% in the period 2008-12, compared to the situation in 1990. The use of renewable resources is a way of contributing to this objective by conserving fossil resources and by assuming a certain raw material independence. Agriculture has an important part to play in CO_2 emissions mitigation.

Vegetables are an important source of resources for the production of raw materials for industry as a substitute for petro-chemical products (biopolymers, vegetable-based solvents and detergent, etc.), or as source of specific active molecules (biopesticides, colouring, pigments).

In addition to its essential role of food production agriculture is also a producer of renewable resources for non-food processes. The development of non-food agricultural chains generates opportunities of new sources of income for farmers. Furthermore, it emphasises the multifunctional role of agriculture. In order to develop non-food agricultural chains in Wallonia, ValBiom has implemented the FARR-Wal project.

Objectives

The FARR-Wal project aims to improve the income of Walloon farmers and the rural dynamics by the consolidation of the non-food chain. It presents three main objectives:

- To increase and to diversify the activity of Walloon farmers, by the use of biomass and the development of non-food crops;
- To increase the Walloon GDP by developing economic activities in the field of processing, distribution and non-food use of agricultural products and biomass; and
- The sustainable strengthening of socio-economic network in rural environment by setting local activities in processing and use of biomass.

Furthermore, particular attention is given to natural resources and protection of the environment, job creation and socio-economic welfare.

Concerning the environment, actions will be developed according to current environmental priorities: consideration of greenhouse gas mitigation objectives, respect for the environment, etc. These actions also contribute to the “green” image of agriculture held by the public.

In the field of job creation and social economy, bioenergy and the development of industrial opportunities will lead to new economic activities with job creation or security of job tenure in agriculture or in upstream and downstream agricultural activities.

Main activities

The main activities developed by the FARR-Wal project are:

- Information about potential developments (active technological watching);
- Chain actors awareness (farmers, traders, industries, municipalities, consumers, researchers, etc.);
- Connection between supply and demand of the various actors, co-ordination of actions, chains representation;
- Setting up of demonstration projects (supply of wood boilers, for example) and initiation of research and development projects (oil production at the farm).

Biolubricants

Demonstration projects have been set up in the field of biolubricants. Demonstrations of chainsaw oil led to the acceptance of vegetable oils by woodmen. Demonstrations of biodegradable hydraulic fluids are on-going for one forest tractor, 4 branch chippers and 2 farming tractors. All of these machines function correctly.

Tests on motor oil based on vegetable esters for city buses have been finalised. Among the main results was the discovery that the selected oil was not very well adapted to bus engines (its consistency being too viscous). Concerning price, ester-based oil is competitive with mineral oil.

A report entitled “Vegetable-based Lubricants” was finalised by the members of the working group managed by ValBiom. Among the conclusions and actions proposed were the importance of: studying the environmental impacts of rapeseed crops; supporting the implementation of a European “ecolabel” for lubricants; implementing measures of support (as in other European countries) and supporting initiatives such as the “Vegetable-based Lubricants” working group.

Biofuels

Concerning biofuels, a report was written on technical, environmental, economic, agricultural, statutory and implementation aspects for biofuels in Wallonia. Among the conclusions of this report, it is interesting to note that biofuels have often been a subject of polemic in Belgium, sometimes based on subjective elements. Nevertheless, biofuels offer interesting prospects in the field of energy, environment and agriculture. Many examples testify in other countries.

Furthermore, ValBiom participates in the European Bioenergy Networks (EUBIONET). The European Commission has established three bioenergy networks (Solid Biofuels, Biogas and Liquid Biofuels) to promote the use of bioenergy and to support the Campaign for Take-Off and dissemination of the information of directives related to bioenergy.

Wood energy

At the present time, the activities in the field of wood energy are mainly orientated to the pellets sector. In October 2002, ValBiom implemented the “Belgian Pellets Club”, a working group bringing together the main actors of the pellet chain in Belgium, whose main objective is to contribute to the development of this new chain in Belgium. Some people are interested by this new fuel in Belgium,

but there are only a few examples in Wallonia (stoves and central heating systems). ValBiom promotes the use of this new fuel by organising workshops and by writing and distributing information leaflets, etc. Another objective is to identify the obstacles to the development of the chain and to propose appropriate solutions.

Other activities

Other activities concern the rapeseed chain (culture contracts on set-aside land, rapeseed trituration at the farm, etc.), potatoes or biomethanation, for example.

Prospects

ValBiom, through the FARR-Wal project, will continue to contribute the development of the various non-food agricultural chains in Wallonia. Furthermore, enhanced communication systems will lead to the improved knowledge of these chains throughout the population.

KEY FACTORS FOR THE SUCCESSFUL MARKET DEVELOPMENT OF BIOENERGY: EXPERIENCES FROM AUSTRIA

Christian Rakos[1]

Abstract

Over the last 20 years more than 600 Biomass District Heating plants have been implemented in rural villages in Austria. These plants provide about 5 PJ of energy per year. An assessment of the obstacles and critical issues for the successful dissemination of this technology shows that various factors have been important: technological performance; economic factors; socio-economic boundary conditions; and the socio-cultural context of plant establishment. Supportive policies have played a critical role and included a multitude of measures. It has proved very important to the success of the scheme (particularly in the early phase of diffusion) to assign professionals to manage the initial, day-to-day hitches, and accelerate the learning process by co-ordinating communication and feedback.

"Systemic management" can be defined as managing technology introduction, taking into account all elements of the system the technology interacts with – particularly the social system in which it is embedded. The present example also gives an interesting indication of what happens if some of the elements of the system are neglected: success is seriously affected.

This paper includes results of the doctoral thesis of the author: *Fünfzehn Jahre Biomasse-Nahwärmenetze in Österreich*, Technische Universität Wien, 1997. This thesis was written in the course of the EU-funded project "Pathways from Small-scale Experiments to Sustainable Regional Development", "EXPRESS PATH", CEC Contract No. EV5V-CT92-0086.

Introduction

Energy from biomass provides about 13% (130 petajoules [PJ]) of primary energy consumption in Austria. The greatest part of this bio-energy use (60%) can be attributed to traditional stoves and boilers using wood logs. Over the last 20 years a new technology for providing domestic heating in rural areas has been introduced: small-scale district heating plants that use woodchips, industrial wood wastes and straw as fuel. By 2001 more than 600 Biomass District Heating (BMDH) plants had been established. This example of introducing a new technology provides an opportunity to study closely the interaction between the driving forces and barriers that finally led to the technology's widespread deployment.

The scheme of a BMDH system is simple. A large furnace fuelled with biomass heats water that passes through a pipe grid and supplies the energy for heating individual houses in a village. Austrian villages with BMDH plants usually have between 500 and 4 000 inhabitants and are of a predominantly rural character. Accordingly, the size of BMDH plants varies between a few hundred kilo watts (kW) up to 8 Mega watts (MW), with corresponding grids of between 100 m and 20 km. About two-thirds of all plants produce less than 1 500 kW.

1. Austrian Environment Agency, Vienna, Austria.

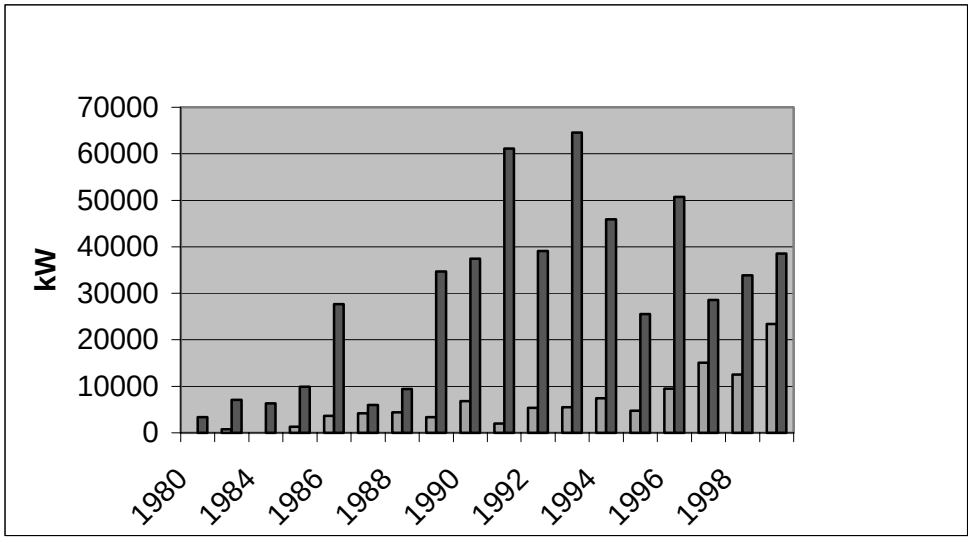
Biomass district heating has a number of significant advantages compared to traditional heating systems. It substitutes all fuel-handling work, provides continuous heat and significantly reduces emissions from predominantly old and technically poor individual heating systems.

The introduction of BMDH was by no means an easy process, however. Its success is due to a combination of dedicated top-down policies and local bottom-up initiatives. Top-down policies were not restricted to financial incentives, but also included the establishment of organisations dedicated to managing the initialisation phase, which worked continuously on solving the various problems arising during the introduction process.

Figure 1 shows the number of newly established BMDH plants in four provinces (Lower Austria, Upper Austria, Salzburg and Styria), where the largest numbers of plants were built. There is an obvious saturation of the market for village heating systems and a sharp increase in what are called micro grids.

During the first phase, which ended in 1984, private companies, mostly sawmills, were the predominant developers and operators of BMDH plants. They were succeeded by municipalities and farmers' co-operatives, which now operate the great majority of plants. Conventional utilities generally became more interested in BMDH in the 1990s, but were rather cautious about setting up projects. In some cases, interesting forms of joint ventures with farmers' co-operatives were established; utilities adopted the role of developers, making use of their professional, technical and management resources, while farmers took on the role of operating the plant and arranging for the supply of fuel. The general dominance of farmers as developers and operators is related to the enhanced availability of subsidies for this group.

Figure 1. Number of plants established on an annual basis



Note:
The dark columns show plants producing in excess of 800 kW, which typically supply whole villages, and the light columns show smaller plants which heat only a few larger buildings in village centres.
Source: Author.

Obstacles and critical issues for technology diffusion

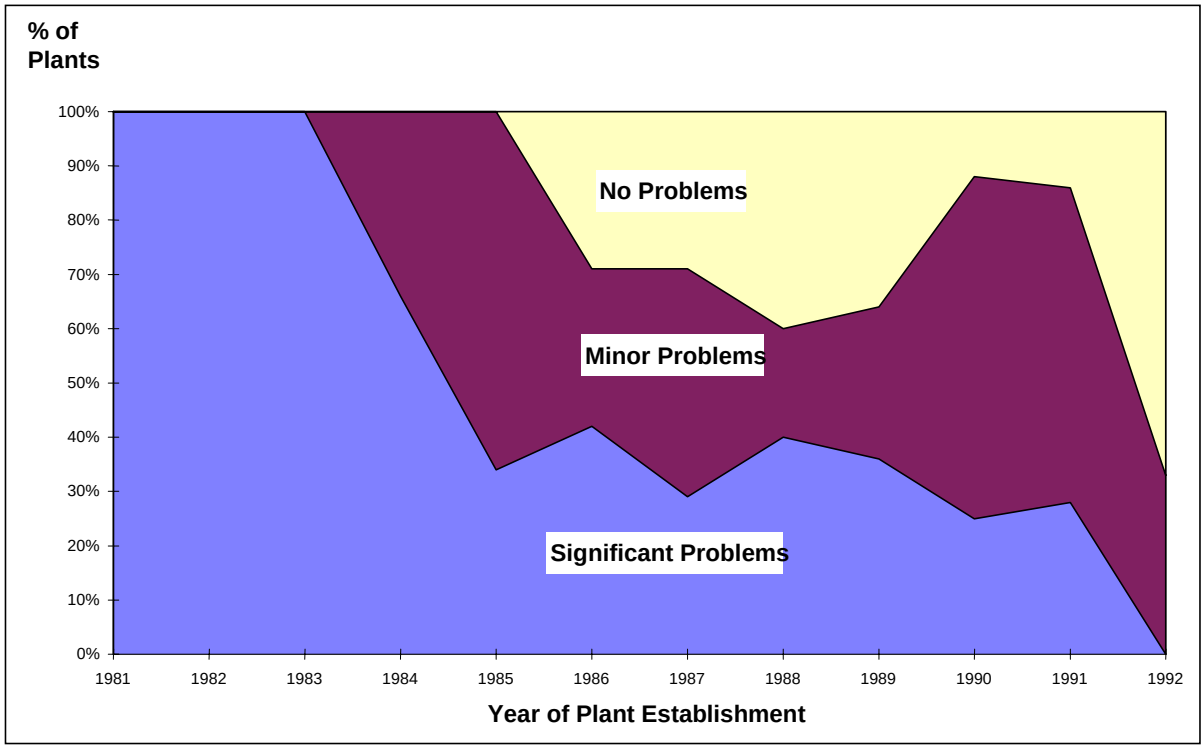
The role of technological performance and the qualifications of related professionals

It is important to distinguish four aspects of technology performance that have influenced the diffusion of BMDH plants in quite different ways: the performance of the central heating plant with respect to reliable operation; with respect to emissions; the performance of the technical interface in supplying heat to consumers; and the overall efficiency of the system.

To put it briefly, reliable operation posed significant problems for the operators, particularly during the start-up phase, but, because the plant owners managed to conceal the existence of these operational problems from the public, the rate of conversion to the new technology was not adversely affected. The plant operators overcame the day-to-day technical problems, and central plant failures of a few hours largely went un-noticed by the customer, due to the heat-retaining capacity of the hot water in the grid.

Close feedback loops to industry organised by the supporting organisations (the "technology introduction managers") led to the necessary technological training for reliable plant operation. Figure 2 shows clearly the effect this has had: the percentage of plants with serious operation problems dropped sharply after the first few years.

Figure 2. Development of operational problems in BMDH plants



Source: Rakos, 1994.

The second aspect was emissions from the heating plant. At the beginning of BMDH development in the early 1980s emissions played a secondary role in the public perception of plants. Nevertheless, during the early 1990s, a publicly funded research and development (R&D) programme led to the deployment of emission-minimising equipment, such as continuous power control, electronic combustion control and flue gas condensation. This proactive attention to the issue of emissions played an important role in the general diffusion which took place during the 1990s, in a climate of increased environmental awareness.

The greatest threat to technology diffusion originated in deficiencies in the technical interface between the district heating grid and heating systems for individual houses. This interface (heat exchanger, regulation, piping) does not form part of the BMDH plant. Usually it is planned, installed and maintained by independent local plumbers with no specialised experience of district heating. Failures in the sub-system directly affect consumer comfort. In some cases, plumbers repeated the same mistakes in many installations, which seriously affected the local attitude towards biomass district heating and, on a number of occasions, plants could not be established in neighbouring villages because their reputation was so bad.

The last aspect is overall plant performance. While considerable R&D efforts were made to minimise emissions, the overall technical performance of the system was largely neglected. The annual system efficiency is only around 50% in many plants. Heat losses and high electricity costs are due to over-sized boilers, district heating pipes and electric pumps, vents, etc. Operators were frequently unaware of the high heat losses and electricity costs of their plant and interpreted their technical problems as an economic problem caused by low oil prices. As public attention had not been drawn to monitoring the plants' overall technical performance, and as the operators did not fully understand the problems involved, no feedback reached the technical planners responsible, which had the effect of slowing down technological progress considerably.

The impact of deficiencies in planning and operation on the dynamics of diffusion is difficult to quantify. It undoubtedly gave rise to certain economic problems, but these were never allowed to become public knowledge. Politicians managed to prevent open financial disasters by requiring public utilities to take over plants with serious problems. Proactive policies to upgrade plants technically were only put in place 20 years after the original establishment of BMDH plants, with the introduction of technical quality criteria as a precondition for subsidies.

To sum up, major technical obstacles for renewable energy diffusion arose from the lack of specialised knowledge on the part of the relevant professionals such as plumbers, planners and plant operators. It is unwise to focus attention only on the technical device producing the renewable energy without regarding the periphery, both in technical terms, and in terms of the skills of the professionals responsible for setting up and maintaining the system. Feedback is fundamental for technological advancement and it must be regarded as a central task for renewable energy management to install appropriate feedback mechanisms.

The role of socio-economic boundary conditions

A key factor in understanding BMDH development in Austria is the difficult economic situation facing farmers, particularly in areas with low tourism and a declining industrial base. Due to the lack of alternative sources of income, farmers in these areas are anxious to explore any possibility of increasing their earnings from agriculture or forestry. The majority of Austrian farmers are also forest owners, and about half of Austria's forests are owned by farmers possessing areas of less than 40 ha of forest. During the last 20 years wood prices have decreased considerably for a number of reasons.

Cheap wood imports, periodic crises in the pulp-and-paper industry and the increased use of recycled paper, combined with other factors, have led to an over-supply of wood. The substantial decline in wood prices was a driving force behind the development of BMDH, which created a new, value-added use for wood that was unsuitable for sawmills or paper production.

Even if the opportunities of earning a living in other economic sectors – such as tourism or industry – are good, interest in further developing BMDH is generally low. This is true for most of the western states of Austria. However, there are some cases of prosperous touristic villages, where BMDH plants were established for reasons of comfort, lowering of local air pollution, and prestige. Thus, an entirely different socio-economic context also supports the technology – but it requires particularly advanced technologies (such as flue gas condensation) to prevent any visible emissions that could offend tourists. Nevertheless, the majority of BMDH plants in Austria were established in peripheral regions and were motivated by a desire to improve the local socio-economic situation.

Economic aspects

The economics of biomass district heating plants depends on investment costs and operation costs. In practice, the specific investment costs show widely differing values, which depend on local conditions, planning competence and philosophy, operators, etc. The range of costs extends from EUR 360/kW of installed power all the way up to EUR 1 800/kW, with average values at around EUR 850/kW.

The two most critical factors for BMDH operation are the cost and sales of producing heat. Thus, a central economic precondition is the willingness of consumers to connect to the district heating grid and pay a somewhat higher price than for individual heating. This is a feasible condition, as biomass district heating offers significantly enhanced comfort compared to individual heating systems which are frequently still in poor condition in rural areas. Apart from enhanced comfort, environmental protection and local self-sufficiency also play a significant role in the motivation of district heating customers. Economic considerations are not a primary motive, nor are they consistent. This conclusion is emphasised by a survey on the opinions and experiences of customers in different villages, which showed that there was no consistent relationship between the economic evaluation of BMDH by consumers and the actual prices paid for heating (which differed by more than 20%).

Here again, management failures led to serious problems: some of the consulting organisations advised operators to sell heat as cheaply as possible, to increase sales – a disastrous proposal in economic terms.

The socio-cultural context and conflicts regarding plant establishment

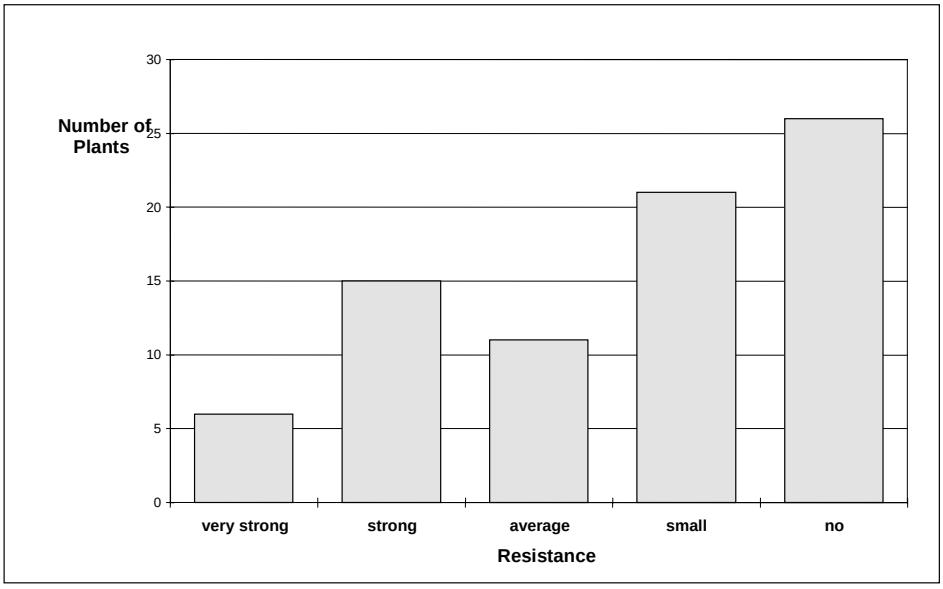
A major barrier to the establishment of BMDH plants has been initial misgivings about the new technology (this was especially true of the first villages to convert to the system). Will it work? What will be its impact on village life? Who is going to profit from the project? These were some of the questions discussed at length at the village inns. There seems to be no way of avoiding this distrust of new technology. It is an anthropological constant, present regardless of the type of innovation and the specific cultural context. Mistrust of unfamiliar innovations plays a central role in the cultural integrity of a society. This form of distrust is not only an individual phenomenon; it is also a social one. Rational economic and technical considerations will only serve to create trust if they both symbolically and factually converge with the social meaning accepted by the majority of the society affected.

Since the 1950s rural communities in Austria have experienced the profound impacts of technical innovations in agriculture that have not only completely changed the way agriculture was conducted, but have also changed rural culture. New ways of living and increasing economic pressures on farmers have resulted in social disintegration and the sense of a lack of purpose in many places. The result is suspicion regarding any form of innovation which might further change and possibly destroy local cultural habits, simultaneously combined with a strong desire for any meaningful initiative that will give new hope for rural development. The tension between these two dispositions explains the great spectrum of responses provoked whenever the establishment of a BMDH plant is suggested. Both full collective support and vivid conflicts may be associated with a project. Figure 3 shows that conflicts have taken place in the majority of cases and have often been quite important.

In most cases studied these conflicts have, eventually, been settled. However, BMDH consultants tell me that in many villages considering the installation of a BMDH plant, such conflicts have actually resulted in the project being stopped.

I distinguished two basic categories of conflicts. The first one is related to the so-called "syndrome of acquired depression" that seems to be linked to the general cultural and social disintegration in rural areas such as those as mentioned above. This issue was further investigated in the course of the EXPRESS PATH project by Kunze (1994). These developments, in many places combined with the existence of a long-established autocratic local political élite, may lead to total apathy within the population and people may lose all hope for a better future. An innovative project challenges not only this depressed attitude, but probably also the ruling élite. The principal attitude in such villages is one of distrust and rivalry. Under these conditions, according to my survey, the main arguments against a BMDH project are irrational or pseudo-economic.

Figure 3. Resistance to BMDH projects



Source: Rakos, 1994.

The second type of conflict is related to the "NIMBY (not-in-my-backyard) syndrome". BMDH is nice for everybody – except those who live close to the chimney and are bothered by smoke or noise pollution. This type of conflict appears quite often in places with many new residents, usually affluent residents from urban areas seeking unspoiled nature in the countryside. They are usually well organised and try to use rational or even scientific arguments to stop the projects.

It is of central importance for a BMDH project that conflicts are properly addressed on time and managed in the best possible way. Even if a project succeeds despite severe conflicts, the economic disadvantages are often considerable. It has been found that the average investment costs for plants meeting strong or very strong resistance were 30% higher than for plants facing no resistance. Cost increases are caused – by the necessity to change the site, for example, or by extra requirements for licensing. Lower heat sales, due to the unwillingness of opponents to connect to the grid, may also have a serious economic impact.

The institutions that were managing technology deployment were so much geared to economic and technical questions that they did not adequately address the social aspect of introducing new technology. Any systemic management approach needs to take this point into account as a key issue. If it is neglected, serious negative impacts and limited diffusion may result. It is quite likely that the early decline of the number of newly established village heating systems is due to the fact that many potentially well-suited villages were lost due to the mismanagement of local conflicts.

The role of policies for supporting technology introduction

The Austrian political system allows a study of the effects of different policies on individual cases of BMDH deployment. Austria is a federal republic with nine different states. The energy policy of these states is quite distinct and this has had a profound impact on the rate of BMDH technology diffusion. The majority of BMDH plants are situated in only four states (Lower Austria, Upper Austria, Salzburg and Styria).

The comparison of state policies and their impact shows the differing role of economic incentives during diffusion. During the early development phase of BMDH implementation, management was of central importance. The introduction of BMDH plants was only successful in provinces that established a dedicated institution or focal point to manage the minor problems usual in the early days of introduction. These institutions facilitated co-operation among all relevant actors, conducted public information activities and provided advice to local developers. After 5-10 years of dedicated introduction management, the establishment of a plant became more of a routine process. Economic incentives established in neighbouring provinces were able to assist diffusion immediately. Nevertheless, management efforts to keep the development on-track are still necessary even though 20 years have passed since the first plant was established. Current tasks that need to be addressed are, for example, the establishment of a programme to upgrade old plants, benchmarking of plant performance, educational activities for operators, etc.

Given the complex approach necessary to get technology deployment started, two common myths regarding renewable energy can be discarded: myth one says renewable energy is primarily a question of research: myth two says it is nothing but a question of economic incentives. Neither is true. Both research and economic incentives are important ingredients – however, they must be integrated in a systematic approach that takes into account the complexity of setting up a new energy system.

This is also confirmed by a recent investigation by the International Energy Agency (IEA) that compares approximately 30 different cases of successful market deployment of energy technologies (IEA/CERT, 1993). In the majority of cases discussed, success was closely linked to dedicated institutions managing the innovation.

Conclusions

The case of biomass district heating in Austria shows the complexity of establishing a renewable energy system. It is of fundamental importance for the success of renewable energy policies to address this complexity and to refrain from looking for easy answers to difficult questions (as suggested by strictly economic or technical perspectives). The most direct consequence of this finding is that it is essential that sufficient resources are made available for "systemic management" during the introduction of renewable energy technologies. Money invested in proper advice, monitoring of technical development, benchmarking, quality control, educational measures, and promotion based on a profound understanding of the social processes in communities, are indispensable prerequisites for success.

BIBLIOGRAPHY

IEA/CERT (1993), *Lessons learned and best practices in energy technology deployment:* www.iea.org/impag/Deploy/INDEX.HTM (userid: IMPAG password: BRANDY).

Kunze, G. (1994), "Cultural Change and the Diffusion of Sustainable Energy Technologies" (unpublished paper).

Rakos, C. (1994) doctoral thesis: "Fifteen Years of Biomass District Heating in Austria".

Part II
BIOMASS AND AGRICULTURE: POLICY APPROACHES, IMPACTS AND OPTIONS

1. Europe

Page

European Commission Policies for the Promotion of Bioenergy
Kyriakos Maniatis, European Commission, Belgium *317*

Renewable Raw Materials and European Union Research Policy
Ciaran Mangan, European Commission, Belgium; and Jim Coombs, CPL Scientific Publishing Services Ltd, United Kingdom *335*

Biomass from Agriculture: the Viewpoint of European Farmers
Horst Jauschnegg, Austrian Biomass Association (on behalf of the International Federation of Agricultural Producers), Austria *349*

Austrian Policy Approaches Towards Biomass in Agriculture
Valerie Zacherl, Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, Austria *355*

Bioenergy Policies and Tools in Belgium
Yves Schenkel and Romain Crehay, Centre de recherches agronomiques de Gembloux (CRA), Belgium *359*

Agricultural Biomass in Greece: Current and Future Trends
M. Mardikis, A. Nikolaou, N. Djouras and C. Panoutsou, Centre for Renewable Energy Sources (CRES), Greece *363*

Long-term Perspective of the Use of Biomass for Energy in Hungary as a Part of the European Union Accession Procedure
Károly Kocsis, St. Stephen's University, Hungary *377*

Review of Current Policy Approaches Towards Bioenergy Production from Agriculture in Northern Ireland and the Republic of Ireland: a Perspective from the Irish BioEnergy Association
Michael Doran, Irish BioEnergy Association, and Rural Generation Ltd., United Kingdom *387*

Favourable Policy Conditions to the Development of Biogas Production as a Sustainable Form of Energy in Luxembourg
Gérard Conter, Ministry of Agriculture, Luxembourg *405*

Bioenergy and Agriculture: the Norwegian Policy Perspective
Frode Lyssandtrae, Ministry of Agriculture, Norway *417*

Page

State of the Art of Bioenergy in Poland – Barriers and Opportunities
M. Rogulska, A. Oniszk-Popławska, M. Pisarek and G. Wisniewski, EC Baltic Renewable Energy Centre and Centre of Excellence and Competence in Renewable Energy in Poland, Poland *423*

Conditions for Increased Market Penetration of Short Rotation Coppice for Energy Purposes in Sweden
Björn Telenius and Paul Westin, Swedish Energy Agency, Sweden *435*

Biomass Use and Potential in Turkey
F. Taner, I. Ardic, B. Halisdemir and E. Pehlivan, University of Mersin, Turkey *439*

United Kingdom Government Energy Policy: Aims and Support for Sustainable Energy Production
Melvyn F. Askew, Central Science Laboratory (CSL), United Kingdom *455*

EUROPEAN COMMISSION POLICIES FOR THE PROMOTION OF BIOENERGY

Kyriakos Maniatis[1]

Abstract

This paper presents an overview of the several European Union policies and actions on renewable energy sources that are shaping the European Union's future energy system, with the emphasis on the role of bioenergy. The overview covers the present energy situation in the European Union and outlines the contribution that renewable energy sources can make if member states implement the policies successfully. Bioenergy is seen to be the most important renewable energy source since it has the highest potential and it is the only one that can directly replace fossil fuel-based energy. The paper also identifies some of the important barriers that have to be overcome in order to accelerate bioenergy's penetration into the energy markets. International trade of biofuels (solid or liquid) will assist in the establishment of biofuels markets. Overall, bioenergy has an important potential to mitigate greenhouse gas emissions and contribute to sustainable development.

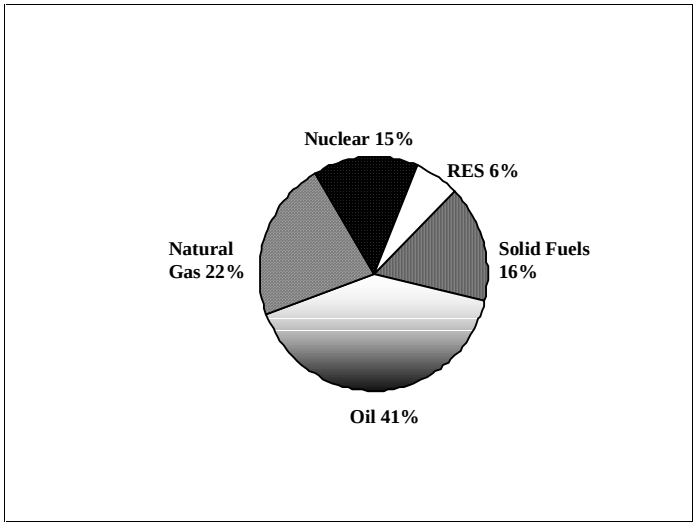
The current energy situation and the contribution of renewable energy sources in the European Union

According to the European Commission's *Green Paper* on the security of supply (EC, 2000*a*), 80% of the European Union's (EU) current energy demand is covered by fossil fuel, of which over 40% is oil. At present, renewable energy sources (RES) have a share of around 6% of total energy consumption, although there is a target of 12% by 2010. The level of energy-related pollution caused by today's energy mix (where the main concern is CO_2) is too high. The European energy mix in 2001 is presented in Figure 1, where it can be seen that the contribution of renewables is at present 6%.

While the rate of energy intensity in the EU actually fell over the last decade, due to improved energy efficiency and structural change in the energy sector and industry, energy consumption *per capita* continued to increase, along with the rate of global oil consumption. The change in the EU's energy consumption and CO_2 emissions between 1990-99 is graphically represented in Figure 2 (EC, 2000*a*). This situation is unsustainable in the long term and policies have to be implemented to reduce fossil fuel consumption.

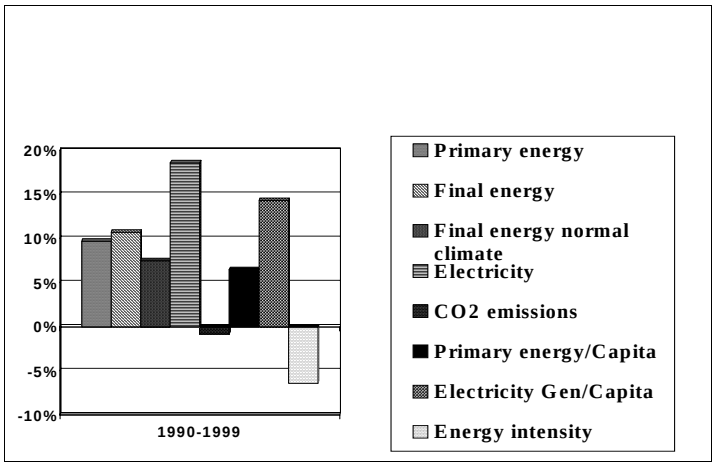
1. New and Renewable Energy Sources Unit, Directorate-General for Energy and Transport, European Commission, Brussels, Belgium.

Figure 1. The European energy mix in 1998



Source: EUROSTAT, 2000.

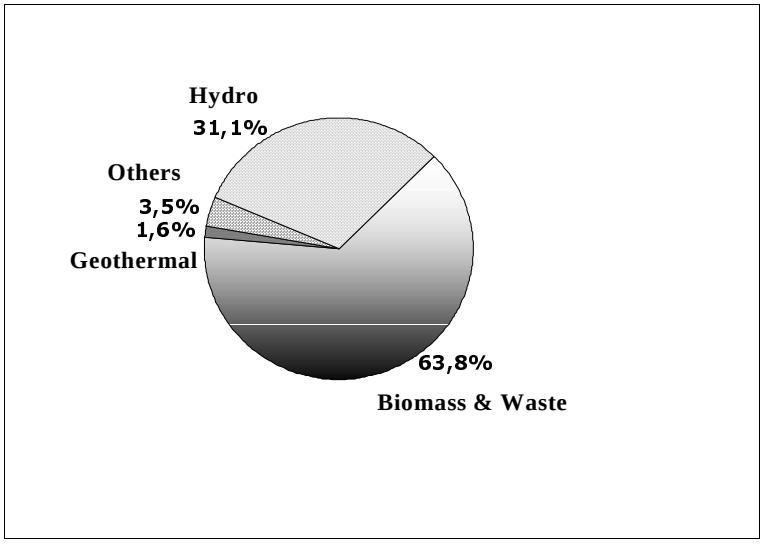
Figure 2. EU Energy consumption and CO_2 emissions % change between 1990-99



Source: EC, 2000a.

Figure 3 shows the contribution of the various RES to the EU's energy mix. Even though in this figure large-scale hydropower is also included, it is clear that bioenergy (energy from biomass and waste) offers by far the highest contribution amongst all renewables. Bioenergy is globally recognised as the renewable resource that will make the most significant contribution to sustainable energy in the near to medium term (Maniatis and Tustin, 2002; Faaij *et al.*, 2002; TERES, 1977).

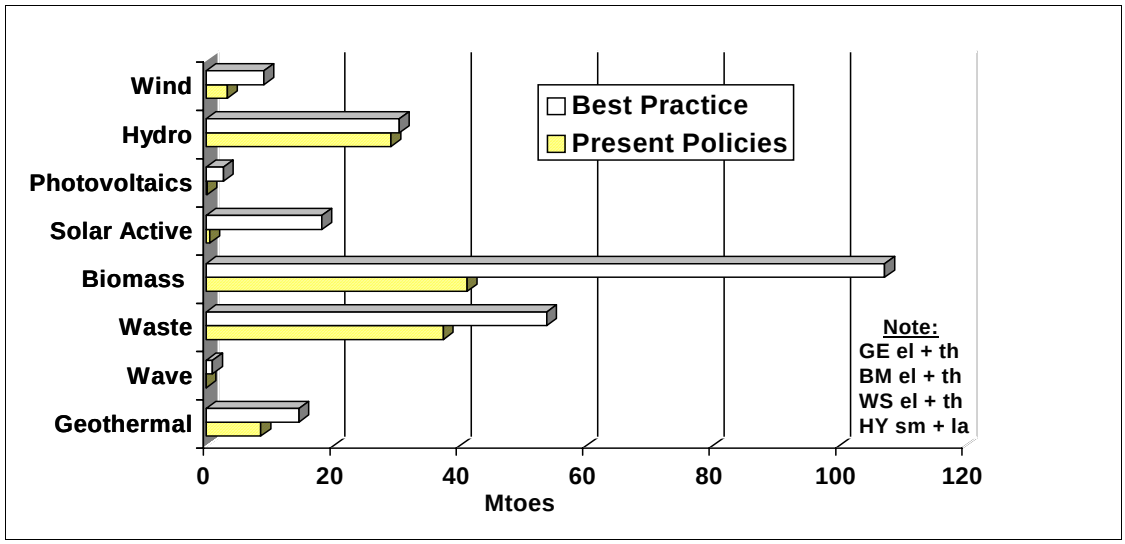
Figure 3. Bioenergy's contribution to RES energy



Source: EUROSTAT, 2000.

RES are widely available, although not always in circumstances favourable for energy production. In the TERES II study (TERES, 1997) the technical potential of RES (*i.e.* the resource that could be developed for energy in the absence of any competing use and without any economic constraint) has been determined, based on certain assumptions. The EU-15's total renewable resources in 2020 are estimated at approximately 412 Mtoe (million tonnes of oil equivalent) – that is, the equivalent to about a quarter of the forecast demand in that year. Although it is not possible to utilise this potential, even under the best-case scenarios, the forecast is indicative of the importance of RES. A significant part of this potential could be reached, however, given the right policies and support by the EC and national policies of the member states. Figure 4 presents the renewable energy penetration, by technology, for the EU-15.

Figure 4. Renewable energy penetration in 2020, by technology



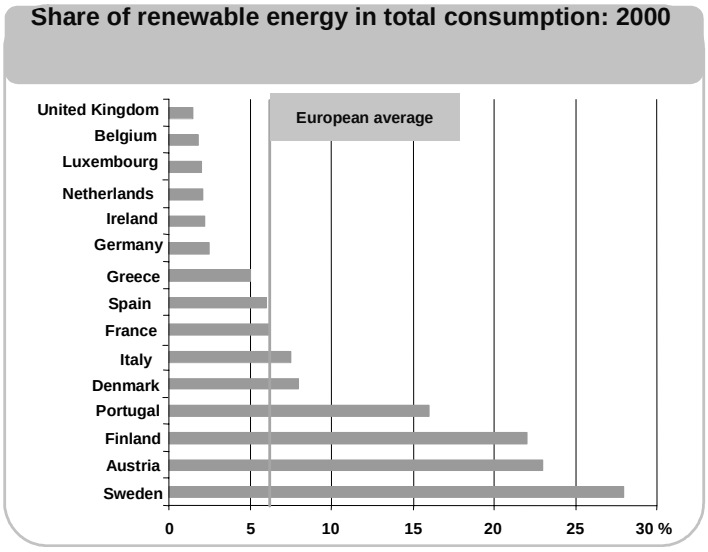
Source: TERES, 1997.

In Figure 4 it should be noted that, for reasons of clarity, only two of the policy scenarios from the TERES II study have been taken into consideration. The data for geothermal, biomass and waste also include the potential for heat production, while the data for hydro include small and large applications. These data are impressive since they show that for most technologies penetration will more than double if the best practice policies are adopted.

Intermittent renewable technologies for electricity, such as wind, can make major contributions to power generation, especially for the smaller, decentralised end of the electricity market, as their production availability is relatively low (in the range of 25-60%) when compared to fossil fuels (usually 80-90%). However, recent developments in large wind farms – especially offshore wind farms – have created a new potential for wind energy. State-of-the-art geothermal technologies and large and small-scale hydro offer the prospect of cheap power generation, while advanced biomass conversion technologies, such as co-firing and large-scale combustion for power generation, can provide modern energy services and help stimulate rural development. In the area of transport fuels, alcohol from grain and sugarbeet and rape methyl ester from rapeseed are the focus of current industrial efforts, while a complete new generation of liquid biofuels is under intensive research and development (R&D) work.

All RES can provide energy with very low levels of local pollutant emissions, which offers substantial greenhouse benefits. The development of renewables is a central aim of the EU and numerous activities at local, regional, national and EU level are interactive. The result is a dynamic renewable energy sector that varies distinctly among renewable sources and from member state to member state. The EC's *White Paper* (EC, 1977) and its Campaign for Take-off laid the foundations for the development of key technologies in all renewable energy sectors. Yet in spite of all these initiatives, renewables, in general (with the possible exception of wind energy), and bioenergy, in particular, lag far behind the goals set by the *White Paper*. Figure 5 shows the share of renewable energy in the member states for the year 2000 (EUROSTAT, 2000). While some countries, for example Sweden, Austria, Finland and Portugal, have achieved a significant share of renewable energy contribution to total primary energy supply, others fall well below the EU average.

Figure 5. Share of renewables in member states



Source: EUROSTAT, 2000.

The need for legislative action to support renewable energy sources

Various global scenario studies for bioenergy indicate that biomass may contribute from 100 to over 400 Exajoule to the world's energy supply over the course of this century (this is equivalent to 25% to almost 100% of the world's current energy use) (Hoogwijk *et al.*, 2003; Ishitani *et al.*, 1996; IIASA/WEC, 1998; Shell, 1995). However, the enormous potential of bioenergy will never be achieved unless appropriate policies are defined and implemented in order to create a level playing-field for all energy sources. Indeed, RES face stiff competition from the established fossil and nuclear sources of energy, which received very high levels of financial and political support from both national and EU sources over the last century – support that was necessary to provide the energy supply that formed the foundations of modern society before global problems, such as climate change, became apparent. At the same time, it has become clear that the present global energy system is not sustainable and new approaches to energy supply and demand have to be developed to ensure a sustainable and functioning global economy. Whatever new energy system or strategy is designed, RES will, in future, have a more prominent role to play.

Figure 6 shows the costs of electricity produced by the various renewable sources in comparison to coal and natural gas since the early 1980s and compares them to the cost of electricity production including the external costs (Kotronaros and Maniatis, 1999). The external costs were taken from the EXTERNE study carried out by the EC (EXTERNE, 1999) and are given in Table 1 according to the various sources of energy. The cost of electricity production from photovoltaic technologies is still too expensive in spite of the significant cost reductions achieved over the reported period. While the reduction in the cost for producing power from hydro and geothermal is relatively small, wind and bioenergy-based technologies have achieved significant cost reductions over the last decade and at present are just below EUR 5 cent per kWh.

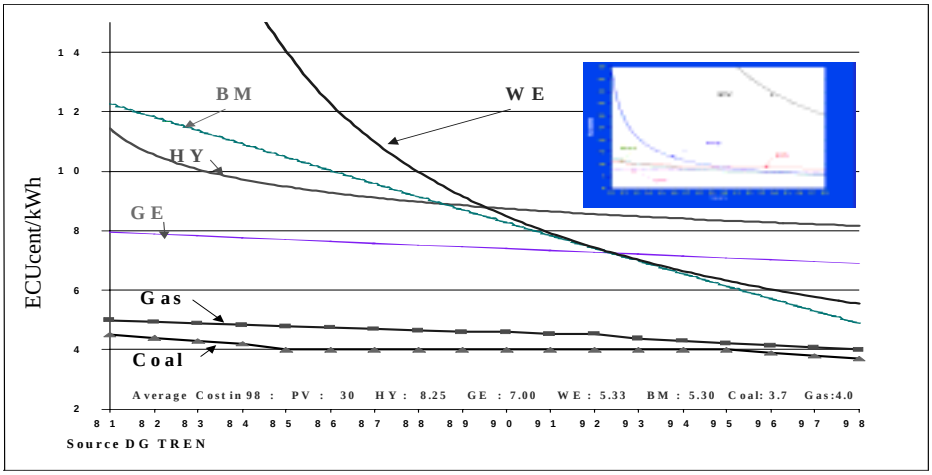
The data in Figure 6 show that, had the external costs been taken into consideration, both wind and biomass-based power generation would have been competitive with natural gas-based power (since 1997) and with coal-based power (since 1989). Under these conditions there would have been no need to undertake special action and propose legislation for the promotion of renewable energy sources. However, in spite of the effects of climate change, which are becoming increasingly apparent, the inclusion of the external costs of energy into the overall energy cost will not take place in the near future. Therefore, legislative action is needed in order to assist RES to penetrate the energy markets.

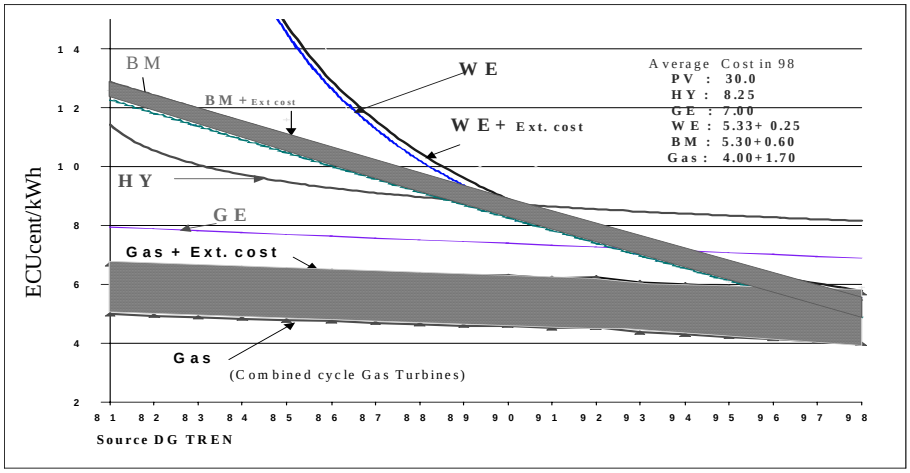
Table 1. Damage cost estimate for power fuel cycles, (UK specific results)
(all in euro cent per kWh)

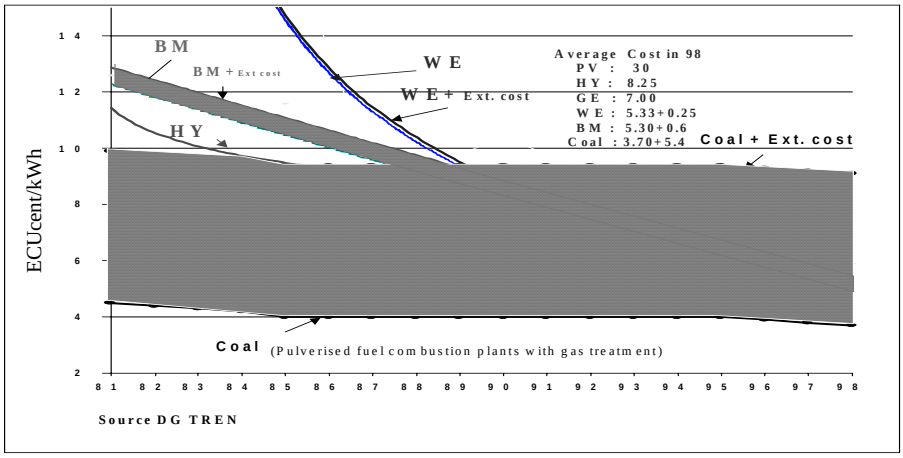
	Coal	Oil	Natural gas	Nuclear	Wind energy	Bioenergy
Public Health	2.280	1.600	0.28	0.25	0.11	0.46
Occupational Health	0.093	0.110	0.0	0.0	0.0	0.0
Crops	0.093	0.0	0.0	0.0	0.0	0.0
Materials	0.093	0.175	0.12	0.15	0.0	0.11
Noise	0.0	0.0	0.0	0.0	0.12	0.0
Global Warming	2.860	2.000	1.30	0.0	0.0	0.0
TOTAL	5.419	3.885	1.70	0.40	0.230	0.570

Source: EXTERNE, 1999.

Figure 6. Renewable power plants production costs versus fossil power plants: without and with external costs







Source: EC, Directorate-General for Energy and Transport.

Legislative actions initiated by the European Commission

The UN Framework Convention on Climate Change of 1992 requires the parties to adopt policies and to take measures to reduce and limit greenhouse gas emissions consistent with the objectives of the Convention. This commitment has been quantified by the Community as an 8% reduction commitment as laid down in the Kyoto Protocol of 1997. Whereas the RES sector can already provide a substantial contribution to the Community efforts to meet the Kyoto target in the relatively few years left before 2012, it will play an even more important role in the period beyond 2012, where the Commission's proposal for a Sixth Environmental Action Programme foresees a 20-40% reduction by the year 2020.

In view of the expected increase in CO_2 emissions in the absence of further measures and the challenge that the majority of member states may face in meeting their commitments under the EU burden-sharing agreement, a reinforcement of policies and measures at EU level becomes an important part of the overall EU climate strategy.

In its *Green Paper* on the security of energy supply (EC, 2000*a*) the EC outlines the prospective energy situation in the EU for 2010 and beyond. One of its essential observations is that the EU will, in the short and medium term, have a limited possibility to influence the supply side of energy. However, as the EU is one of the main consumer areas, it should do its utmost, notably on the demand side, to reduce its heavy dependence on external suppliers.

The EC has undertaken a series of legislative proposals in order to support RES penetration in the energy markets in view of the Community efforts to meet its Kyoto obligations and in improving the EU's security of energy supply situation. These are discussed below.

Directive on the promotion of electricity produced from RES in the internal electricity market

This Directive, of 27 September 2001 (EC, 2001*a*), is intended to promote an increase in the contribution of RES to electricity production in the internal market for electricity and to create a basis for a future Community framework. The Directive sets National Targets for electricity from RES and, more specifically:

- Member states are obliged to establish national targets for future consumption of RES-E. The Directive gives *indications* for these national targets in its Annex, which was amended in view of the enlargement of the EU.

- If the targets are met, consumption of electricity from RES will rise from 14% in 1997, to 22% by 2010.

- The Commission will monitor progress made by member states towards achieving their national targets.

Concerning the support systems for RES-E, the Directive abstains from proposing a harmonised Community-wide support system. However, the Directive obliges the Commission to make, *if necessary*, a proposal for such a harmonised support system within 4 years, taking into account the experiences gained in member states with the operation of the different national support systems.

The Directive obliges member states to: a) assure guaranteed access for RES-E; b) issue guarantees of origin of RES-E and c) assure that the calculation of costs for connecting new producers of RES-E should be transparent and non- discriminatory. As regards the application of the state aid rules to electricity from renewable energy sources, in December 2000 the Commission adopted a new framework which is coherent with the aim of promotion of RES electricity. It thus offers member states several opportunities to grant support to renewable energy production.

The transposition of the Directive should have come into force by 23 October 2003. All member states have now published their national RES electricity targets, independently of the support system or scheme in force. Overall progress in the member states is well advanced. However, some have introduced support systems for renewable power, while others have introduced "green certificate" schemes. Most member states are maintaining their "feed in" systems.

Directive on the promotion of the use of biofuels or other renewable fuels for transport

The transport sector accounts for more than 30% of final energy consumption in the Community and is expanding – a trend which is bound to increase, with consequent increased CO_2 emissions – and this expansion will be greater in percentage terms in the candidate countries following their accession to the EU. The transport sector's overwhelming dependence on oil is expected to reach 90% by 2030. The sector is thus responsible for an important amount of the EU's greenhouse gas emissions and is contributing to the problems the EU is facing regarding security of energy supply. The EC (2001*b*) expects CO_2 emissions from transport to rise by 50% between 1990 and 2010, to around 1 113 million tonnes, the main responsibility for this resting with road transport, which accounts for 84% of transport-related CO_2 emissions. From an ecological point of view, therefore, the *White Paper* calls for dependence on oil (currently 98%) in the transport sector to be reduced by using alternative fuels such as biofuels.

Directive 2003/30/EC (EC, 2003) aims at promoting the use of biofuels or other renewable fuels to replace diesel or petrol for transport purposes in all member states, with a view to contributing towards objectives such as meeting climate change commitments, maintaining an environmentally friendly security of supply and promoting RES.

The Commission considers that the use of biofuels offers the greatest potential in the short to medium term. This is why the Directive established an indicative minimum level of biofuels as a proportion of all gasoline and diesel sold, starting with 2% in 2005, and reaching 5.75% in terms of the energy content of all fuels sold by 2010 in the EU. The Directive was adopted on 8 May 2003 and entered into force immediately. By July 2004, the member states are required to confirm their national targets or propose "motivated" lower levels. The Commission will monitor progress made by member states towards achieving their national targets.

The Directive recognises that although at present the only biofuels available for transport applications are biodiesel, bioethanol and biogas (or bio-methane produced after the purification of biogas), R&D work is underway for the next generation of biofuels which may include, among others, bioethanol from lignocellulosics; biodiesel from waste streams and animal tallow; bio-synthetic fuels produced from synthesis gas after biomass gasification (such as biodimethylether and bio-Fischer-Tropsch); and last, but not least, biohydrogen. The new production technologies for biodiesel and bioethanol are expected to be commercialised in about 3-6 years, while a time frame of 8-12 years is needed for the commercialisation of synthetic biofuels.

The Directive also focuses on the need to develop appropriate European Standards so that biofuels can be traded freely within the EU. It notes that in the case of biodiesel for diesel engines, where the processing option is esterification, the European Standard 14214 of the European Committee for Standardisation (CEN, 2003*a*) on fatty acid methyl esters (FAME) could be applied: European Standard EN 14213 can be applied whenever biodiesel is used as a liquid fuel for heating purposes (CEN, 2003*b*). However, bioethanol standardisation work has been recently initiated and standards for pure bioethanol as a blending component, (a 5% blend in gasoline and an 85% blend for fuel-flexible vehicles) are under development.

Proposal for a Council directive on the taxation of energy products

Recognising the key role of taxation instruments in achieving the EU's Kyoto Protocol objectives (by reducing the price differential between biofuels and competing fossil fuels), a proposal was made to give member states the option of applying a reduced rate of excise duty to pure or blended biofuels, when used either as heating or motor fuel. This has been incorporated into the proposal for a Council directive restructuring the Community framework for the taxation of energy products and electricity. Article 16, "Biofuels and other products produced from biomass" allows member states to apply exemption or reduced rates of taxation. The proposal was expected to be adopted in October 2003.

The above package of directives on biofuels is designed to be the first element in achieving the EU's target of substituting 20% of diesel and gasoline fuels with alternative fuels in the road transport sector by 2020.

Proposal for a Council directive on Combined Heat and Power

The aim of the proposal for a directive is to create the framework for the promotion of combined heat and power (CHP) applications. The target of the directive is the doubling of energy savings that can be achieved if the share of CHP electricity increases from 11% in 1998, to 18% in 2010. To realise the importance of CHP, one should take into account that from 1994-98 the annual energy saving due to CHP use was 28 Mtoe (or equivalent to the total annual energy consumption in Austria or Greece). The instruments to be used to achieve the above targets are:

- Definition of CHP – criteria to define high-efficiency CHP.
- Guarantee of origin.
- Easier access to the electricity grid.
- Reporting on national potential for high-efficiency CHP, barriers, implementation and progress.

The European Commission's programmes

In addition to legislative actions, the EC has been working extensively to increase the deployment of renewable energy technologies and applications. Barriers to the smooth functioning market are being removed wherever possible. This is being done with the help of Community technology development programmes, such as the *RTD Framework Programme* (EC, 2000*b*), and with pro-active support programmes such as the *ALTENER.* Regulations and various other actions to promote energy efficiency and renewables are being put in place, with the aim of developing an "Intelligent Energy for Europe", with a system of energy production, distribution and consumption that is safe, secure, cost-effective and sustainable.

The emphasis laid on technology support in various programmes has changed significantly over the years, with the evolution of technology development and the identification of the most promising technologies in terms of the accelerated penetration of bioenergy into the EU energy markets. In the Fifth Framework Programme (FP5) (EC, 2000*b*), which came to an end on 31 December 2002, care was also taken to identify the most promising technologies for the future generation of technologies in combination with societal, economic and industrial demands. In the Sixth Framework Programme, which followed FP5, the emphasis has been on combining the European capacity in infrastructure with scientific and technical knowledge into a more comprehensive structure with closer co-operation between activities at national and European level (EC, 2001*c*), with the aim of maintaining and strengthening the international leading role of the European Research Area.

The "Intelligent Energy for Europe" programme has been designed as the Community's main instrument for non-technological support in the field of energy over the period 2003-06. It provides continuity for actions taken under the ALTENER, SAVE and, to a certain extent, SYNERGY programmes, and combines all activities in the energy sectors that contribute to the main aims of Community energy and transport strategies in terms of energy aspects and the sustainable development strategy. The "Intelligent Energy for Europe" programme aims to strengthen the "renewable energy sources" and "energy efficiency" strands and introduces a third and a fourth strand on energy in transport and the promotion at international level, particularly in the developing countries, of RES and energy efficiency. It will also strengthen measures to disseminate and promote best-practice policies and best-available technologies so as to prepare stakeholders in this field, businesses and individual citizens for the changes which have already begun but which will develop rapidly in the future. It is also expected that the programme will bring about a genuine change in behaviour regarding energy through awareness campaigns, education and the promotion of investment in new technologies.

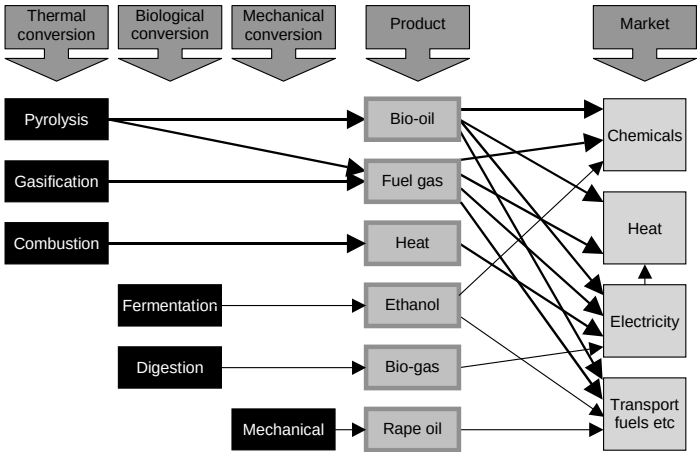
The sector of Energy from Biomass and Waste has been recognised as a very important RES sector by the European Commission services in the both the Research and Energy and the Transport Directorates-General that manage the programmes in relation to energy, and it has received significant support under all EC services (Maniatis and Kotronaros, 2002). Among the numerous technologies and market applications, thermochemical conversion has received dedicated support, with priority, so far, being given to gasification, with other combustion technologies that already compete in EU energy markets (Maniatis, 2001 and Maniatis *et al.*, 2003). Strong support has been given to pyrolysis technologies too, although, there has as yet been little interest from the market in demonstration projects based on this conversion technology. It is nevertheless expected that more pyrolysis demonstration projects will emerge in the future.

Status of biomass conversion technologies

Biomass fuels and residues can be converted to energy via the thermal, biological and mechanical or physical processes summarised in Figure 7 (Bridgwater and Maniatis, 2003). Thermal processing currently attracts the most interest, and gasification receives the most R&D support as it offers higher efficiencies compared with combustion, while fast pyrolysis is still at a relatively early stage of development but offers the benefits of a liquid fuel, with the concomitant advantages of easy storage and transport, as well as comparable power generation efficiencies at the smaller scales of operation that are likely to be realised from bio-energy systems, as compared with fossil-fuelled systems. The higher efficiency of gasification systems arises from the high efficiency in converting to gas (up to 98% hot gas efficiency is possible), and higher efficiencies in utilising heat from gas combustion. This includes larger-scale power generation of up to 100 MWe (mega watts power electricity) with Integrated Gasification Combined Cycle (IGCC) processes, with predicted electricity production

efficiencies of 45%-50%, compared with only 25%-35% via combustion; and small-scale power generation systems of up to 5 MWe, using engines that offer up to 30% efficiency, compared to 10%-15% using combustion and a steam cycle. Both of these thermochemical conversion processes offer high conversion efficiencies (as explained above), potentially competitive costs and considerable flexibility in scale of operation and range of products. Combustion, biological conversion processes (fermentation and digestion) and mechanical processing (*e.g.* vegetable oils) are well established and are available commercially.

Figure 7. Biomass conversion processes, products and applications



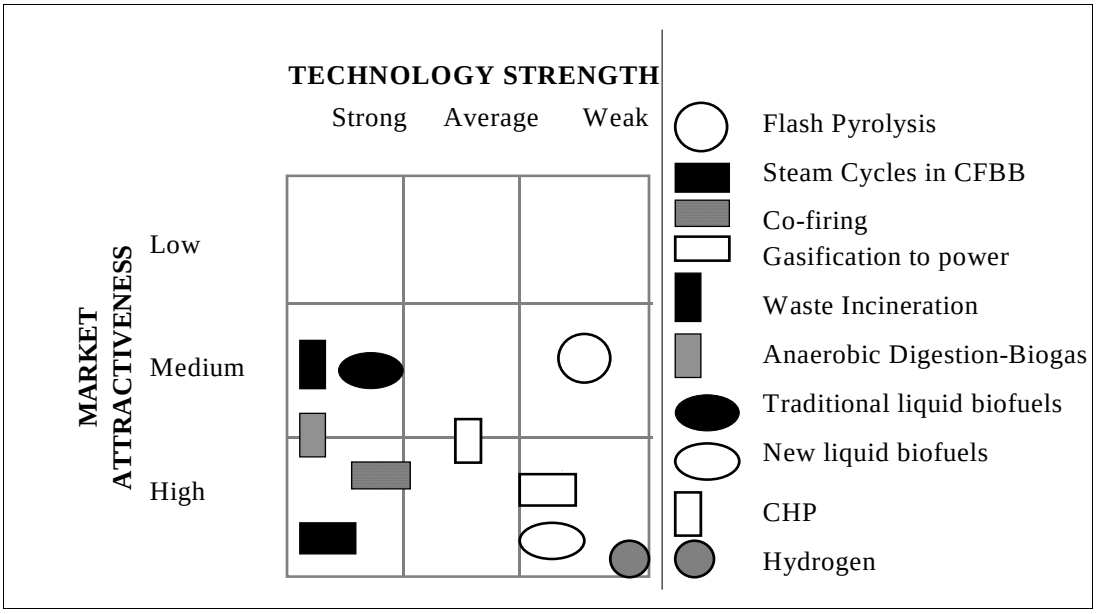
Source: Bridgwater and Maniatis, 2003.

The key difference between thermal and biological conversion is that biological conversion gives single or specific products such as ethanol or biogas (the latter containing up to 60% methane) and is a slow process, typically taking hours, days, weeks (anaerobic fermentation and farm digestion) or years (landfill gas by digestion) for reactions to be completed. Thermal conversion produces multiple and frequently complex products, with catalysts often used to improve the product quality or spectrum, and take place in very short reaction times of typically seconds or minutes.

Few studies exist concerning the status of the various biomass conversion technologies. Figure 8 presents a tentative representation of the status of biomass conversion technologies in view of their market attractiveness for power, heat or liquid biofuels generation and the present strength of the various conversion technologies (Maniatis, 2000).

Steam cycles in general have proven very reliable with a variety of feedstocks and are relatively easy to scale up from a few MWth (Mega watts thermal) to 100 MWth. The industry is expected to be able to provide reliable operating boilers even for capacities above 100 MWth. Circulating fluidised bed boilers (CFBB) in particular appear to be the preferred system for large-scale applications in competition with grate-fired boilers, and this type of combustion technology has been used in most industrial applications in recent years. Therefore, steam cycles in CFBB have high market attractiveness and are technically well proven.

Figure 8. Bioconversion technology status and strategic planning for development



Source: Maniatis, 2000.

Co-firing of biomass and waste in existing coal-fired power plants was an interesting development in the last decade, as this process eliminates the need to invest in the power cycle. In such applications the biomass is either pre-mixed with the coal and fed simultaneously in the boiler for the combustion process, or the biomass and waste are gasified in dedicated circulating fluidised bed gasifiers and the fuel gas (after some preliminary cleaning mainly to remove coarse particulates) is fed to the boiler, where it is combusted. Thus coal is directly replaced by biomass and waste. Examples are the Kymijärvi Power Station in Lahti Finland (Nieminen, 1999) and the coal-fired heating unit of EPZ, Amer 9 at Geertruidenberg in The Netherlands (Willeboer, 2000). Co-firing technologies are considered reliable, but more plants are needed to really convince the power industry and improve their market attractiveness.

Anaerobic digestion for the production of biogas is a successful technology and has been commercialised in practically all EU countries, especially for waste effluents such as sewage sludge, abattoir waste streams and even for the biological part of municipal solid waste. Liquid-state technologies are the most common, but solid-state fermentation technologies have been developed and are also used widely, especially for substrates with moisture content in the range of 30%-40%. Technically, anaerobic digestion technologies are very reliable; however, they are site-specific and thus market attractiveness is somewhat limited.

Municipal solid waste incineration is a mature and reliable technology and the emissions of pollutants can be effectively controlled with state-of-the-art techniques; however, its market attractiveness is limited due to negative public perception and to competition with new waste management strategies such as source separation, recycling of raw materials and production of refuse-derived fuel.

CHP applications are attractive as the technology is reliable and the need to identify a heat client can be possible; however, combined heat and power energy vectors make CHP applications more site-

specific than is the case when each energy vector operates independently. In order to decrease the operating costs it is often necessary to implement multi-fuel operation, which by increasing the complexity of the feeding system and the flue gas cleaning, results in some degree of increased maintenance.

Gasification technologies for power have yet to demonstrate reliable commercial operation, although there have been some successes with downdraft gasifiers and fluidised bed systems. Efficient tar removal and economics still remain the main technical and non-technical barriers, respectively. However, the success of the Värnamo plant in Sweden (Ståhl *et al.*, 2001), the first – and only – plant to demonstrate an IGCC based on biomass, and recent advances in tar elimination (Simell and Kurkela, 1997) indicate that these problems could be overcome in the short to medium term.

Flash pyrolysis for the production of bio-oil is an attractive process as the bio-oil can be stored and transported, therefore separating the conversion process from the energy production process; however, there are as yet no large-scale demonstration plants to provide reliability for commercial energy applications (Bridgwater *et al.*, 2002).

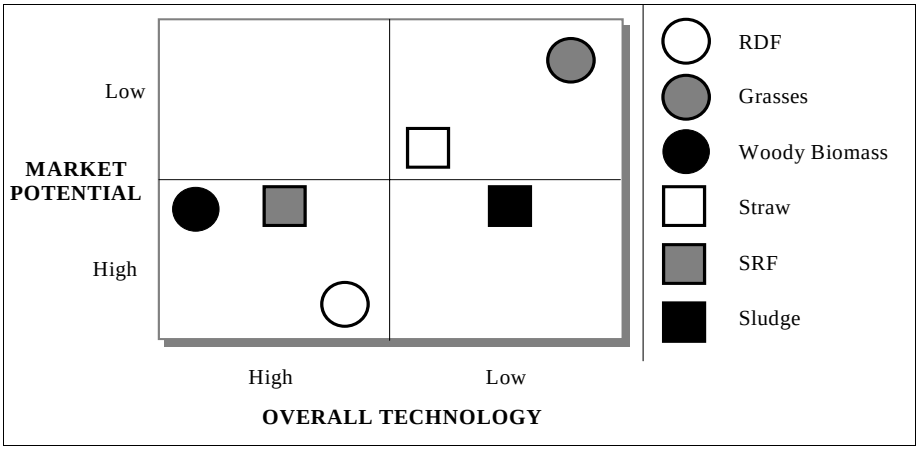
The production of bioethanol and biodiesel from sugar and oil-based crops, respectively, are well established industrial processes; however, their overall energy and CO_2 balance – although positive – could be improved significantly. Although the technical reliability of these traditional technologies is very high, their market attractiveness is limited in view of their carbon emissions. New technologies, such as those utilising biodiesel from used coking oils and animal tallow (or plant residue for CHP applications) for biodiesel and ethanol from lignocellulosics, at present are still in the development stage and still need to improve their technical reliability. However, if these technologies are commercialised, their market attractiveness will increase significantly.

Finally bio-hydrogen can be produced from biomass in a variety of ways, the most straightforward being bio-methane produced from biogas and bio-ethanol. Alternative routes are from synthesis gas via gasification. However, these technical approaches are at the very early research stage.

Feedstock technology reliability

One of the most important barriers to an accelerated penetration of all biomass conversion technologies is adequate resource supply. Figure 9 (Maniatis, 2000) depicts the technological reliability of using the most important feedstocks in gasification applications. Clean biomass feedstocks are becoming scarce and, with rare exceptions, there is hardly any reliable long-term supply. In some countries, such as Germany, all industrial wood waste and other wood residues are consumed completely and there is no other clean biomass available to increase the contribution to bioenergy. Thus, the industry has been obliged to look into relatively uncompetitive fuels and fuels with little practical industrial experience in order to create new market opportunities. Fuels recovered from waste present the advantage that they often have a negative cost associated with their disposal, which can significantly decrease a plant's operating costs. In addition, since the 1990s there has been significant interest in energy crops and especially short rotation forestry (SRF) as a means of increasing the production of biomass fuels while simultaneously creating new jobs for the farming community. SRF operations can also contribute significantly towards sustainability and meeting the Kyoto obligations. However, given that agricultural and forest lands are fixed there will always be some concern of competition between land for food and land for energy or carbon sinks.

Figure 9. Status of feedstock technology reliability and market potential



Source: Maniatis, 2000.

Woody biomass has the highest reliability for feeding into a conversion reactor and most problems related to bed sintering in fluidised bed reactors, or slag formation on heat exchange surfaces are relatively well understood and the industry has sufficient confidence to use effectively most types of woody biomass. The industry has also attained a high degree of reliability for pre-treatment operations such as drying, size reduction and storage. However, the market potential of woody biomass is limited, as most of the locally available feedstocks are already consumed in various industrial or district heating applications.

SRF has comparatively good potential for use on non-arable land and provides a sustainable approach to energy (Berna, 1998); however, since the land has to be blocked for about 15-20 years, farmers in the EU are reluctant to implement SRF schemes. The only exceptions are Sweden, where there is a long tradition for SRF, mostly for pulp and paper, and the United Kingdom, where successful schemes have recently been introduced to the farming community (Wright and Christersson, 2000). The United States (Costello, 1999) also has an ambitious programme for the development of SRF, and Canada, too, has carried out significant work and is examining various SRF implementation schemes. Brazil has successfully established eucalyptus plantations. On the other hand, very few tests have been carried out with SRF feedstocks and the industry is somewhat uncertain about the properties of SRF fuels. A sensitive area is that of heavy metals, some of which are easily up taken by plants (*e.g.* cadmium).

Grasses (Elbersen *et al.*, 2001) have attracted interest recently since they can be cultivated in many different places –even on roadsides – however, their market potential is still uncertain as there are, as yet, no dedicated plantations and there is relatively little experience with such feedstocks. Technically, grasses present problems in all pre-treatment operations such as size reduction, storage, drying – and even their rather rapid biodegradability, that can result in significant weight loss unless they are dried and properly stored. In addition, their low bulk density results in solid flow problems and can create local hot spots in the gasifier.

Straw has a fairly low market potential due to seasonal availability, but successful combustion technologies have been developed. There is little experience with straw gasification and severe problems of ash sintering and bed agglomeration are known to exist in fluidised bed gasifiers. Due to the low bulk density, straw has been palletised in some applications, – an expensive operation. However, successful operation of the IGCC Värnamo plant was achieved with 100% straw feeding (Ståhl, 2001).

Refuse Derived Fuel (RDF) has significant potential as it does not have such a negative public image as incineration and the industry has sufficient experience of it. Significant quantities of RDF are used by the cement industry to replace coal. However, the feeding systems for fluff RDF need to be developed further to ensure reliable operation and more experimental results at large-scale applications are needed to prove efficient operation.

Finally, sewage and other industrial sludges can also be utilised in energy applications and although little experience exists, it is expected that the application with sludge may increase in the future. Technical reliability still has to be demonstrated, although the cement industry does have experience with the handling and feeding of large quantities of this waste stream.

Recently an extensive feedstock database has been established by ECN where a significant amount of information is provided for a variety of biomass feedstocks (PHYLLIS, 2000). In this database, the basic physico-chemical properties of biomass fuels can be found which will provide basic information to gasifier developers, as well as gasifier users, on the quality and suitability of the various fuels for the gasification technologies they either develop or use.

Conclusions

There is substantial and growing interest in bioenergy to produce energy. Several conversion processes exist at various stages of industrial development, but they have different market opportunities and should not be viewed as competitors. In all technologies, there is still considerable progress to be made in the optimal interfacing of conversion and utilisation of the primary products from conversion, as well as the important interface between biomass production and conversion.

The main challenges lie first, in bringing the conversion technologies closer to the power/heat production processes and biofuel blends for transport, with both sides of the interface moving to an acceptable middle position and second, in fully appreciating that, with rare exceptions, bio-energy systems will always be relatively small and must therefore be technically and economically competitive at much smaller scales of operation than the major power and fossil-fuel generation industries are used to handling.

It has been recognised by the EC and national governments that it is necessary to create a competitive market environment in order for bioenergy, along with the other renewable energy resources, to be able to compete with fossil fuels and, to this end, various forms of legislative actions have been put in place, while others are in preparation.

BIBLIOGRAPHY

Berna, G. (1998), *Integrated Biomass System*, Final report, AIR1-92-8004-IT, European Commission [EC], Luxembourg, EUR 17541 EN.

Bridgwater, A.V. and K. Maniatis (2003), *The production of biofuels by the thermochemical processing of biomass*; Chapter 10 in M.D. Archer and J. Barber (eds) *Photo-conversion of Solar Energy Molecules to Global Photosynthesis*, Imperial College Press.

Bridgwater, A.V., A.J. Toft and J.G. Brammer (2002), "A techno-economic comparison of power production by biomass fast pyrolysis with gasification and combustion," *Sustainable and Renewable Energy Reviews*, 6, pp. 181-248.

CEN (2003*a*), European Standard EN 14214, *Automotive Fuels – Fatty acid methyl esters – Requirements and test methods*, Brussels, Belgium.

CEN (2003*b*), European Standard EN 14213, *Heating Fuels – Fatty acid methyl esters for diesel engines – Requirements and test methods*, Brussels, Belgium.

Costello R. (1999), "An overview of the US Department of Energy's biomass power program" in *Power Production from Biomass III, Gasification and Pyrolysis R&D for Industry*, K. Sipila and M. Korhonen (eds), VTT Symposium 192, VTT Espoo.

Elbersen, H.W. *et al.* (2001), *Switchgrass variety choice in Europe, in Proceedings, 1st World Conference and Exhibition on Biomass for Energy and Industry*, S. Kyritsis, A.A.C.M. Beenackers, P. Helm, A. Grassi and D. Chiaramonti (eds), James & James Science Publishers, London, United Kingdom.

European Commission [EC] (2003), Directive of the European Parliament and of the Council of 8 May 2003, *On the promotion of the use of biofuels or other renewable fuels for transport*, Directive 2003/30/EC, Brussels, Belgium.

EC (2001*a*), Directive of the European Parliament and the Council *On the promotion of electricity produced from renewable energy sources in the internal electricity market*, Directive 2001/77/EC, Brussels, Belgium.

EC (2001*b*), *White Paper - European transport policy for 2010: time to decide*, COM(2001)370, Brussels, Belgium.

EC (2001*c*), *Specific programmes implementing the Framework Programme 2002-2006 of the European Community for research, technological development and demonstration activities*, COM(2001)279: www.cordis.lu/fp6.

EC (2000*a*), *Green Paper: Towards a European Strategy for the Security of Energy Supply*, COM(2000)769, Brussels, Belgium.

EC (2000*b*), *Fifth framework programme of the European Community for research, technological development and demonstration (RTD) activities for the period 1998 to 2002*, OJ L 26, 1 February 1999; for work programme, see European Commission Decision C(2000)670, Brussels, Belgium: www.cordis.lu/fp5/.

EC (1997), *White Paper for a Community Strategy and Action Plan: Energy for the Future: Renewable Sources of Energy*, COM(97)599, Brussels, Belgium.

EUROSTAT (2000), *Energy: Yearly Statistics 1998*, EC, Luxembourg.

EXTERNE (1999), *Externalities of Energy*, Commission of the European Communities, Directorate General Science, Research & Development, EUR 19083, EUR 18836, Luxembourg.

Faaij, A.P.C., B. Schlamadinger, Y. Solantausta and M. Wagener (2002), "Large scale international Bio-energy trade", in W. Parz, J. Spitzer, K. Maniatis, K. Kwant, P. Helm and A. Grassi (eds), *Proceedings of the Twelfth European Biomass Conference*, ETA Florence, Italy and WIP Munich, Germany.

Hoogwijk, M., A. Faaij, R. van den Broek, G. Berndes, D. Gielen and W. Turkenburg, "Exploration of the ranges of the global potential of biomass for energy", *Biomass and Bioenergy*, Vol. 25, No.2, pp. 119-133.

IIASA/WEC (1998),*Global energy perspectives*, Nakicenovic N., A. Grubler and A. Mc Donald (eds), International Institute for Applied Systems Analysis (IIASA) and World Energy Council (WEC), Cambridge University Press, Cambridge.

Ishitani, H. and T.B. Johansson (1996), "Energy supply mitigation options", Chapter 19 of the Second Assessment Report, *Climate Change 1995, Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses*, the contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Kotronaros, A. and K. Maniatis (1999), *Comparison of renewable sources cost for electricity production*, own data, Unit D2: New and Renewable Energy Sources, Directorate-General for Energy and Transport, EC, Brussels, Belgium.

Maniatis, K. (2000), own data, Unit D2: New and Renewable Energy Sources, Directorate-General for Energy and Transport, EC, Brussels, Belgium.

Maniatis, K. (2001), "Progress in biomass gasification: an overview", in Bridgwater A.V. (ed.), *Progress in Thermochemical Biomass Conversion*, Blackwell, Oxford, United Kingdom, pp. 1-32.

Maniatis, K. and J. Tustin (2002), *"The IEA Bioenergy Research Network: Promoting Bioenergy for Sustainable Development"* in W. Parz, J. Spitzer, K. Maniatis, K. Kwant, P. Helm and A. Grassi (eds), *Proceedings, Twelfth European Biomass Conference*, ETA, Florence, Italy and WIP, Munich, Germany.

Maniatis K. and A. Kotronaros (2002), *The Bioenergy Policy of the European Commission*, in W. Parz, J. Spitzer, K. Maniatis, K. Kwant, P. Helm and A. Grassi (eds), *Proceedings, Twelfth European Biomass Conference*, ETA Florence, Italy and WIP, Munich, Italy.

Maniatis, K., G. Guiu and J. Riesgo (2003), "The European Commission Perspective in Biomass and Waste Thermochemical Conversion" in Bridgwater, A.V. (ed.), *Pyrolysis and Gasification of Biomass and Waste*, CPL Press, Newbury, United Kingdom.

Nieminen J. (1999), *Biomass CFB gasifier connected to a 350 MW_{th} steam boiler fired with coal and natural gas — THERMIE demonstration project in Lahti, Finland, in Power Production from Biomass III, Gasification and Pyrolysis R&D&D for Industry*, K. Sipila and M. Korhonen (eds), VTT Symposium 192, VTT Espoo.

PHYLLIS database: www.ecn.nl/phyllis/.

SHELL (1995), *The evolution of the world's energy system 1860-2060*, Shell International, London, United Kingdom.

Simell, P. and E. Kurkela (1997), "Tar removal from gasification gas" in *Biomass Gasification and Pyrolysis: State of the Art and Future Prospects*, M.K. Kaltschmitt and A.V. Bridgwater (eds), pp. 207-217, CPL Scientific Ltd.

Ståhl K., M. Neergaard and J. Nieminen (2001), "Final report: Värnamo demonstration programme", in A.V. Bridgwater (ed.), *Progress in Thermochemical Biomass Conversion*, pp. 549-563, Blackwell, Oxford, United Kingdom,

TERES (1997), *The European Renewable Energy Study (TERES II)*, prepared by ESD for the EC, DG XVII, "Energy", Merlin Multimedia Ltd, United Kingdom.

Willeboer, W. (2000), "AMERGAS biomass gasifier starting operation" in *Proceedings, EU Seminar*: *The Use of Coal in Mixture with Wastes and Residues II*, V. Brem (ed.), BEO, Jülich, Germany.

Wright, L. and L. Christersson (2000), *Short Rotation Crops for Energy Purposes*, IEA Bioenergy, Task 17, Short Rotation Crops for Energy Purposes, Meeting Proceedings, Auburn, Alabama, United States.

RENEWABLE RAW MATERIALS AND EUROPEAN UNION RESEARCH POLICY

Ciaran Mangan[1] and Jim Coombs[2]

Abstract

European Union interest in the non-food industrial uses of agricultural raw materials arose some 15 years ago. A major influence was the need to find alternative uses for agricultural surpluses, or intervention stocks, which were being produced as a result of the way the Common Agricultural Policy (CAP) operated at that time. Subsequent reforms of the CAP and the Uruguay Round (conducted under the auspices of the General Agreement on Tariffs and Trade [GATT]) in the early 1990s led to greater production controls and resulted in the set-aside of productive land. Restricted subsidy schemes were introduced that enabled this land to be used for the production of industrial crops. In parallel, commitments were signed by the European Union to clean up and control environmental damage caused by local pollution and global emissions. In this context non-food crops were seen as a potentially sustainable and environmentally benign source of industrial feedstock for energy and industry. A further driving force was technological progress in modern biology that profoundly increased understanding of the plant and microbial kingdom. In part such understanding arose from a series of EU-funded research programmes that focused on aspects of crop production, conversion processes and end-use of bioproducts. Products researched include liquid biofuels, bulk chemicals, biocomposites, oleochemicals, biodegradable plastics, biocontrol agents and natural products (flavours, fragrances, pharmaceutical intermediates, etc.). Most of the results from the hundreds of projects supported over more than a decade have been made public through the website www.biomatnet.org. Analysis of the information available from this source shows the contributions made by the EU research programmes to date in promoting the industrial uses of biological raw materials. This paper examines this period of research funding, while focussing mainly on the non-energy uses of renewable raw materials, and attempts to describe the future direction of such work and needs for the new millennium. The effect of the substantial non-technical factors on the rate of introduction of renewable raw materials into the marketplace is also covered. This includes public attitudes towards genetically modified crops, consumer desire for natural, biodegradable products and the desire and capacity of industry to use novel raw materials.

Introduction

EU support for research and demonstration projects covering the production of energy from the by-products of agricultural crops and from forestry residues goes back to the late 1970s. Due to the oil crisis at the time, biomass for energy was investigated as a possible way of reducing Europe's dependency on imported oil and gas. The research proved generally positive and it is now regarded as one of the best ways of meeting targets for fossil carbon dioxide mitigation. In contrast, the interest in the non-energy biomaterial use of agricultural raw materials arose originally from a need to find

1. Directorate-General for Research, European Commission, Brussels, Belgium.

2. BioMatNet, c/o CPL Press, Newbury, United Kingdom.

alternative uses for intervention food stocks. Agricultural support through the CAP up to the early 1990s provided farmers with guaranteed prices that encouraged greater mechanisation, increased agrochemical inputs, and the breeding of new high-yielding varieties. This led to a massive over-production of most agricultural commodities at a high cost to the Community, as well as causing global concern about the impact on agriculture in other regions as surpluses came onto world markets at low, subsidised prices.

Subsequent reforms of the CAP and agreements reached under GATT at the Uruguay Round in the early 1990s led to production controls with the resulting availability of set-aside land. Restricted subsidy schemes were introduced that enabled this arable land to be used for growing industrial crops, the use of which was restricted to non-food applications. In parallel, global commitments were signed by the EU, aimed at reducing the level of fossil carbon dioxide released from industry, transport and homes and at stabilising the suspected environmental damage in terms of climate change resulting from release of these "greenhouse gases".

At the same time, European legislation, in the form of Directives and Regulations covering the generation and disposal of waste and encouraging recycling, were being introduced to reduce local pollution caused by an increasingly populated and industrialised society. This stimulated the search for new types of recyclable, biodegradable and less toxic materials.

In summary, the development of non-food crops during this period was seen as contributing to a wide range of Community needs, including:

- reducing surpluses and finding a valuable and productive use for set-aside land;
- providing a source of potentially sustainable and environmentally benign industrial feedstocks for energy and industry;
- contributing to the reduction in use of fossil carbon feedstocks and thus reducing greenhouse gases;
- generating biodegradable and/or natural products;
- decreasing the use of conventional agrochemicals through the use of organic fertilisers and biological control agents;
- providing cleaner transport fuels (biodiesel and bioethanol) or blending agents [ethyl tertiary butyl ether (ETBE)], facilitating the removal of lead from petrol;
- contributing to the generation of jobs and improving rural economies;
- encouraging the setting up of new small and medium-sized businesses (SMEs) in niche markets; and
- offering large and international conglomerates the opportunity to expand into new product ranges.

Providing legislation, however, is not always sufficient unless technology exists to implement stated objectives. This has to be done in a way acceptable to both the industry and the consumer. In the case of the industrial use of renewable raw materials (RRM) this means providing substitutes for products of similar quality, performance, and price to those being replaced. Since these criteria could not be met in the short term, the EU funded, through its Research Framework Programmes, a number of initiatives aimed at new crops, processing technologies and products to address these needs.

A definition for renewable raw materials

The term RRM describes the use of biological raw materials as commodities for industrial production. It is a wide-ranging and comprehensive field, and many of the end-products have little in common other than the fact they are biological in origin. The industrial applications also vary widely from the continuation of pre-industrial practices such as the use of wood for building, vegetable oils for surfactants, lubricants and coatings, to heavily researched efforts into new and more specialised markets. These include the use of natural fibres to replace glass fibre in composite materials, the production of "bioplastics", such as poly-lactate or polyhydroxybutarate, and the use of micro-organisms and enzymes as industrial catalysts.

Renewable raw materials can be described by various classification systems. Firstly, based upon the crops they are derived from, they can be divided into several broad groups of raw material: oils and fats, carbohydrates (sugar, starch and inulin), proteins, fibres and wood (lignocellulose). In addition there is a very wide range of so-called niche or specialised crops, from which secondary products such as alkaloids, terpenes, pigments, phytosteroids, etc., which can be extracted and deployed as flavours, fragrances, cosmetic or pharmaceutical intermediates, dyes, vitamins or other high-value, low-volume products. A second type of grouping can be made based upon actual industrial applications such as polymers, lubricants, solvents, surfactants, fibres, fine chemicals, paper, bioenergy and forest products etc.

Why has the EU supported RRM?

As with all Community actions, the European Commission (EC) makes proposals in line with objectives set by different treaties to meet the needs and development of an expanding EU. The proposals are submitted to the European Parliament and various committees, for consideration and modification and eventual ratification by the Council. The ultimate objective is to generate a self-supporting economic area with a common currency (the euro) offering farmers, and businesses, opportunities for free trade in an environmentally responsible context. In this respect, the development of RRM touches upon a wide range of important policy areas, where different proposals for legislation exist in various degrees of progress. The major ones are described here.

Energy policy

A revival of interest in renewable resources began in the mid-1970s with the first oil-price shock following the Middle-East war. Industries and Western governments realised that fossil resources could no longer be considered a cheap and reliable raw material. Biomass was investigated as one of a range of renewable energies through research supported in the Non-Nuclear Research Programme, and in member states' national programmes. The resulting emphasis on research into combustion and anaerobic digestion (including the use of landfill gas) has yielded technical developments and national investment to such a degree that some EU countries such as Sweden, Austria and Portugal, now obtain a significant proportion of their energy from wood and wastes (Commission of the EU, 1997). In fact throughout the EU, renewable energy is around 6% of the total energy usage, with more than 3% of that coming from biomass. There is now well-proven technology readily available for biomass combustion systems to provide heat, electricity, and for the generation of liquid fuels (bioethanol and biodiesel). However, significant non-technical barriers remain. These include high costs and, in the case of many larger facilities, difficulties in obtaining planning permission. These issues have been addressed in a series of recent EU Directives and proposals covering the generation of electricity, the use of liquid biofuels and the application of combined heat and power (CHP). Research in this area continues under the Sixth Research and Technological Development (RTD) Framework Programme, while in parallel a non-technical Energy Framework Programme promoting renewables, *Intelligent*

Energy for Europe, nears ratification (European Parliament and European Council, 2003). Although not in itself an answer to energy self-sufficiency in Europe, renewable energy can contribute to the saving of petroleum oil reserves for future generations, a persistent objective in the international community in recent years. Further details of these aspects can be found on the EU website http://europa.eu.int, while convenient links to the information can be found at www.managenergy.net.

Agricultural policy

In contrast to biomass for energy, the concept of RRM has been driven from the "producer end", rather than by "market need". In 1982 a strategic study report recommended closer collaboration between industry and agriculture and the application of new technologies towards agricultural diversification. A further study, in 1984, highlighted the technical possibilities of renewable biomaterials. This study, along with the 1985 "Great Debate" on the future of Community Agriculture, resulted in the creation of the ECLAIR Programme (1988-93) an EU Research and Development (R&D) programme (European Commission, 2000*a*) dedicated to a greater harmonisation of industry and agriculture through the application of new technologies, such as biotechnology and information science. The benefits promoted were reduced food surpluses, additional market outlets for agricultural products, new value-added products, and sustained employment for farmers and related industries. As the transformation of biological material is possible through small, local processing units, the RRM industry, if developed close to the source of the raw material, was advertised as a possible way of strengthening the economy of rural areas. Encouraging non-food crops was also seen as a way of enhancing biodiversity by broadening the number of crop species grown in a certain area, thus reducing the impact of intensive monoculture.

The overriding reason for over-production was continuing technological progress resulting in ever-increasing yields that outstripped the food consumption needs of a stable EU population. The surpluses were being stored at high expense, or being sold at a low price on world markets, resulting in distortion. The initial reaction to the problem was to take land out of production (set-aside) and revise the subsidy system – in part in favour of non-food crops. However the reform package was more a way of controlling food prices than a means to develop a non-food industry and, with the subsequent control of commodity prices and cereal production, the problem was seemingly solved and non-food initiatives were somewhat forgotten. Agricultural policy moved onto bigger issues such as the impact of an enlarged EU with increased agricultural production capacity, and how to fit EU agricultural policy into global markets as required by new initiatives of the World Trade Organization (WTO).

The WTO rounds succeeded GATT in setting agreements on international trade and, as such, have strongly impacted EU agricultural policies, influencing the changes to the CAP with respect to global trade and aid. However, industrial crops and products benefit from agricultural market regulations under different schemes, some of which have been transitory, or still exist with uncertain futures. In some cases (such as with biofuel planting grants) financial support is not available unless the producer has a contract in place to supply to a defined end-user. In some areas the details of the support available differs from country to country. Some examples of support include:

- *Market regulations dedicated to the production of non-food crops (e.g. cotton, flax and hemp, non-fibre flax seed).* Cotton, flax, hemp and non-fibre flax seed cultivation is covered by EU agricultural market regulations, supporting either the actual production, or being paid as a per-hectare premium. Proposals have been made to modify existing regulations, since the cost of subsidies has risen as the area cultivated to flax grew from 70 000 ha in 1994 to over 200 000 ha in 2000, resulting in Community spending of EUR 173 million. The proposals suggest that support for this sector (per hectare) is brought in line with that for cereals, with support provided in the form of aid per tonne of flax with maximums set for the guaranteed quantities of short flax fibre that would cease in year 2005/6.

- *Set-aside regulations, which allow for the growing of certain non-food crops under a set-aside premium.* With the reform of the CAP in 1992, support for agricultural production in the EU changed drastically. The price support for cereals was reduced and partially replaced by a per-hectare premium. To qualify for this compensatory payment of 300–500 ECU/ha, those farmers who were significant producers of cereals, oilseeds and protein crops had to set aside a certain percentage of their arable land, which amounted to 10% in 1996. The use of set-aside land for new, supplementary uses outside the food and feed market was allowed, with full compensation premium, but subject to restrictions in terms of end-user contract, obligatory non-food use and avoidance of double funding through other schemes. This scheme was a success in 1995. Out of 6.4 million ha set aside in Europe, nearly 1 million ha were used for non-food crops. Although the regulation gave plenty of choice for the non-food crops to be grown, more than 90% of the crops were rapeseed and sunflower seed, while the main end-use was in the biofuels sector. Unfortunately, this production was limited by the Blair House Agreement, whereby oilseed by-products could not exceed a one million tonne equivalent of soyabean meal. This limit was almost reached in 1995, resulting in an unsatisfactory situation whereby the quantity of industrial oils that could be produced was dependent upon food markets. However, the lifting of this agreement commenced in 2002, with new arrangements for oilseeds. The reform of the CAP has now to be viewed as an imperfect mechanism for the development of a non-food industry, as the obligatory aspect of set-aside was modified, while the CAP reform proposed by Agenda 2000 did not foresee "a non-food policy", as such. This view is supported by an EU Committee position paper on the CAP mid-term review (January 2003) which suggests, under the heading of *Non-food uses of crops*, that: *If these are supported it should be to meet specific objectives e.g. climate change, renewables strategy – objectives that are part of other Community policies. Those elements in the MTR that go in this direction are appropriate. More thought needs to be given, however, to the needs of the food chain versus the needs of other industries for products from agricultural raw materials and whether precedence should be given to certain needs.*

- *Planting grants for energy crops.* Schemes exist for the support of planting trees on agricultural land. These may aim to enhance the environment or generate income through subsequent sale of timber. In the United Kingdom, for example, this extends to the planting of both short rotation coppice and other energy crops, such as *miscanthus*.

- *Processing aids, which make EU raw materials price-competitive with imports from third countries.* Since 1986, the non-food use of European starch and sugar has benefited from a refund scheme. The aim of this scheme was to equate the difference between raw materials obtained in the EU and on the world market. Around 180 000 tonnes of sucrose and 2.3 million tonnes of starch fell under this scheme, annually. With the reform of the CAP, the importance of the starch regulation has decreased for cereals.

It is obviously a substantial challenge for local authorities to convince farmers and the processing industries of the potential for growing completely new crops, when quality, performance, yield and price remain uncertain. Energy crops grown to supply solid fuels are faced with competition from agricultural residues and wastes, while with RRM the chemical-technical needs of the European oleochemical industry can be met with imports (soya, palm) and manufacturers can use cheap sawdust in biocomposites in preference to more costly purpose-grown fibres.

Environmental policy

Environmental considerations have impacted on RRM activities at three levels: the consumer; local pollution and waste; and climate change. Although the specifics vary, the underlying influence has been the realisation that the non-sustainable intensive industrial practices of the Western world have been seriously damaging the environment. This has encouraged consumer demand for "green" products, resulting in

- European Directives covering the generation and disposal of waste and encouraging recycling.
- Measures to promote the use of clean transport fuels and the fixing of specific targets aimed at reducing the emission of "greenhouse gases" that may be contributing to climate change.
- The 1994 waste packaging Directive, which has important implications for biodegradable plastics.
- Proposals to eliminate volatile organic chemicals (VOCs) from solvents and paints.
- Proposal for a CO_2 tax.
- Legislation towards more environmentally neutral agricultural production.

Achieving member state unanimity on the above measures in the European Council has always been difficult, but one overall positive result is that it has made industry aware that legislation will eventually change and alternatives to existing processes have to be investigated. The interest in the carbon dioxide output of biomass production and processing arises initially from legislation originating from the 1997 Kyoto world climate conference that aimed to drastically reduce global CO_2 emissions. In fact, the emphasis of environmental issues and accompanying or proposed legislation is now very much on a global scale, with mitigation of greenhouse gases a priority, as indicated, for instance, within the second phase of the European Climate Change Programme (2002-03). This includes considerations of a Directive promoting biofuels, as well as the promotion of CHP and changes to vehicle (fuel) taxation. It also extends to considerations of the role of agriculture and the management of agricultural soil as a sink for carbon while reducing emissions from over-use of nitrogen fertiliser. Some documents from the working groups on climate change recognise that "The increased use of renewable raw materials could provide a considerable contribution to the challenge of climate change", the industrial applications of traditional agricultural raw materials represent a neglected subject in the overall dialogue (European Commission, 2003). Examples where biological materials can replace petrochemical-based products include fuels, lubricants, plastics and adhesives, while wood or composite building materials based on natural fibres in other consumer goods can also result in considerable levels of carbon sequestration. Furthermore, life-cycle analysis has shown that bio-based products producing lower net CO_2 emissions than products derived from fossil resources can help improve air quality, and promote the concept of "sustainable development".

Economic policy

Renewable raw materials could, in theory, contribute to industrial growth and related aspects of economic development as spelt out in the Commission's 1994 *White Paper* on "Growth Competitiveness and Employment" (European Commission, 1993). For example, biotechnology is a scientific domain where Europe has a high degree of competence, while industrial crops and products

was regarded as one of the most promising areas for the application of this generic technology. Yields could be increased, quality improved and novel industrial compounds produced, through bio-catalysis or recombinant expression in higher plants or micro-organisms. The full exploitation of European biological resources could also potentially reduce European dependency of imports from third countries, thus improving the balance-of-payments in the longer term. However, as indicated in the next section, reality has proved somewhat different.

Biotechnology

Over the last two decades great technical progress has been made in many areas of biology. Not least is that associated with manipulation (genetic engineering) and sequencing of the genome of a very wide range of organisms, extending from viruses, through microbes to higher plants, animals and man. This progress in modern biology has profoundly increased understanding of the plant and microbial kingdom and shown new ways in which natural resources could be adapted for the benefit of mankind. This includes the development of improved energy crops and plants tailor-made with properties and/or chemical composition designed for industrial use. In fact, within EU Framework R&D Programmes research has been carried out to modify starch and lipid metabolism, decrease lignin content in trees, generate molecules more suited to industrial needs, and provide processes requiring less polluting chemicals. Plants and micro-organisms have been created that are capable of producing novel biodegradable polymers, that contain increased levels of vitamins, precursors of anti-cancer drugs and enhanced fragrance or better taste.

The activity and tolerance towards diverse environmental factors have been increased in both micro-organism and microbial enzymes, the catalysts for the formation of a very wide range of fermented products for non-food use. At the same time, the performance of such reactor-based technology has been dramatically increased through the greater use of computers, analytical and detection systems now available through the equally dramatic evolution of smaller, much more effective microelectronics.

Accepted by most scientists, and adopted in many countries in both North and South America as well as throughout Asia, the public attitude in Europe towards genetic engineering (of plants in particular) has been antagonistic. Concerns have been raised about both the safety of the consumption of food products based on genetically modified organisms (GMOs) and the longer-term impact on the environment of growing such plants. These fears stem in part from the technology used and in part from the “targeted” changes brought about in the initial commercially developed crops (herbicide and pesticide-resistant maize, rapeseed, soya, sugarbeet). Fears concerning issues such as antibiotic resistance genes used as markers in selection of transformed plants may lead to an increase in the incidence of drug-resistant disease organisms, while adventitious transfer of herbicide resistance to weeds poses a threat to biodiversity.

The consequence of these fears has been a low level of consumer acceptance, with the destruction of trials and the withdrawal of companies from this area of activity in Europe. Most important has been the loss of many of the discoveries made through EU-funded research to North America and Japan, though acquisition and company take-overs. An example here would be Plant Genetic Systems (Belgium), which originated at the University of Ghent and participated in a significant number of EU-funded plant genetic engineering projects, as well as laying down many of the basic principles of plant genetic engineering. During the 1990s it was acquired by AgrEvo (a collaboration between Hoechst and Schering) that later merged with Rhone Poulenc to form Aventis. Aventis divested its Crop Science Division to Bayer, with the technology now being exploited in North America. This is only one of many similar series of take-overs that have seen discoveries arising from work funded in the EU pass to the US or to Japan.

Industrial policy

The above sections strongly indicate that the policy issues promoting the non-food use of biological materials for industrial use relate, in the first instance, to possible remedies for the problems of agriculture, rather than means of meeting industrial needs. In fact, as shown in Table 1, industries using substantial amounts of starch and vegetable oil already exist within the EU. Many are subsidiaries of, or are owned by, international conglomerates whose business in Europe is more dependent on economic issues, such as the cost of raw materials, than technical ones. In particular, the European fermentation industry has suffered as costs have increased, reflecting both the high cost of fermentation feedstock and the costs of meeting the increasing demands of environmental legislation and pollution control. However, both large organisations and a wide range of smaller business concerns have actively participated in EU-funded research activities. They can be shown to be crucial to the success of bringing products from such research into the market place.

Table 1. A comparison of global and European production and usage of biological raw materials in the European food and non-food industries

(million tonnes)

	Global production	European production	European food usage	European non-food usage
Plant fibres	23	0.5	0.0	0.5[1]
Starch	22	6.5	4.1	2.5[2]
Sucrose	112	16.1	14.0	2.1
Oils and fats	100	14.0	9.6	2.5[3]

Notes:
1. Mostly for the textile industry.
2. Almost 70% for the paper industry.
3. Only 400 000 tonnes of the 2.5 million tonnes comes from EU oilseeds.
Source: European Commission, 2000*b*.

How has EU research contributed?

The EC has funded over 200 individual research projects and networks in specific actions aimed at RRM (excluding bioenergy and forestry-based research) over the past ten years or more. As in all areas of research, boundaries are blurred: a project aimed at solving a waste problem may use fermentation to generate a bulk chemical that is then used as a fuel additive. As such, it might be supported by environment, energy or RRM programme funds. Over the last ten years, the total research budget amounted to around EUR 400 million, of which EU funding was less than 50%. The typical EU project make-up is around eight European partners, ranging from industry to universities and public research institutes, following a pre-defined three-year technical annex addressing one or more aspects of an individual crop or a product derived from a feedstock. This funding is additional to that found in National Programmes and various related industrial developments.

Within the RTD programmes three areas of relevant research may be recognised. The first covers those programmes aimed specifically at RRM development, while a second is related specifically to biomass energy. In fact bioenergy was one of the first areas to be funded, originating within the area of non-nuclear energy research. It evolved through the Biomass energy programmes of the 1980s, through several phases of JOULE (research) and THERMIE (demonstration), which continued within the present, Sixth Framework Programme (FP6), the first call for projects being made earlier this year. A third area encompasses generic research of crucial importance to RRM development, such as forest products and the "wood-chain", food production, agricultural advancement and dedicated biotechnology programmes such as the "Cell factory".

Details of many of these funded projects and some of the results are available through the internet on a number of websites. These include BIOMATNET (see the website at www.biomatnet.org), supported by the EC and dedicated to the dissemination of RRM information, as well as CORDIS and EUROPA, which include additional information covering policy and legislation.

Some of the dedicated RRM programmes which have been supported include:

- *ECLAIR: European Collaborative Linkage of Agriculture and Industry through Research*, the first EU Programme to have a specific focus on agro-industrial activities. Funded by the Second RTD Framework Programme (1988-93).

- *AIR: Agriculture and Agro-Industry including Fisheries Programme of Research and Technological Development*, of the Third Framework Programme (FP3, 1990-96), jointly managed by DG Research, DG Agriculture and DG Fisheries.

- *FAIR: Agriculture and Fisheries, including Agro-Industry Food Technologies, Forestry, Agriculture and Rural Development)* of the Fourth Framework Programme (FP4, 1994-98).

- *KA5: The integrated production and exploitation of biological materials for non-food uses*, area 5.2 within Key Action 5 (Sustainable Agriculture, Fisheries and Forestry), of Quality of Life and Management of Living Resources (FP5, 1998-2002).

More than 40% of the 42 research projects in ECLAIR dealt with the development of renewable bioproducts from non-food crops. Results coming from this Programme were very encouraging, leading to a range of higher value-added products such as flavours, detergents, biocomposites, agrochemicals, bioplastics, diagnostics and animal feed. Other benefits included a greater understanding of the fundamental cell biology involved in fatty acid, lignin, cellulose, starch and plant protein production.

The Third Framework AIR Programme (1990-94) continued this theme with a larger number of RRM projects, including seven demonstration projects dedicated to demonstrating the viability of non-food crops and products at industrial production scale. It was also instrumental in setting up extensive European research projects and networks with high industrial interest and participation.

The Fourth and Fifth Framework Programmes (1994-2002) consolidated these earlier approaches and funded RRM projects which identified key objectives along the production and processing chain to the final end-product. The research emphasis was on the final product and its market niche, which directed the production requirements and specifications of the original biological raw material. The overall results of these research projects over the past decade have been:

- The development of integrated, multi-disciplinary projects and networks, which have brought together producers and users of biological raw materials in co-operation with academics and industry.

- The definitions of market functional requirements and potential market size.

- The application of traditional and modern biotechnological methods to improve quality and understanding of the function of biological materials at a cellular level.

- Integrated systems and models that have improved the homogeneity and security of supply and use in energy, chemical and forest products industries.

- Improved cost-efficient and environmentally sound processing technologies.

- Important contributions towards recognised industrial standards for new materials and fuels such as biodiesel and bioplastics.

Such direct support for RRM by the EU has now come to an end and does not figure as a major specific objective in FP6. Reasons for this can be deduced by considering the commercial outcome of the research in general and the following impacts on agriculture and industry.

Technology, products and markets

As far as technology is concerned there is a vast, almost unlimited, range of end-products available from trees, plants, animals and their wastes. The production of RRM commodities from the farm to the end-product involves a diverse range of extraction and processing technologies and an even wider range of potential end users, making the supply chain complex and difficult. Tackling this problem has been one of the main objectives of the agro-industrial research programmes within the EU since their inception in 1988 under the Second Framework Programme. While the first programme (ECLAIR) looked at a number of separate niche issues, subsequent programmes initially became more focused. Within the AIR Programme, topics covered production, bioenergy conversion and biological conversion, as well as major sectors based on vegetable oils, bioplastics, specialty chemicals, paper/pulp and wood products. Under FAIR, investigations were aimed at establishing complete production chains from the field to the ultimate consumer with an emphasis on areas such as bulk chemicals, non-wood fibre, bioplastics and polymers, cosmetics, drugs and vaccines as well as biological control products. In the most recent programme of Key Action 5 in the Fifth Framework Programme, 20 RRM projects were supported.

In spite of this substantial RTD investment, production figures for most of these commodities indicate that increased European usage of RRM has been minimal outside the traditional textile, paper, and chemical industries. The end-products are in many cases competitors with, and substitutes for, fossil source-based products. Estimates suggest that current European usage of biological material for industry amounts to less than 3% of that from fossil feedstock. It has been predicted that this will remain so until oil prices rise to USD 40 per barrel, or unless the production costs of biomass drop by 40% or more.

Even so the global, as opposed to the EU, market for industrial applications of RRM is large, growing and competitive. Precise data on global trade in RRM are not readily available, but indications are that the value of the world market may be in the order of USD 250-300 billion annually. The range of new entrants into various segments of the market underscores the potential growth and competitiveness of the marketplace. Some examples include:

- Archer Daniels Midland’s buying into high-end corn products.

- Cargill’s joint venture with Dow Chemicals to produce bioplastics from corn.

- A leading automobile company’s adoption of biocomposite panels in all its models.

- Japanese government and industry support of biodiesel technologies using vegetable oils.

- Continuing bioethanol programmes, notably in the United States and Brazil.

As with the GMO debate, it would appear that Europe is lagging behind in commercialising RRM products. In Europe the liquid biofuel market has not grown as it has done in the United States and production of polylactate (PLA) remains at the pilot plant level, whereas in the US PLA production heads towards 100 000 tonnes per annum, with resulting products being legally recognised as a new class of material.

In Europe there is hope that evolving environmental regulations will remain as a major driving force behind RRM development. Petrochemical-derived industrial inputs are on average 42% less expensive than similar products originating from plant materials. However, the wisdom of a global industry where 90% of all industrial applications produced today are derived from petroleum feedstock is undergoing serious debate. Changing the industrial diet from hydrocarbon to carbohydrates is essentially a strategic issue. Because biobased industrial applications will, over time, have to be processed close to sources of production for logistical and demographic reasons, and because efficiency in this market involves tight integration between production and processing, a role for developing countries in the biobased industrial applications marketplace is assured. Indeed, this has already manifested itself in Europe, where the production of many fermentation products has ceased as a result of competition from China, in particular.

Assessing the industrial impact

Obviously there is a time gap between the completion of any research and the appearance of a product on the market. In the case of EU-funded research this gap may be extended since the EU, by definition, funds pre-competitive research. In order to assess the commercial impact of RRM research programmes two studies have been carried out. The first of these reports indicated that many of the projects resulted in products that reached the marketplace (European Commission, 2000*a*). These results depended significantly on the extent of commercial participation in the project, in that those that succeeded best were those with an industrial co-ordinator that took the process or product to market. Projects generating higher-value niche products, developed to the point where they can be sold directly to an end-user, appeared to fare better than those that aimed to introduce a new crop or develop a generic process, product or use. For example, an SME achieved a worldwide market for nematodes sold as biopesticides. However, many of the projects looked at developing new varieties or novel crops, some through genetic engineering. Commercial progress though, requires much longer periods of funding beyond that supplied by EC research grants. Furthermore, over this period, the global changes in the seed and agrochemical business sectors, with acquisitions and mergers, meant that much of the background technology was vested in a few large commercial organisations, with substantial in-house research budgets. Some of the large organisations were involved in EU-funded work in areas that appeared peripheral to their core business or which were related to generic breeding or processing activities, rather than actual specific product development.

Subsequent analysis of the AIR Programme showed that the actual commercial impact was less than might have been hoped for (Coombs and Hall, 1999). In the first place, there was less actual commercial participation than in the ECLAIR Programme and hence less vested interest in bringing results to the marketplace. Of greater significance in this period were changes in public perception of GMOs, along with extensive acquisitions and mergers of the European agrochemical seed and supplier industries. The launch of the AIR Programme coincided with the first open field trials of GM crops in Europe. The application of such techniques was expected to yield valuable results in terms of both crop development and modification of plant constituents to favour industrial processing. However, public opposition to GM crops in Europe detracted from the final applications of several of the projects. A number of products did reach the marketplace, but were mostly applicable in the food sector. Around 20 AIR projects generated results that encouraged applications for funding within the subsequent FAIR Programme, including three that dealt with further developments at pilot plant-scale which were addressed through demonstration projects.

Almost all projects produced results of scientific interest, and generated many publications and patents. Quite a few projects were unfortunately caught up in other changes, such as the privatisation of what had been publicly-funded research institutes (in the UK and the Netherlands in particular) and changes in other areas of EU policy. A number of projects aimed to contribute to the production of liquid biofuels from lignocellulose, investigating the production and properties of cellulytic enzymes as a means of generating sugars. Exploitation of this work was dependent on legislation lowering tax on biofuels, or legislation requiring the addition of ethanol to petroleum. This did not happen. A number of projects indicated technical options of interest to industry. These included advances in oleochemistry as well as the use of biocomposites in car parts. These results were welcomed by industry but, apart from applications in niche markets, were not fully exploited. On the other hand, as a direct or indirect result of EU projects and private developments a wide range of vegetable oil products (including biodiesel, chain saw oil, engine oils, surfactants, lubricants and alkyd resins for use in paints) has been introduced into the marketplace over the last decade. Reports arising from AIR activities, participation in conferences, and media attention given to AIR projects have contributed to this market growth. Unfortunately, the commercial activities have been based on conventional sources of vegetable oil, including imported palm and soya oils, rather than the new oil crops investigated in the AIR and FAIR Programmes. This supports the view expressed by industry, at an EU-funded workshop on the use of vegetable oils, that it is better to increase the use of existing vegetable oils, rather than develop new ones while developments in novel oils can be "piggy-backed" on those developed for the food industry (CTVO, 1998).

A future for RRM?

These impact reports, and other sources of information, account for slow industrial uptake of the vast R&D data in RRM generated over the past decade. They indicate that, although the ambitions were laudable, it has become clear that industrial enthusiasm for the potential advantages of RRM have not materialised as had been hoped. With this in mind, the hard realities of modern trade and fixed industrial processes, as well as consumer choice in terms of product price and performance, will have to shape the future R&D agenda in this sector.

The major bottlenecks preventing RRM development which have been distilled from the research work and extensive dialogue with industry are listed below:

- The quantity, quality and price of agricultural raw materials are not sufficient or consistent enough to supply industries with appropriate amounts or quality of feedstock for their processes. In some cases, such as for palm oil, industry can obtain a lower-price raw material from outside the EU.

- The composition of biological raw material varies from batch to batch. So they can be deemed inconvenient or even unsuitable for highly automated industrial processes.

- For the past decades, industrial R&D largely focused on the processing of fossil fuel resources. Industries relying solely on renewable resources have disappeared, along with the knowledge base. In addition, some of the traditional process technologies used in processing biological raw materials no longer fulfil current environmental requirements.

- Agricultural and environmental legislation has been generally positive towards this sector, but other factors, such as a lack of tax breaks and international agreements like the GATT (Blair House Agreement) can limit the introduction of biological raw materials, processes and products in the short term.

- All modern products are integrated into sophisticated production, consumption and marketing systems. New feedstocks or products have to fit into these existing systems or to present sufficient economic benefits to encourage the creation of new plant and equipment.

- Industry has reservations about such investments, where the price and availability of the raw material is dependent on transitory legislation, such as that covering the production of rapeseed oil for industrial use.

On a more positive note, none of the above bottlenecks is insurmountable and, indeed, the EU has introduced and continues to formulate policies and legislation that should encourage a greater industrial use of agricultural crops and forest resources. The largest market, as well as the greatest area of potential use, is in the area of energy crops, even though they must compete with the widespread availability of agricultural residues, forest by-products and other organic wastes which are available at a significantly lower cost.

Initially seen as a means of improving the level and security of energy supply in Europe, the use of biomass as a fuel is now seen as a major contributor to the reduction of fossil carbon dioxide emissions. The use of RRM can seriously contribute to carbon abatement; however, the potential is probably not yet sufficiently widely recognised. Increased use of agricultural raw material by industry was initially seen as a way of increasing the use of farm products, creating employment and improving rural economies. However, the markets that have developed from EU-funded research have favoured higher-value, smaller-market, niche products. As a result, the actual impact on agricultural production has been relatively modest.

Work in this area, funded by the EU, together with an extensive number of workshops, conferences and publications, has contributed to a significant increase in knowledge and demand for information concerning the potential of RRM, as witnessed by the high degree of information requests to the BIOMATNET website. The extent of market penetration, other than that of niche products, has been less notable. This reflects higher raw material prices as well as the quality, appearance and performance of some material as compared to petrochemical-based equivalents.

At present there is no area within the current RTD Framework Programme specifically aimed at RRM, although there is some scope to be found within Priority 3 (materials) and 6 (climate change). This separation of RRM from agriculture may prove beneficial as industry and markets pull developments along lines of demand, rather than attempting to meet the requirements of the push from agriculture. Nevertheless, as a result of the EU agro-industrial research programmes, a crossroad has been reached and another piece of the jigsaw towards a sustainable use of our natural resources has been addressed. The feasibility for RRM has been clearly demonstrated and it now takes the resolve and commitment of governments and industry to develop it further.

BIBLIOGRAPHY

Coombs, James and Katy Hall (1999), *Assessment of the Commercial Success of the AIR Programme (1990-1996) in the Area of Biomaterials & Green Chemicals (Non Food), Relevance to the Sixth RTD Programme (FP6),* EUR 20343, CPL Press, Newbury, United Kingdom.

CTVO, Bonn, 1998: http://dainet.de/fnr/ctvo/.

European Commission (1997), "Energy for the Future: Renewable Sources of Energy", Communication from the Commission, *White Paper for a Community Strategy and Action Plan*, COM(97)599 final, Brussels, Belgium.

European Parliament and European Council (2003), "Intelligent Energy – Europe" (2003-2006), Decision No. 1230/2003/EC of the European Parliament and of the Council of 26 June 2003 adopting a multiannual programme for action in the field of energy, *Official Journal L 176 , 15/07/2003 P. 0029 – 0036.*

European Commission (2003), "Can We Meet Our Kyoto Targets?", *Second ECCP Progress Report*, Brussels, Belgium, April.

European Commission (2000a), "Report on Commercial Success of ECLAIR Programme", EUR 19338: www.nf-2000.org/secure/Fair/S1120.htm.

European Commission, (2000b), Interactive European Network for Industrial Crops and their Applications: REPORT: www.ienica.net/ienicareports.htm.

European Commission (1993), *White Paper on Growth, Competitiveness and Employment: the Challenges and Ways Forward into the 21st Century*, COM(93)700FINAL, Brussels, Belgium, December.

European Commission, European Climate Change Programme (ECCP) HOMEPAGE: http://europa.eu.int/comm/environment/climat/eccp.htm.

BIOMASS FROM AGRICULTURE: THE VIEWPOINT OF EUROPEAN FARMERS

Horst Jauschnegg[1]

Abstract

A key factor in the biomass chain is of course the farmer's decision whether or not to grow biomass, use its by-products or be involved in the process of conversion into energy. Biomass is composed of many raw material sources and end uses. As far as agriculture is concerned, the following main biomass energy chains can be considered:

- use of wet co-products (like manure) for methanisation;
- use of dry co-products (like straw) for thermo-chemical conversion;
- growing dedicated lignocellulose crops (like short rotation coppice or miscanthus) for thermo-chemical conversion;
- growing conventional crops (like sugarbeet, cereals, oilseed rape or sunflower) or new crops (like sorghum) for liquid biofuel production.

For all these chains farmers might be involved in the production of the raw biomass material alone, or in the processing of the biomass into heat and/or power or liquid biofuels.

It is important to note that this paper focuses on biomass chains that can be undertaken by farmers on agricultural land or with traditional livestock by-products, and not in forests. In Europe the connection between farmers and biomass varies widely. In Austria and Sweden for example, farmers have owned forests for a long time and are now involved in forest management for energy and in the conversion process. In Austria 80% of the forest is owned by private persons and most of them are farmers. In Sweden 25% of farmers are still working both in agriculture and in the forest.

Content of the *White Paper* regarding biomass from agriculture

In November 1997, the European Union's (EU) Commission published a *White Paper* entitled "Energy for the Future – Renewable Sources of Energy" (European Commission, 1997). The paper sets an ambitious goal of doubling from 6% to 12% the share of renewable energies in the total energy demand. Current production and objectives for each renewable energy source are provided in this paper (Table 1). Biomass should produce more than 80% of the additional contribution to total Renewable Energy Sources (RES) by 2010.

1. Austrian Biomass Association (on behalf of the International Federation of Agricultural Producers), Vienna, Austria.

Table 1. Renewable energies – *White Paper* goals for 2010

(Mtoe*)

Type of RES	Contribution in 1995	Contribution in 2010	Additional contribution
Biomass	44.80	135.00	+ 90.20
Hydropower	26.40	30.55	+ 4.15
Wind energy	0.35	6.90	+ 6.55
Solar thermal collectors	0.26	4.00	+ 3.74
Photovoltaics	0.002	0.26	+ 0.26
Geothermal	2.50	5.20	+ 2.70
TOTAL	**74.31**	**181.91**	**+ 107.60**

* Million tonnes of oil equivalent.
Source: EU Commission, 1997.

Within the category of biomass, the Commission proposed a breakdown between biogas, residues and energy crops (Table 2). Finally, agriculture is expected to contribute to more than 60% of the total additional contribution of all renewable energy sources (biogas from livestock: 5 Mtoe; residuals from agriculture: 15 Mtoe; energy crops: 45 Mtoe).

Table 2. Proposed breakdown of the additional supply from biomass

(Mtoe)

Type of biomass resource	Mtoe
Biogas (livestock, sewage treatment, landfills)	15
Residuals from agriculture and forestry	30
Energy crops (10 million ha)	45[1]
TOTAL	**90**

Note:

1. 18 Mtoe of liquid biofuels and 27 Mtoe of heat/power.
Source: EU Commission, 1997.

The *White Paper* opens new opportunities in the energy sector for agriculture with ambitious goals. This is a real challenge for agriculture.

Kyoto Protocol

In the framework of the Kyoto Protocol the EU and its member states agreed on an 8% reduction of greenhouse gas emissions in the period 2008-12, as compared with 1990 levels. This will require a significant effort of about 600 million tonnes CO_2 equivalent. Two main strategies can be considered:

- Reduction of energy consumption;
- Increased use of RES.

Taking into account the fact that current low prices for fossil fuels are not favouring energy savings, renewables have to be given serious consideration. As biomass has the biggest potential for growth among renewables, its penetration in the energy market is essential in order to comply with the Kyoto Protocol objectives.

EU directives and their importance for biomass

Within recent years two important directives regarding biomass have been published by the European Parliament and The Council of the European Union:

- *Directive 2001/77/EC "on the promotion of electricity produced from renewable energy sources in the internal electricity market" (27 September 2001)*

  The purpose of this Directive is to promote an increase in the contribution of renewable energy sources to electricity production in the internal market for electricity. Member states shall take appropriate steps to encourage greater consumption of electricity produced from renewable energy sources in conformity with the national indicative targets set by the Directive. According this Directive, the EU has to increase the share of electricity produced from renewable energy sources (RES-E) to gross electricity consumption from 13.9% in 1997 up to 22% in 2010. Austria has he highest national indicative target, with an increase from 70.0% RES-E in 1997 up to 78.1% RES-E in 2010.

  Member states shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive not later than 27 October 2003.

- *Directive 2003/30/EC "on the promotion of the use of biofuels or other renewable fuels for transport" (8 May 2003)*

  This Directive aims at promoting the use of biofuels or other renewable fuels to replace diesel or petrol for transport purposes in each member state, with a view to contributing to objectives such as meeting climate change commitments, environmentally friendly security of supply and promoting renewable energy sources.

  Member states should ensure that a minimum proportion of biofuels and other renewable fuels is placed on their markets, and, to that effect, shall set national indicative targets. A reference value for these targets shall be 2% by 31 December 2005 and 5.75% by 31 December 2010, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets.

  Biofuels may be made available in any of the following forms:

  – as pure biofuels or at high concentration in mineral oil derivates;
  – as biofuels blended in mineral oil derivates;
  – as liquids derived from biofuels, such as ethyl tertiary butyl ether (ETBE).

  Member states shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 31 December 2004 at the latest.

There is a wide range of biomass that could be used to produce RES-E and liquid biofuels, deriving from agricultural and forestry products, as well as from residues and waste from forestry and the forestry and agri-foodstuffs industry. Promoting the use of biomass in keeping with sustainable farming and forestry practices could create new opportunities for sustainable rural development and could open a new market for innovative agricultural products with regard to present and future member states.

In the case of RES-E, the production of biogas might be the most interesting source of additional income relevant for agriculture, because farmers not only supply the raw material, but are also involved in processing the biomass into electricity and heat. Raw materials for biogas production are manure and grass as well as agricultural crops (*e.g.* maize silage). Technologies to produce RES-E based on solid biomass are the steam process for units above 1 MW_{el} (megawatt power electricity); the organic rancine cycle (ORC) process; the gasification process; and co-firing to coal-fired power plants. Such plants are mainly fired with woody biomass from forestry. However, in future woody biomass planted on arable land or grassland (like short rotation coppice or miscanthus) will also be necessary to supply large biomass consumers (*e.g.* combined heat and power [CHP] plants) with sufficient amounts of raw material. For larger plants farmers will only supply the raw material. Smaller plants based on ORC or gasification processes can also be operated by farmer groups, so that farmers can sell electricity and heat and earn additional income as "energy farmers".

Biofuels for transport will only be able to achieve market penetration if they are widely available and competitive. Therefore a package of supporting measures will be necessary, including tax exemption and financial assistance for the processing industry. Raw materials for the production of biodiesel, bioethanol and other biofuels for transport include oilseed rape, sunflower, cereals and sugarbeet. The cultivation of agricultural crops for energy purposes could be an interesting alternative for farmers in the EU.

- *A Directive promoting the use of heat from RES is required*

  As far as RES are concerned, in the EU specific attention is given to the production of electricity and biofuels for transport, whereas the importance of the heat market tends to be underestimated, even though it is the principal energy form, with about 50% of the total energy market. It is therefore necessary to establish a Directive promoting the use of heat from renewable energy sources. The format of this legislation should be modelled on the RES-E Directive for electricity from renewable energy sources, *i.e.* it should cover targets, support schemes, certification, easier administrative procedures, etc. for heat from:

  – Biomass;
  – Active solar systems; and
  – Geothermal sources.

  The technology for heating houses with biomass has improved significantly over the last decades. Two different methods of using bioenergy for heating purposes have developed over time: individual heating systems and collective heating systems.

  – Individual household systems

    - Wood log systems;
    - Wood chip systems;
    - Pellet systems.

  – District heating

    - Biomass heating systems can be fuelled by forestry products, residues and waste from forestry and the forestry industry as well as straw or lignocellulose crops such as short rotation coppice and miscanthus.

Mid-Term Review of the Common Agricultural Policy

In the context of Agenda 2000, the Common Agricultural Policy has no non-food policy as such. However, by decreasing the gap between internal and world prices of raw materials, it makes them more affordable for non-food industries.

Under the Commission proposals within the Mid-Term Review, the current set-aside arrangements shall be replaced by long-term environmental set-aside. At present, support for energy crops is provided through the authorisation to grow industrial crops on set-aside land. Energy crops account for the largest amount of non-food production on set-aside land today, and will be of increasing importance should biofuel incorporation become compulsory, as foreseen by the Commission. However, the new set-aside arrangements will no longer lend themselves to the production of energy crops.

The Commission proposes replacing the existing arrangements for non-food crops with a carbon credit, a non-crop-specific aid for energy crops, with the objective of achieving CO_2 substitution. The aid level shall be EUR 45/ha of energy crops with a maximum guaranteed area of 1.5 million ha and will be paid to producers entering into a contract with a processor. The area allocation between member states shall take into account historical energy crop production on set-aside and CO_2 commitment burden-sharing arrangements. The arrangements shall be reviewed after a period of five years, taking into account the implementation of the EU biofuels initiative.

Comments on the Commission's proposals

- The contribution of bioenergy to the EU energy system should be increased from 50 Mtoe in 2000 up to 135 Mtoe in 2010 in order to reduce the EU's dependence on energy imports. The figure of 1.5 million ha of supported energy crops proposed by the Commission is seriously inadequate: 15 million ha would be necessary.

- It is proposed that, in future, energy crops may continue to be cultivated on set-aside land.

- A supporting scheme for energy crops is welcome. However, the suggested system is rejected, because the proposed amount of aid (EUR 45/ha) will have too marginal an effect on the production costs of electricity from biogas, or bioethanol from cereals. This level of aid would lower the price of electricity from biogas based on maize silage by only 0.2 cents/kWh (kilowatt-hour), and one litre of bioethanol would become cheaper by 1 cent. The creation of attractive, guaranteed feed-in tariffs for renewable electricity, or tax exemptions for biofuels for transportation would make this system of aid unnecessary.

- A form of support is proposed for new energy crops such as short rotation coppice or miscanthus. The aid level should be EUR 300/ha for energy crops cultivated on arable land (including set-aside land) as well as grassland. This will allow the increasing demand for lignocellulose biomass from CHP/district heating plants to be satisfied.

Farmer aspects

Farmer involvement in biomass crops seems globally feasible, but will depend on the related financial aspects (support and profitability) and the means undertaken to promote this chain. An outlet for the final product, either wood, fibre, liquid biofuels, heat or electricity, should be ensured – for example, through a guaranteed selling price or a premium scheme. This is even more important where perennial crops are concerned.

- Farmers consider the biomass option realistic and feasible for them and are open to this alternative, although only the most innovative will take the first step. Profitability is the main criterion in their decisions.
- Energy crops should form part of a dedicated policy, on the same level playing-field as food crops. Economic calculations should take all costs involved into account.
- Farmers are open to diversification into the energy sector, but if biomass is to take off successfully, a strong and coherent political commitment, backed up with financial support, will be required. This should be accompanied by information, technical support, education and financial measures.
- To an increasing extent, farmers are taking environmental aspects into account, even if there is no direct economic effect on their farm. For certain biomass derivates, such as biogas, the environmental aspect frequently turns into an obligation to invest, making the profitability of the biogas plant a secondary issue.
- Biomass implementation in agriculture requires time, because a lot of individual decisions have to be taken and because the actual process of innovation does not produce immediate results. Conventional crops will be easier to develop than new crops and farmers' involvement in the conversion into energy will be greater. There is a need to start demonstration projects with the potential to become sustainable over the long term. This is especially important for innovative crops and processing technologies.
- Profitability remains the key factor in the farmer's decision to enter the biomass chain. The level of profitability could be guaranteed through fixed and stable prices, especially when perennial crops or investments in conversion plants are considered, and has to be attractive in comparison with alternative land use or other activities open to the farmer.

BIBLIOGRAPHY

AEBIOM [European Biomass Association] (2000), *Biomass from agriculture: the viewpoint of farmers*, Position Paper of AEBIOM.

European Commission (1997), *White Paper for a Community Strategy and Action Plan: Energy for the Future: Renewable Sources of Energy*, COM(97)599, Brussels, Belgium.

European Commission (2002), *Mid-Term Review of the Common Agricultural Policy*, Communication from the Commission to the Council and the European Parliament; COM(2002)394 Final, 10 July, Brussels, Belgium.

European Parliament and the Council of the European Union (2001), *The promotion of electricity produced from renewable energy sources in the internal electricity market*, Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on; *Official Journal of the European Communities*, L 283/33, 27 October, Brussels, Belgium.

European Parliament and the Council of the European Union (2003), *The promotion of the use of biofuels or other renewable fuels for transport*, Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003; *Official Journal of the European Communities*, L 123/42, 17 May, Brussels, Belgium.

AUSTRIAN POLICY APPROACHES TOWARDS BIOMASS IN AGRICULTURE

Valerie Zacherl[1]

Abstract

The use of biomass as a raw material as well as for generating energy has a long tradition in Austria, where forests cover 50% of the surface area. Wood has therefore always been, and remains, the most important renewable raw material in Austria. However, we are currently witnessing a greatly increasing awareness of the possibilities offered by other forms of biogenic material – particularly in the field of energy production. Especially in the light of Kyoto-target requirements, biomass has lately become a focus of not only environmental and energy politics, but also of agricultural politics – thus meeting the entire array of requirements for sustainable development in terms of its positive ecological, economical and social effects:

- climate protection;
- strengthening of the regions and creation of domestic jobs; as well as
- the reduction of dependency on other countries.

Biomass markets

On the one hand, there is the agricultural sector, which is in the position to offer the required raw materials. On the other hand, there is a demand for these raw materials in a wide array of market sectors. As in the past, the most significant market sector is the energy market. Austria is working on creating an appropriate set of comprehensive framework conditions for these market sectors.

On the supply side, our endeavour is to inform individual farmers, through the existing network of chambers of agriculture, about market perspectives and developments in the field of biomass – thus assisting them in forming individual market strategies.

On the demand side, however, it is necessary to put in place a much greater number of measures, since a wide array of different market sectors need to be addressed. Our strongest instruments here are precisely targeted impulse programmes as well as a clear legal framework (the first being indispensable in an early phase of the market development).

1. Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management, Vienna, Austria.

In the energy sector, the political objectives as defined in the government coalition treaty are remarkably ambitious and clear-cut:

- To increase by 75% the national capacity in green energy production from biomass; and
- To increase annually the overall share of renewable energy by 1% until 2010 – thus achieving a total of approximately 30%.

Research and development

One essential aspect of precisely targeted impulse programmes is investments in research and development. The most significant R&D activities are being undertaken within the framework of an impulse programme called "Sustainable Economy". This programme has been underway since 1999 and focuses on the use of renewable raw materials in the two sub-programmes "House of the Future" and "Factory of the Future". Within this framework, baseline studies, feasibility concepts, research projects with company participation and technology developments all the way to pilot and demonstration projects can be financed. The use of renewable raw materials to generate energy (bioenergy) will be the main focus of the sub-programme "Energy Systems of the Future", which came into effect in 2003.

Through national projects and the support of participation in international programmes (IEA), the area of bioenergy has been a field of intense activity at the Federal Ministry of Transport, Innovation and Technology for almost 25 years. For instance, a joint research initiative of the Federal Ministry of Research and the Ministry of Environment has successfully reduced to a minimum the emissions of small biomass boilers – an illustration of the progress that has been made in technical development. Today, Austria is the technology leader in this field, and in renewable energy there is a true alternative to gas and oil-based central heating.

Measures on the demand side – legal regulations

In addition to the overall objective of satisfying 78.1% of its electricity consumption from renewable energy sources, Austria has adopted the so-called "Green Electricity Act", setting itself the explicit goal of 4% of its electricity coming from "innovative" technologies by the year 2008.

The promotion of co-generation plants, with solid, liquid and gaseous biomass serving as an energy source (apart from wind power), represents the key to achieving this goal.

The Green Electricity Act created the following essential legal and economic conditions:

- cost-covering rates guaranteed for 13 years;
- a purchase commitment for power utilities to prices that lie above those of the electricity market; and
- funding of additional costs via surcharges passed on to the consumer.

Tax incentives for biodiesel

There is a complete mineral oil tax exemption for fuels made exclusively from biogenic material. A mineral oil tax exemption of up to 2% is granted when admixing biodiesel to fossil diesel.

EU Directives

The imminent implementation of two further EU directives will also have a positive effect on the use of biogenic fuels:

- The Directive "on the energy performance of buildings" prescribes a compulsory examination of the use potentials for renewable fuels in large new buildings.

- The Directive to "promote biofuels" prescribes further measures in order to ensure a 2% share of biofuels by the end of 2005 and 5.75% by the end of 2010.

Ecologically motivated regulating policy

This policy aims to protect biologically sensitive regions by a ban on the use of fossil lubricants and fuels was introduced in these areas.

Measures on the demand side aids and subsidies

Subsidies for environmental development in companies are granted by the Ministries for Environment and Agriculture. This involves investment aid for climate friendly technologies, such as heat generation plants using biomass and, in special cases, co-generation plants.

Investment aid for agricultural holdings

In the framework of this subsidy scheme, agricultural power plants using biomass and other energy alternatives are promoted. Currently, the projects involve biomass district heating, biomass heating plants, small biogas plants and biofuel systems.

Housing assistance

A noteworthy Austrian scheme is the coupling of subsidy grants, which actually pursue other objectives, with climate protection criteria. The primary objective of the housing assistance scheme, or *Wohnbauförderung* (WBF), is of a social nature: to ensure that the population receives ample housing at reasonable costs. The housing subsidies are allocated by the various Austrian provinces according to various criteria and are gradually being developed as an incentive for climate protection in that they offer a financial incentive to those who use energy-efficient construction and renovation techniques and renewable energy sources.

These are two positive examples:

- Exclusion of fossil heating from the housing subsidy in Styria; and

- The point system of the WBF housing subsidy in Salzburg, which has led to a boom in renewable energy-based heating systems. This system offers higher energy efficiency by linking the subsidies with the installation of bio-heating systems.

Measures on the demand side soft measures

So-called "soft measures" are essential for the success of the Austrian policy to promote the use of biomass. Two examples from among the many measures implemented on the federal and provincial levels include:

The bio-heating training programme of the Austrian Biomass Association

A training programme for professionals such as installers and chimneysweeps was instrumental in triggering the boom of innovative biomass heating systems in Austria. In just a few years, one out of four installation businesses has acquired a "bioheating" certificate. These and similar measures are extremely important because they ensure that consumers have ease of access to well-trained professionals.

Energy consulting

A wide network of energy consultants in the federal provinces of Austria provides consumers with an impartial source of information about the possibilities of biomass technologies. In federal provinces such as Upper Austria, participation in consulting sessions is a pre-condition to obtaining a housing subsidy.

New demand-side measures

Climate Protection Campaign – a new programmatic approach

As can be seen from previous statements, an extensive mix of instruments is required in order to achieve political objectives. With that in mind, the BMLFUW is launching an extensive climate protection campaign called *klima:aktiv* ("Active Climate") in 2003. The objective of *klima:aktiv* is to accelerate the market penetration of climate-friendly technologies and services. Apart from the energy efficiency focus, various sub-programmes are planned to selectively promote renewable energy technologies. The following activities are planned, which directly concern the biomass sector:

- Further support of the development of biomass heating through consulting, networking and training measures complementary to the existing lines of provincial and federal assistance;

- Promotion of insulation measures incorporating the use of renewable raw materials; and the

- Development of appropriate training courses, or co-ordination of the existing incentives related to energy efficiency, renewable energy and associated topics, such as encouraging the use of renewable building materials by the building industry.

BIOENERGY POLICIES AND TOOLS IN BELGIUM

Yves Schenkel and Romain Crehay[1]

Abstract

Energy agencies in Belgium are distributed between the Federal Authority and the Regional Governments. Several policies and plans are issued by each level of the State. They are all connected with one other and also at the international and European level.

All of these policies are large-scale plans, defining objectives for the respective governments on several topics, including energy. They do not suggest any direct course of action. The Walloon Plan for Sustainable Management of Energy is the most advanced strategy on bioenergy in Belgium.

Besides energy matters (fulfilling the Kyoto Protocol, etc.), the driving forces for bioenergy development in Belgium are industrial and rural sustainable development combining environmental, economic and social matters.

Introduction

Belgium is a Federal State made up of three regions: the Walloon Region, the Flemish Region and the Brussels-Capital Region. Since the regionalisation initiated in 1981, an ever-increasing number of agencies of relevance to the energy sector has been transferred from the Federal Authority to the Regions.

In the field of energy the Regions became responsible for the areas of supply and transport of gas and local electricity (up to 70 kV); heat supply networks; renewable energy sources; energy recovery and the rational use of energy – thus, mainly the energy distribution and demand control side.

The Federal Authority remains responsible for the production and transport of energy, nuclear power, large storage infrastructures and energy pricing (fixing rates and indirect taxes for fuel) – thus, mainly the production and transport side.

The Belgian energy market

The Belgian energy market is characterised by an important consumption rate per capita of 5.5 tonnes of oil equivalent (toe) in 1998 and the importance of nuclear power and petroleum products are respectively 21% and 41% of primary energy consumption. Less than 1% of renewable energy was used in 2001.

1. Centre de recherches agronomiques de Gembloux (CRA), Belgium.

The evolution of Belgian energy policy has been shaped by the general political evolution of the country, leading to the transfer of large areas of responsibility from the State to the Regions. This devolution is also enshrined in the building of Europe and the greater role now being played by European Union institutions in the major political and socio-economic decisions, particularly in the field of energy.

Federal policies

The energy-related priorities of the Federal Government are security of supply, energy prices and the environment. It also remains sensitive to the implications of climate change and the necessity for sustainable development. In 1999 the Federal Government created the post of State Secretary for Energy and Sustainable Development, attached to the Minister for Mobility and Transport. National energy policy focuses mainly on the topic of climate change and sustainable development through two plans.

1. ***The National Climate Plan*** defines the general Belgian strategy to fulfil the Kyoto Protocol commitments in keeping with a policy of industrial expansion. It integrates all sustainable development-related policies and programmes at European, Federal and Regional levels (*e.g.* the Federal Plan of Mobility, Federal Plan for sustainable development, CO_2 Flemish Plan, etc.). It operates with a co-operation agreement between the Regional and Federal level, within their fields of responsibility.
2. ***The Federal Plan for Sustainable Development*** is a frame plan, defining the objectives for the Federal Government for the sustainable development of the country for the 2000-04 period. The Plan proposes a collaboration between the Region and Communities concerned with these matters. Energy is one of the main topics of the Plan. In this regard, several frame actions have been planned among which are: several policies to support the development of renewable energies (price policy favouring renewable energies, …); actions (promotion, liberalisation of electricity and gas markets, green certificates, …); and technology development.

These plans concern each ministry of the Federal Government. They do not suggest any direct actions, but set out the priorities and methods of action necessary to attain the objectives. They target a 7.5% mitigation of CO_2 emissions, compared to the 1990 level, by 2008-12 (the Belgian Kyoto commitments). By 2003 a minimum of 2% of the total consumption of primary energy must be renewable energy and by 2004, a minimum of 3% of the final electricity consumption must come from renewable energies.

The main consequences of the federal policies are :

- the progressive withdrawal from nuclear power production until 2025;
- the opening of the power and gas market, in accordance with EU legislation; and
- the green certificate system.

The green certificate system has been implemented in order to promote the use of renewable energies. The certificates are given to power producers attesting their production according to the CO_2 saving made (co-firing, combined heat and power [CHP], renewable energies, etc.). Every company (not necessarily a producer) delivering power to consumers is legally bound to sell a certain percentage of “green power certificates”. If the quota is not respected, grid managers have to pay a fine for every missing certificate. The certificates can be obtained in two ways : by self-generating or by purchasing them on the market (green certificates have a marketable value).

Regional plans

Considering the Regions' involvement with most energy plans, the green certificate system is managed by them. This way, the Walloon, Brussels and Flemish Regions have their own individual management and funding systems but they are very similar, with only minor differences (*e.g.* CHP-produced electricity is considered as green electricity only within the Walloon system).

The Regions have also elaborated energy strategies and policies. The Updated Contract for the Future of Wallonia (CAWA) is a political regional declaration. It plans the objectives for the Walloon Government for the next ten years in accordance with the different actors (population, unions, associations, etc.). The CAWA defines 20 main objectives for Wallonia, among which are the development of renewable energies, the increase of R&D activities, and the development of the agricultural sector.

The Flemish CO_2 Plan comprises 33 Action Plans, of which the 2nd and the 32nd concern bioenergy. The second Action Plan stimulates renewable energies with green power certificates. This Plan also includes a subsidy scheme and information campaigns. The 32nd Action Plan examines the potential of energy crops. Ratification by the Flemish Government is expected.

Like the Federal Plans, these two Regional ones only define general objectives and general actions.

The Walloon Plan for the Sustainable Management of Energy is in keeping with international, European, Federal (Federal Plan for Sustainable Development) and Regional (CAWA) energy contexts (sustainable development, supply security, energy dependence, environmental matters, etc.). Its main aims are to reduce by 2% Walloon energy consumption and by 7.5% CO_2 emissions by 2010, and offset the very important use of nuclear power in Wallonia (30% of gross internal consumption in 1998) through improving management of energy supply and demand, avoiding waste, up-grading energy efficiency (CHP, etc.) and using renewable energies. The Plan specifically deals with the energy sectors concerned (industry, offices, tertiary and agriculture) through three tools: cultural (information, promotion, etc.), financial (incentives, sanctions, support, etc.) and legal. Special systems are planned for supporting renewable energy sources. For bioenergy, the objectives are 355 GWh ((1.5%) electricity consumption for 2005, and 820 GWh (3.3%) for 2010; 3 650 GWh (7.3%) heat production for 2005, and 5 850 (11.7%) for 2010.

The Walloon agricultural and forestry sectors are looking at potential new uses for their products. Aware of the benefits bioenergy development should contribute to agriculture, forestry and rural development, the Ministry of Agriculture and Rural Affairs has decided to set up development projects to promote bioenergy chains and identify obstacles to their development in Belgium.

The Wood-energy and Rural Development Plan combines energy and agricultural matters. Instigated by the two relevant Walloon Regional Ministries, this programme allows the implementation of ten municipal wood-energy heat networks.

Environmental matters aside, the development of bioenergy is motivated by the willingness of the Governments to implement an industrial and rural sustainable development. All policies and programmes are elaborated according to these driving forces and are integrated within international, European, Federal and Regional contexts.

Regarding renewable energies and particularly bioenergy, no specific driving forces or priorities have been defined.

All energy-related policies propose the same solutions: energy efficiency, rational use of energy and use of renewable energy. Bioenergy is not specifically underlined. Therefore, renewable energies are supported through broadening the scope of policies and research programmes.

Except for the Walloon Plan for Sustainable Energy Management, there are no energy or bioenergy dedicated policies in place in Belgium, although national policies concerning climate change, sustainable or rural-economy development include energy topics. Some of these only mention bioenergy as a way of reaching the objectives; others clearly plan actions for the use of biomass as an energy source.

Currently, renewable energies are not well developed in Belgium. It is a relatively young concept. Some barriers, such as logistical or psychological barriers, still exist. But there are some initiatives to overcome these obstacles. Measures such as pilot installations (*e.g*. the Wood-energy Plan) have an important role to play as they can have a favourable influence on public opinion.

AGRICULTURAL BIOMASS IN GREECE: CURRENT AND FUTURE TRENDS

M. Mardikis, A. Nikolaou, N. Djouras and C. Panoutsou[1]

Abstract

Agriculture is an important sector of economic activity in Greece which can be a considerable source of biomass for regional bioenergy schemes. It has been estimated that approximately 3.8 million dry tonnes of field crop and arboricultural residues are theoretically available for energy production, as well as 600 000 dry tonnes of agro-industrial residues, with a respective total energy potential of 69 PJ/year and 10 PJ/year. Intensive livestock farming results in the daily production of 3 200 000 livestock and 2 000 m^3 animal wastes, from cattle, pig and poultry, with a biogas potential of 240 000 m^3/day, corresponding to 5.6 PJ of annual energy production. So far, cultivation of energy crops has not been established for commercial purposes. However, some very promising energy crops have been investigated in several research and development programmes. It is expected that biomass use for energy purposes, and especially the integration of energy-dedicated crops to local agricultural systems, could result in significant social and economic restructuring of the agricultural sector at both national and regional level (maintaining farmers' present levels of earnings, or providing them with additional sources of income, maintaining jobs in rural areas, etc.)

Introduction

Agriculture is an important sector of economic activity in Greece, accounting for 6% of gross domestic product (GDP) (Ministry of Agriculture, 2003) and 20% of civilian employment. Agriculture's contribution to GDP has been declining, while agricultural employment has shrunk by 5 percentage points as a share of total employment since the early 1990s.

From a total of 13.2 million ha of the total land area of Greece, the area devoted to agriculture constitutes 9.2 million ha, of which 5.2 million ha are pastureland, 3.9 million ha are cultivated with various crops and about 0.5 million ha are left fallow every year (NNS*a*, 1999).

Agriculture has remained the most heavily subsidised sector. In 1999, it received budgetary transfers estimated at 51% of the sector's value-added (3.7% of GDP). Moreover, the amount of support has increased since the early 1990s. Nearly 75% of total support (2.8% of GDP) comes from the European Union's (EU) Common Agricultural Policy (CAP) transfer schemes. Cotton, wheat, olive oil and tobacco are the most heavily protected products, attracting nearly 80% of total budgetary transfers. The rest of CAP transfers aim at the restructuring of production under the European Agricultural Guarantee and Guidance Fund (EAGGF). Most of the national budgetary transfers (around two-thirds) are earmarked for investment, including improvements of rural infrastructure and

1. Centre for Renewable Energy Sources, Athens, Greece.

matching grants for farm modernisation programmes eligible for EU support. A significant part of national transfers also consists of support to young farmers, early retirement and preservation of the countryside. In addition to such direct budgetary transfers, substantial indirect support comes from national sources to fund a non-contributory scheme for farmers' pensions.

The sector suffers from structural weaknesses that are reflected in poor international competitiveness. Structural impediments to enhance productivity are mostly due to the large number of small, inefficient farms, with the average farm size being just 25% of the EU average.

Agriculture has also become very intensive, with the heavy use of fertilisers and pesticides, which has led to a levelling of yields, a declining quality of farmland, and signs of environmental damage (Ministry of Agriculture, 2003). In addition, easy access to water resources (through, for instance, unlicensed artesian wells) and low prices have encouraged inefficient use of water resources.

As agriculture accounts for 85% of the country's water consumption, water shortages are looming.

On the other hand, environmental problems associated with fossil fuel use, such as global warming and acidification, are forcing a rethinking of the world's energy supply system for the 21st century. Biomass is a renewable source in so far as its production is carried out in a sustainable way and is generally considered a "CO_2-neutral" energy carrier, based on the reasoning that the carbon emitted through combustion is taken up again by the growing plants. Additionally, the provision of locally sourced energy through the exploitation of various biomass resources, such as agricultural residues, livestock waste or energy crop plantations, could stimulate rural economic development, while at the same time offering an option for improved energy supply (FAO, 2000).

Renewable energy sources (RES) contributed 5.2%, (1.46 million tonnes of oil equivalent [Mtoe]) to the Greek Total Primary Energy Supply in 2000 (Table 1) and of this, biomass accounted for 67% (0.946 Mtoe). Domestic use of wood for cooking, water and heating accounted for about 74% (0.70 Mtoe) of total biomass energy production. The remaining 26% (0.24 Mtoe) was produced by the combustion of wood by-products and agro-industrial residues and the utilisation of biogas produced in landfills, agro-food industries and municipal wastewater treatment plants. A number of biogas-to-electricity installations – including a 240 kWe (kilo watt electric) plant in a municipal solid waste landfill in northern Greece, a 193 kWe plant in a municipal wastewater treatment plant and a 166 kWe plant in southern Greece, as well as ten biogas-to-heat installations (with a total heat production of 58 TJ) – have been realised so far, and others are currently being planned.

Agriculture is a source of considerable quantities of biomass that can be used in regional bioenergy schemes. This paper will provide an assessment of the current and future agricultural biomass resources in Greece, including an overview of energy crops examined under Greek conditions. Furthermore, an assessment of future trends concerning energy production from agricultural biomass will be made, by analysing the agricultural sector in Greece and the national and EU policies.

The quantities of residues from the annual and perennial crops cultivated in Greece were estimated, in tonnes of dry matter per year, using data from *Agricultural Statistics* on the areas cultivated and the quantities of the main product produced per year for each crop over the years 1996-98 (NSS*a*, 1999). Additionally, coefficients that indicate the ratio of residue quantity to product yield and the moisture content of each type of residue were derived from the literature (Apostolakis *et al.*, 1987) and are presented in Table 2.

Table 1. Contribution of RES to the Greek energy balance for 2000

Energy Balance 2000	k toe*	%
Fossil Fuels	9 038.0	32.11
Liquid Fuels	15 941.0	56.63
Gas Fuels	1 703.0	6.05
RES:	1 165.3	4.14
Solar	*99.0*	*0.35*
Wind	*106.0*	*0.38*
Biomass – Industry	*241.0*	*0.86*
Biomass – Households	*705.0*	*2.50*
Small Hydro	*14.3*	*0.05*
Large Hydro (0-10 MW)	*303.3*	*1.08*
TOTAL	**28 150.6**	**100.00**

* Thousand tonnes of oil equivalent.

Source: CRES, 2002.

In a further step, the theoretically available quantities were assessed, taking into account the percentages already used. From the total agricultural residues produced in Greece, a part is already exploited and used in several energy and non-energy markets. Cereal straw is used for various purposes such as animal feeding and animal bedding. In northern Greece there is also a greenhouse using straw for heat production (250 megawatt-hours [MWh]/year [CRES, 2002]). Therefore it has been assumed that only 15% is available for bioenergy applications (Voivontas *et al.*, 2001). In the case of rice straw, cotton and corn stalks and corn cobs, although no alternative markets have been reported, the availability percentage was set at 60% due to difficulties in harvesting and handling. Olive prunings (especially the large stems) are used in stoves and fireplaces for residential heating and their availability was set at 50%, while prunings from vines and other types of trees, which are not the preferred choice for this purpose, were assumed to have an 80% availability for bioenergy applications (Alexopoulou *et al.*, 1999).

Based on the above it was estimated that approximately 3.8 million dry tonnes of field crop and arboricultural residues are theoretically available for energy production, with a total energy potential of 69 PJ (petajoules)/year (Table 2). The geographical distribution of the available quantities of agricultural residues in Greece is presented in Figure 1.

Nowadays, the main volume of the aforementioned field crop residues are either incorporated into the soil or burned on the field. Although there are sufficient quantities of residues in the country, certain parameters should be taken into account before planning a strategy for exploiting this energy.

- Small-scale farming increases harvesting and transportation costs.
- Environmental risks caused by the removal of the residues from the field can result in erosion in sloping areas and nutrient removal in low-fertility areas, etc.
- Opportunity cost of the residue (*e.g.* cereals straw already has a market price as it is sold for animal feeding purposes).
- There is a lack of commercial harvesting machinery for certain types of residue, such as cotton residues.

Agro-industrial residues

The main types of agro-industries in Greece are: rice, cotton-ginning, corn, fruit, wine, seed oil, olives, olive oil and olive kernel.

The evaluation of the quantities and geographical distribution of this category of residues is complicated because of the different processing technologies, the size and location of the processing plants and the characteristics of the final products (Blassi *et al.*, 1997). Furthermore, there are no official data on the production of agro-industrial products at regional level in Greece that could facilitate the estimation of the residues produced. Therefore, it is necessary to follow different methodologies, according to the availability of data for each type of residue.

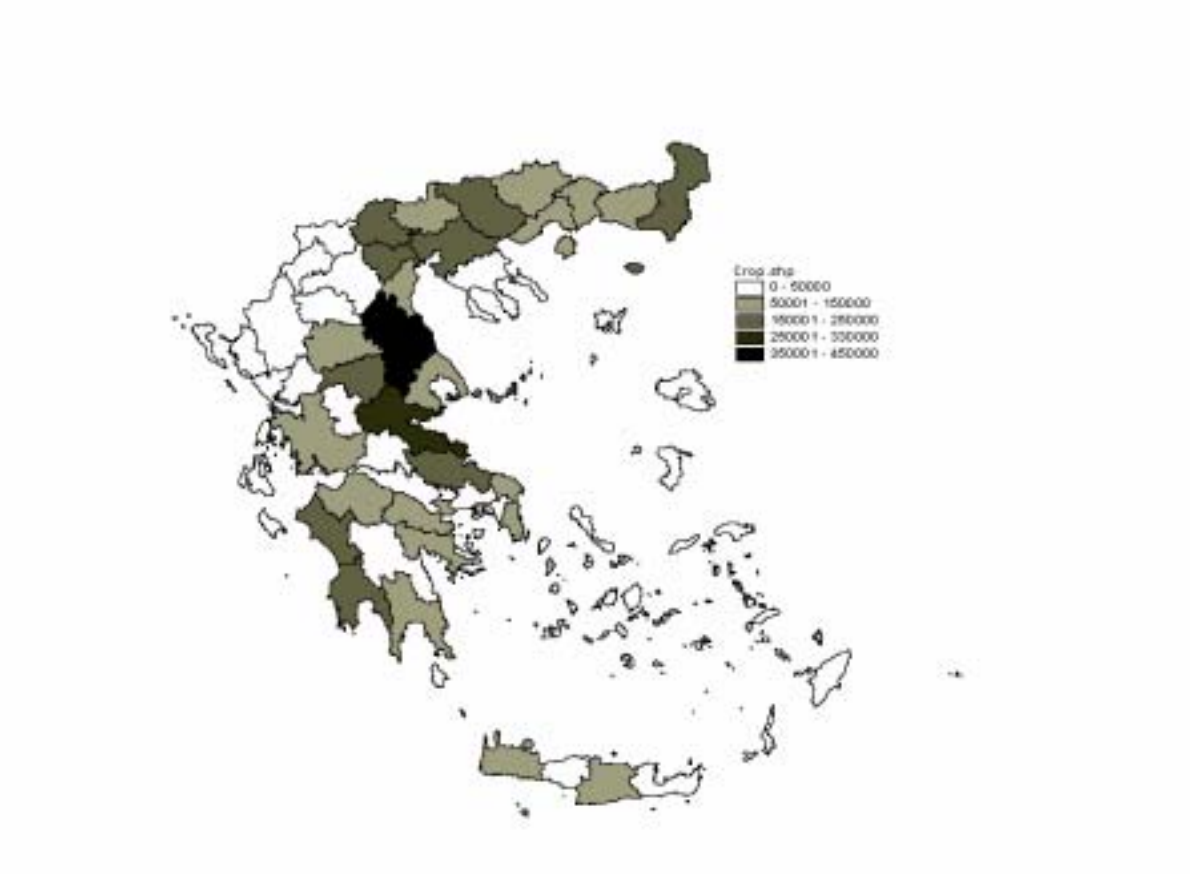
In the case of rice mill residues, rice husk was estimated as a percentage of the harvested rice for which there are available data at regional level. It is reported in the literature and confirmed by the engineers in the rice mills that rice husk is approximately 20% of the processed rice, with an average moisture content of 10% (Table 3 and CRES, 1996). The same assumption was made for cotton, since all of the harvested cotton is sold and processed in the cotton-ginning factories. It has been reported that cotton-ginning residues constitute 10% of the processed cotton, with an average moisture content of 17% (CRES, 1996). In the case of nutshells, the data on the production of almond, walnut and hazelnut shells are only available at national level (NSS*b*, 1999) and these data were used to estimate the quantities of the produced hulls. The average shell/kernel ratios used were 1:2 for almond shells, 1 for walnut shells and 0:8 for hazelnut shells (Pontikis, 1987).

Table 2. Characteristics of crop residues studied for Greece

Residue	Product/ Residue ratio	Moisture (%)	Higher Heating Value (MJ*/kg)	Cultivated area (ha)	Available quantities (dry tonnes/yr)
Durum wheat straw	1.00	15	17.9	245 019	80 415
Soft wheat straw	1.00	15	17.9	612 047	184 378
Rice straw	1.00	25	16.7	27 982	94 320
Barley straw	1.24	15	17.5	144 884	35 741
Oats straw	1.27	15	17.4	43 853	8 307
Corn cobs	3.75	50	18.4	213 181	165 694
Corn stalks	1.42	60	18.5		350 059
Sunflower straw	0.50	40	14.2	26 818	28 603
Cotton stalks	0.50	45	18.2	412 727	877 809
Sugarbeet leaves	2.51	75	14.6	42 585	123 084
Tobacco stems	0.91	85	16.1	67 070	14 260
Vineyard prunings	1.20	40	18.3	133 408	364 471
Olive prunings	0.98	35	18.1	749 522	881 314
Peach prunings	2.51	40	19.4	45 993	121 383
Pear prunings	1.26	40	18.0	4 213	30 727
Apple prunings	1.20	40	17.8	14 874	139 080
Apricot prunings	2.84	40	19.3	5 047	7 864
Lemon prunings	2.22	40	17.6	11 917	39 207
Orange prunings	2.90	40	17.6	40 050	152 404
Cherry prunings	1.20	40	19.1	8 613	19 404
Tangerine prunings	1.55	40	17.6	6 137	22 864
Almond prunings	0.28	40	18.4	23 613	83 921
TOTAL				**2 789 553**	**3 825 309**

* Megajoules
Source: EUBIONET, 2002.

Figure 1. Geographical distribution of the available quantities of agricultural residues in Greece



Source: EUBIONET, 2002.

There are no available data concerning the annual production of fruit canneries. However, it has been reported that the total installed capacity at a national level is 200 000 tonnes/year for peach canneries and according to the literature (CRES, 1996) peach kernels make up 4.5% of the total fruit. Finally, the produced quantities of olive kernel wood were estimated based on the annual regional production of olive oil producing varieties, and the assumption that olive kernel forms 23% of the olive fruit (Aragón *et al.*, 2000).

It was estimated that 593 742 dry tonnes of the above agro-industrial residues are produced in Greece, with a total energy potential of 10 PJ/year.

Table 3. Characteristics of industry residues studied for Greece

Industry	Residue	Residue/ Product ratio	Moisture (%)	Production (dry tonnes/year)
Rice mills	Rice husk	0.16	10	30 311
Cotton-ginning factories	Cotton-ginning residues	0.1	13	132 079
Peach canneries	Peach kernel	0.04	20	6 400
Olive kernel factories	Olive kernel wood	0.21	30	423 110
Peeling plant	Walnut shells	1.5	8	119
Peeling plant	Almond shells	0.95	5	1 328
Peeling plant	Hazelnut shells	1.07	5	395
TOTAL				**593 742**

Source: EUBOIONET, 2002.

According to the *Renewable Energy Sources Statistics for 2000* in Greece (CRES, 2002), several cotton-ginning factories use their residues to produce the heat required for cotton drying and heating their facilities. The total heat energy produced has been estimated at 0.4 PJ/year (CRES, 2002). Most of the olive kernel wood produced is used for greenhouse heating, heating buildings, etc., the total heat energy produced being 8.3 PJ/year. Fruit kernels and nutshells are also used for greenhouse and residential heating (0.01 PJ/year). Rice husk is used as a fuel for processing heat in the rice mills (0.09 PJ) and for power production in one factory (0.44 MWe of installed capacity).

Livestock waste

The Greek livestock system consists of sheep, goats, lambs, cows, calves, swine, broilers, layers and breeding pullets. Poultry farming and sheep and goat breeding represent the highest percentage of the livestock industry, accounting for 90% of the total units in the years 1999/2000 (NSS*c*).

The use of livestock wastes for energy generation and recycling in agriculture is not very well developed in Greece. The common practice of pig manure management is its collection in anaerobic lagoons after collection, mixing and mechanical separation. It is the simplest form of anaerobic treatment and it acts as a psychrophylic anaerobic digester open to the atmosphere. The main problem of this biological treatment system is the release of methane into the atmosphere, which contributes to global warming. Apart from that, local nuisance problems are caused by the ammonia and other odour emissions during warm and dry-weather periods. However, it has been approved as an economical and simplified biological system, which combines the reduction of organic load and effective storage of the liquid pig wastes. In cattle-raising farms, solid manure is collected on impermeable platforms from which liquid is discharged into a septic pool. Poultry manure is collected on dung heaps and, following the composting process, is applied to the soil as fertiliser.

Energy can be derived from animal wastes as long as they are collected in lagoons or large tanks, but this can only be considered feasible with in-stall livestock systems (sheep and goats, therefore, are excluded from such practices since their breeding is extensive and manure is dispersed all over the grazing land). Intensive livestock consists of cattle, brood sows and poultry farming. Furthermore, the exploitation of animal wastes for energy production through the anaerobic digestion process would be feasible only in cases of medium/large-scale livestock units. According to an inventory of the Agricultural Bank of Greece (1996), from the 803 medium/large-scale livestock units in Greece, cattle breeding constitutes the biggest part (355), while pig and chicken breeding units total 277 and 171, respectively. In total, cattle, brood sows and poultry farming amounts to 68 066, 100 780 and 21 524 400 head, respectively (Table 4).

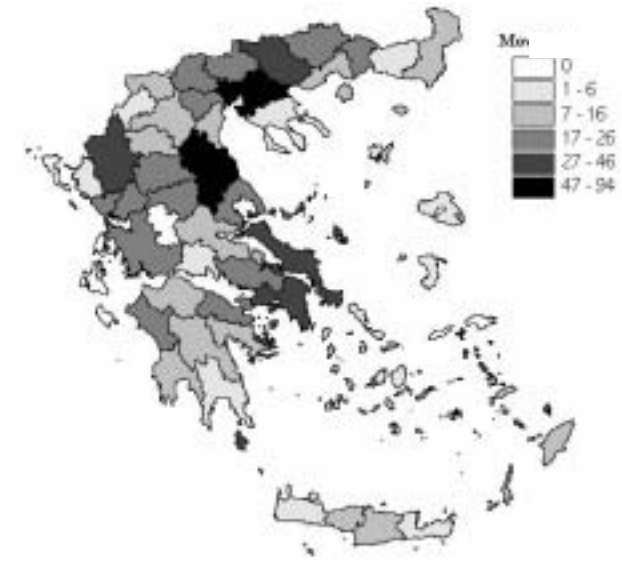
Table 4. Total number of medium/large-scale livestock units, animal heads and daily production of wastes, biogas and nutrients

Livestock type	Units	Head	Waste volume (m^3/day)	Biogas potential (m^3/day)
Cows	78	12 582	724.72	10 484.58
Dairy Cows	240	36 241	2 087.48	30 199.63
Calves	37	19 243	415.65	16 035.19
Swine	277	100 780	491.81	9 523.71
Broilers	79	16 110 000	1 304.91	96 660.00
Layers	72	4 180 900	526.79	58 950.69
Pullets	20	1 233 500	155.42	17 392.35
TOTAL	**803**		**5 706.78**	**239 246.15**

Source: Agricultural Bank of Greece, 1996.

Cattle farming takes place mainly in northern Greece, while pig breeding is more equally distributed over the 52 Greek prefectures (Figure 2). Poultry farming is concentrated in only a few prefectures and, more specifically, the biggest production takes place in Attiki, Ioannina and Evia.

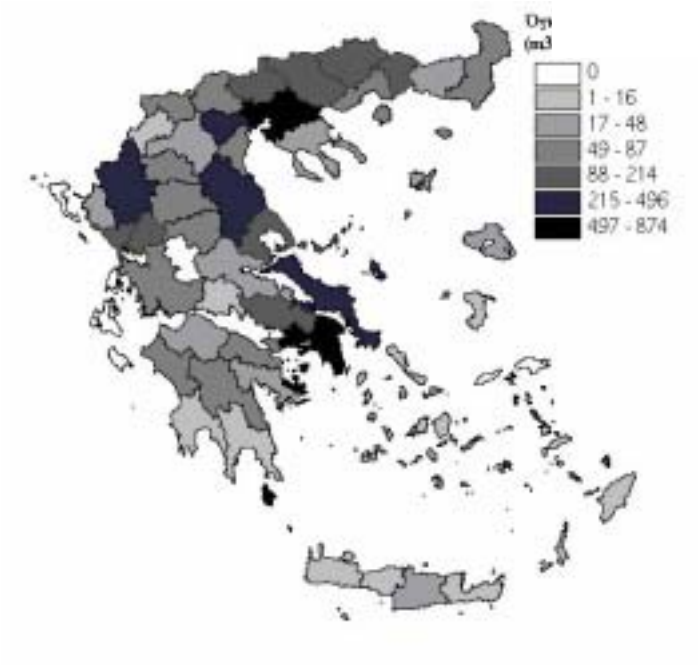
Figure 2. Distribution of medium/large-scale livestock units in Greece



Source: Mardikis, 2003.

Adapting the values of manure production and characteristics established by the American Society of Agricultural Engineers, an estimation of the potential daily production of animal wastes can be conducted (ASAE, 1999). According to this estimation, intensive livestock farming in Greece results in the daily production of 3 200 000 livestock and 2 000 m^3 of animal wastes from cattle, pig and poultry breeding, respectively (Table 4). Figure 3 depicts the distribution of daily animal waste production resulting from medium/large-scale livestock.

Figure 3. Potential daily production of animal waste (m^3/day) per prefecture



Source: Mardikis, 2003.

Concerning biogas potential, it is estimated to be 240 000 m^3/day, with the equivalent energy content of more than 200 tonnes of oil equivalent (toe). This amounts to some 5.6 PJ annual energy production, which could cover 0.7% of the total energy demand in Greece.

Energy crops

The cultivation of energy crops has not as yet been established for commercial purposes in Greece, due to the country's unfavourable technical and economic environment. However, some very promising energy crops have been investigated in several research and development (R&D) programmes. R&D efforts for energy crops in Greece started in the late 1980s and focused on important technological barriers affecting their successful implementation. In detail, research programmes were conducted on: i) agronomic aspects; ii) fuel characteristics; iii) environmental aspects of biomass production; iv) conversion to energy and v) economic and social dimensions of energy crops in Greece.

During the last decade more than 60 experiments have been conducted throughout Greece in order to evaluate the biomass-yielding potential of several energy crops. So far, the following annual and perennial crops have been thoroughly studied:

Annual herbaceous crops: sorghum (*Sorghum bicolor L.*), Ethiopean mustard (*Brassica carinata L. Braun*), rapeseed (*Brassica napus L.*), kenaf (*Hibiscus cannabinus L.*)

Perennial herbaceous crops: cardoon (*Cynara cardunculus*), giant reed (*Arundo donax L.*), miscanthus (*Miscanthus x giganteus*), switchgrass (*Panicum virgatum L.*)

Short rotation woody crops: eucalyptus (*Eucalyptus globulus Labill., Eucalyptus camaldulensis Dehnh.),* black locust *(Robinia pseudoacacia).*

In general, most of the crops studied exhibited good adaptability to Greek climatic conditions as well as high yields in terms of fresh biomass and dry matter. Productivity varied with site, climate, soil, species and agricultural management, but commercial yields of over 20 tonnes d.m./ha^{-1}/y^{-1} (400 GJ[gigajoules]/ha^{-1}/y^{-1}) appear feasible in most of the tested Greek regions. However, differences have been observed so far depending on crop species, climate and cultural practices. A summary presentation of the results obtained for each energy crop studied is presented below.

Sweet sorghum has received considerable attention as an energy crop, mainly for bioethanol production from the fermentable sugars contained in its stems. Fresh biomass yields, under Greek conditions, ranged from 45 to 141 tonnes/ha, while dry matter yields ranged from 13-45 tonnes/ha, depending on site, variety and methods of cultivation. The bioethanol potential in well irrigated and fertile fields was estimated at 6 750 litres/ha. Water use efficiency (WUE) for sweet sorghum has been estimated in central Greece at 181-206 kg water per kg dry matter, with aerial radiation use efficiency (RUE) at 3.5 g of dry matter per MJ intercepted.

Fibre sorghum is a hybrid from grain and broomcorn sorghums and has received attention for energy and paper and pulp production. Experimental data obtained to date from central Greece indicate that it exhibits high biomass yields, similar to that of sweet sorghum. Fresh biomass and dry matter yields recorded in autumn reached up to 90 and 27 tonnes/ha, respectively.

Kenaf is an annual spring crop of great interest as a biomass source for energy and as feedstock for low-cost fibres. A large number of kenaf varieties have been tested, indicating good adaptability and high yields. Fresh biomass yields ranged from 33.8 to 88.6 tonnes/ha and dry matter from 7.6 to 23.9 tonnes/ha. It should be mentioned that the late-maturing varieties were more productive than the early ones. However, although seed production was always feasible for the early varieties, the late ones were occasionally able to produce seed, depending on the prevailing climatic conditions during autumn.

Rapeseed and Ethiopean mustard are two oilseed crops that have received attention mainly for biodiesel production. Experimental data indicate that dry matter yields ranged from 3 to 8 tonnes/ha and seed yields could reach up to 1.4 tonnes/ha, depending on variety and site.

Cardoon is a perennial crop, traditionally cultivated in certain Mediterranean areas and well adapted to the semi-arid conditions of southern Europe. In experimental fields in central Greece, final plant height reached up to 2.6 metres, while dry biomass yields, depending on plantation density, ranged from 17 to 30 tonnes/ha. The respective values for energy potential ranged from 6.9 to 12.9 toe/ha/year.

Giant reed is a perennial grass species of the southern EU area well adapted to Greek conditions. In experimental fields established by CRES, dry matter yields reached up to 30 tonnes/ha from unimproved wild populations and conventional cultural methods, with an energy potential of 12.9 toe/ha/year.

Miscanthus is a perennial rhizomatous grass, originating from South-east Asia. In experimental fields in central Greece, the average height of the plantation reached up to 3 metres, while dry biomass yields ranged from 11 to 34 tonnes/ha and the estimated energy potential was 13.8 toe/ha/year.

Switchgrass is a perennial warm-season grass that has the capacity for high yields on relatively poor-quality sites. In experiments performed in Greece dry matter yields ranged from 14 to 25 tonnes/ha depending on variety and cultural practice.

Eucalyptus has been extensively used for paper and pulp as well as energy production worldwide. In the EU there are some 850 000 ha of eucalyptus plantations, consisting of two species (*E. globules* and *E. camaldulensis*), typically managed with an 8-13 year rotation. In Greece, very short rotation cycles (2 to 3 years) and dense plantations (10 000 to 40 000 plants/ha) have been studied in various regions. Depending on soil fertility and cultural practices (irrigation, fertilisation and plant density) dry matter yields of up to 35 tonnes/ha/year have been obtained with a respective energy potential of up to 15 toe/ha/year.

Black locust is a widely spread species for ornamental, afforestation and reclamation purposes, as well as for timber and energy production, covering, worldwide, 3 million ha and being third among the broadleaved species in terms of area planted, globally. In experimental fields in Greece, dry biomass yields ranged from 5.6 to 17.1 tonnes/ha/year. The average value for energy potential was 8 toe/ha/year.

Assessment of future trends

The agricultural sector in Greece – main structures and peculiarities

Despite the prevailing favourable climatic conditions, Greek agriculture presents a slow rate of development and modernisation, mainly due to certain peculiarities which determine its steps forward, including: the small size of farms; decreasing employment opportunities, unstable incomes; reduced subsidies; lack of alternative cropping solutions and rather slow development.

The average agricultural area by holding is remarkably low (4.4 ha) compared to other EU countries (UK: 67.3 ha, Denmark: 37.1 ha, France: 35.1 ha). Additionally, a large number of farm holdings (808 000) are usually subdivided into 6 or 7 parcels. Only 0.1% of holdings cover an area greater than 100 ha. Out of the total number, only 500 000 holdings meet the EU criteria for a "professional farm business". From the aforementioned figures, it is clear that farmers, in order to ensure a proper income, have to make their cropping choices for the farm as a whole, and cannot easily diversify their activities.

Agricultural employment in the country has fallen significantly from 30% in 1981, to 20% in 2000. The biggest reduction was observed in the islands, where 1981 figures were halved, the difference all going to tourism. Also the number of working days devoted to the agricultural sector was reduced by 14.6% between 1991 and 2000. Family workforces represent 85.5% of total agricultural employment, and 60% of the heads of agricultural holdings are over 55 years old. This last number clearly indicates that the slow rate of modernisation is mainly caused by the unwillingness of people to join the "learning process" and their inability to understand and accept new methods of farm management.

All the aforementioned features have led to the lack of investment in the agricultural sector, resulting in the absence of modernisation. Older farmers with smallholdings are obviously not able to invest in new machinery or new cultural practices.

In order to be able to provide a satisfactory income to farmers, Greek agriculture is heavily reliant on EU subsidies, under the CAP regime. However, income maintenance has proved quite difficult to achieve because of the variability of yields, due to climatic and geographical conditions;

the small size of farm holdings; the lack of proper quality standards to ensure the competitiveness on external markets; the absence of proper infrastructure in the transport and commercial sectors; market price fluctuations and the uncertainty of "subsidy policy".

National and community policies

As stated in Article 130A of the EU Treaty the European Union undertakes to "decrease the differences among several development levels in the regions especially of the remote agricultural areas". Community policy concerning Greek agriculture during the last decade has been based on this Article. Greece is one of the regions where agriculture and forestry are considered very important in terms of share in GDP and employment. Certain measures and programmes have been announced since 1994 focusing on the improvement and further development of structural items in the agricultural system, as well as on agricultural development in order to maintain the rural population, stabilise its income and improve its quality of life. Under this framework the agricultural sector received a total amount of EUR 3 293 million (Table 5).

Table 5. Total amount of subsidies received by the agricultural sector in 1998 in Greece

Subsidy	Total amount (million euros)	%
National structural programmes	196	6
European structural programmes with national contribution	705	21
European support of agricultural products	2 392	73
TOTAL	**3 293**	**100**

Source: Ministry of Agriculture, 2003.

Currently, no specific state policy for the energy exploitation of biomass has been introduced in Greece. The instruments and measures utilised to support energy production from biomass are those employed by the broader national policy for the increased deployment of RES in Greece in compliance with the RES *White Paper* issued by the European Commission and the commitments undertaken by the Greek government at the Earth Summit in Kyoto that call, among other things, for a 25% ceiling on the overall nationwide increase of CO_2 emissions by 2010.

Energy production from biomass is supported by the New Development Law 2601/1998, currently being implemented by the Ministry of National Economy. Also in Measure 2.1 of Subprogramme 2 of the present Operational Programme for Competitiveness (OPC), under the third Community Support Framework (2000-06), that is devoted to providing state support to private investments in RES and RUE, the public subsidy for biomass-biogas installations is 40% of the total eligible cost, independent of the geographical region.

Agricultural biomass future role in Greece: current and potential bioenergy applications

Biomass use for energy purposes is expected to result in significant social and economic benefits (providing additional income to the farmers or maintaining the present standard of income, maintaining jobs in rural areas, etc.), restructuring of the agricultural sector at both national and regional level. In detail, the main benefits of bioenergy in Greece can be summarised as follows:

- Mitigation of CO_2 emissions and reduced growth of lignite use;
- Compliance with the reformed CAP:

- Jobs: maintenance of employment in the agricultural sector, along with the creation of a few jobs at "village level" where the biomass power plant will be established.

- Rural revenue: rural revenue is expected to increase following the creation of supplementary markets for residues, as well as the introduction of energy crops into the existing agricultural system.

- Diversification: the introduction of bioenergy crops may enhance the diversification of agricultural production.

- New enterprises can be established both for the handling/pre-treatment of agricultural biomass and for the operation of local bioenergy plants.

At the moment, current bioenergy applications in Greece include:

- Several cotton-ginning factories use their residues to produce the heat required for cotton drying and heating of their facilities. The total heat energy produced has been estimated at 0.4 PJ/year (CRES, 2002).

- The olive kernel wood produced in the olive kernel factories is being used for greenhouse heating, heating buildings, etc. The total heat energy produced has been estimated at 8.3 PJ/year (CRES, 2002).

- Fruit kernels (produced by fruit canneries) and shells (from almond, walnut and hazelnut peeling plants) are being used for greenhouse and residential heating. The annual energy production from these types of residues has been estimated at 0.01 PJ/year (CRES, 2002).

- Rice husk residue is used to produce the heat needed by the rice-processing factories and the thermal energy produced has been estimated at 0.09 PJ/year (CRES, 2002). There is also a factory using rice husk for power production with an installed capacity 0.44 MWe.

Taking into account the above-mentioned factors and constraints for agricultural biomass production in Greece, the following potential bioenergy applications can be identified:

- Small to medium-scale heat generation or co-generation in the agro-industrial mills.

- District heating applications in central-northern high-elevation villages.

- Co-firing with lignite in the existing power stations.

- Hybrid solar and biomass, in the tourist sector (hotels, apartments, etc.)

- Heat generation for individual buildings, *e.g.* schools, hospitals, public buildings. Improved stoves for households based on the different fuel types available in Greece (*e.g.* olive kernels, fruit kernels, etc.)

BIBLIOGRAPHY

Agricultural Bank of Greece (1996), *Inventory of Livestock Units in Greece,* Athens, Greece, (available in Greek only).

Alexopoulou, E., A. Nikolaou and C. Panoutsou (1999), *National Report on Biomass in Greece,* Al.4.1030/D/97-029/, AFB IV-Bioguide III, CRES, Athens, Greece.

Apostolakis, M, S. Kiritsis and C. Sooter (1987), *The biomass potential from agricultural and forest residues,* ELKEPA, Athens, Greece (available in Greek only).

Aragón, J.M., A. Karagouni, F. Bolle, K. Geissen, P. Daniil, N. Russel, C. Balis, M.D. Manaute, J. Prieto, T. Rützow and A. Margelis (2000), *Improvements of Treatments and Validation of the Liquid-Solid Waste from the Two-Phase Olive Oil Extraction* (IMPROLIVE), Final Report, Contract number FAIR CT 96 1420: www.nf-2000.org/reports/reports.html.

American Society of Agricultural Engineers [ASAE] (1999), *Manure Production and Characteristics,* D384.1, December.

Blassi, C., V. Tanzi and M. Lanzetta (1997), "A study on the production of agricultural residues in Italy", *Biomass and Bioenergy* 12 (5), pp. 321-331.

Centre for Renewable Energy Sources [CRES] (2002), *Renewable Energy Sources Statistics for 2000 in Greece,* Information Systems Division.

CRES (1996), *Possibilities for Electricity Production from Biomass in Greece,* report prepared for the Public Power Corporation, (Biomass Department), Athens, Greece (available in Greek only).

EUBIONET (2002), *National Report, Greece,* Altener 4, 1030/S/01-1000/2001.

Food and Agriculture Organization of the United Nations [FAO] (2000), *The Energy and Agriculture Nexus,* Environment and Natural Resources Service, Sustainable Development Department Working Paper No. 4, Rome, Italy: www.fao.org/sd/EGdirect/EGre0058.htm.

Mardikis, M. (2003), "Energy and nutritional potential of livestock wastes in Greece, 3rd Conference of the Greek Society of Agricultural Engineers, Thessaloniki, 29-31 May (available in Greek only).

Ministry of Agriculture (2003), *The State of Agriculture, Foodstuffs and Agricultural Development in Greece,* Athens, Greece: www.minagric.gr/en/1.2.7.2.html.

National Statistical Service of Greece [NSS] *a,* (1999), *Agricultural Statistics 1996-1998,* Athens, Greece (available in Greek only).

NSS*b* (1999), *Industrial Statistics 1996-1998*, Athens, Greece (available in Greek only).

NSS*c* (2001), *Results of the basic research on the structure of agricultural and livestock holdings (inventory of agriculture-livestock breeding) 1999/2000*, August, Athens, Greece (available in Greek only).

Pontikis, K. (1989), *Tree growing*, Karamperopoulos (ed.), Athens, Greece (available in Greek only).

Voivontas, D., D. Assimakopoulos and E.G. Koukios (2001), "Assessment of biomass potential for power production. A GIS method", *Biomass and Bioenergy* 20, pp. 101-112.

LONG-TERM PERSPECTIVE OF THE USE OF BIOMASS FOR ENERGY IN HUNGARY AS A PART OF EUROPEAN UNION ACCESSION PROCEDURE

Károly Kocsis[1]

Abstract

One of the most important, but from the point of accession to the European Union, perhaps the most contradictory sectors of Hungarian national economy are agriculture and food production. In order to compensate the considerable losses of former positions of these sectors on East European markets and the efficient preparations for the accession to the European Union require the discovering of new ways and means of future development of agricultural production sectors.

The difficulties in formulation of future agricultural development strategy and policies have been strengthened by the dramatic change in land property rights and compensation processes related to economic and political changes in Hungary, during the early 1990, by the considerable losses suffered in East European food-markets, the enormous decrease of financial assistance to agricultural production and heavy increase of rural unemployment in Hungary. On the other hand, our future agricultural policy should be based on the requirements and conditions of *sustainable rural development*. Such a rural development strategy should be formulated and such practical applications should be introduced which may ensure the continuation of high output agricultural production at reasonable profitability for the Hungarian farmers and high-level use of Hungarian lands and natural resources for *sustainable food and fibre production.*

Among the various possibilities one important development trend may be, also in Hungary, the wide-scale commercial and environmentally friendly use of agricultural and forest lands for *production of biomass and phitomass for energy* purposes. During the past decades, wide-scale international and national R&D activity has been carried out, and a great number of demonstration projects were set up in well developed industrial countries for testing and commercial application of new and renewable energy technologies. However, in Hungary, apart from some positive examples and experiences of several pilot projects, the biomass production and conversion technologies for energy production have not been extensive.

In a recently published *strategic study* prepared by the experts of Gödöllő University for the Hungarian Academy of Sciences, detailed analysis of technologies and technical-economic conditions of production and conversion of agricultural and forestry biomass for energy production have been presented and proposals were formulated for the actions to be taken by the governmental agencies for wide-scale practical application of these technologies and energy carriers during the forthcoming decades. Due to the complexity of the relative long-term technical and economic development activities in this study paper only some selected background information is presented on the proposed national biomass energy development programme.

1. St. Stephen's University, Gödöllő, Hungary.

Introduction

The overall objective of the recently published study was to identify the most adequate technical information available on biomass energy production and conversion technologies, the *presentation* of major results of international and national research and development (R&D) activities for governmental organisations and offices, on the basis of which the technical-economic justification of proposed biomass energy technologies and the decisions on the required financial supporting systems can easily be carried out.

The concrete objectives of the study were the *overview* of the most important trends of biomass energy production and conversion technologies in European Union (EU) member countries, which may also influence the major development trends in Hungarian rural sectors; the *justification* and determining of available quantities of national biomass resources and their possible future shares in overall Hungarian and agricultural energy balance; and, *analysis* of practical experiences gained with these technologies in EU member countries. Further more, proposals have been prepared for the necessary steps to be taken by the governmental bodies and offices regarding the relative R&D activities, the establishment of demonstration sites, as well as for extension of relative educational and information activities, in Hungary. In the preparatory study the following concrete problems have been investigated:

- major trends and tendencies of new and renewable energy technologies and in R&D policies of the EU;
- share and extent of renewable energy sources in EU as a whole, and in selected member countries;
- potential of biomass production and spread of conversion technologies for energy in Hungary;
- technical, economic, social and market conditions of energetic use of biomass for energy in Hungary; and
- expected effects of EU accession of Hungary on development of biomass energy technologies.

On the basis of considerable results of the relative R&D activities carried out during the past decades in Hungary and briefly summarised in the above-mentioned study – if positive support will be provided from the part of agricultural and industrial development authorities – the study group is ready to prepare a detailed *strategic development programme* for the wide-scale practical application of biomass energy technologies in Hungary, taking into consideration the objectives and strategic plan of most recent technical development programmes adopted by competent EU boards and offices.

General aspects

The considerable extension of heat and electricity energy demands of industrial, public and private sectors and the rapidly increasing of fuel demands of public and private road transportation – supplied still, mostly with fossil fuels – the *carbon-dioxide emission* and *greenhouse effects* have reached a more and more dangerous level, in highly developed regions. In order to control the unfavourable environment effects, in principle, two major ways are available. The gradual decrease of either the *specific energy demands* and global fossil fuel requirements or at least of their increasing trends, on one hand, and the increase of the share of *new and renewable* and nuclear energy sources, on the other. Within the present structure of energy balance of most European countries, and also of that in Hungary – apart from the nuclear energy sources – biomass is to be considered the most important environmentally friendly alternative energy source.

Besides the dangerous level of unfavourable environmental effects due to increasing energy consumption, the steady over-production of foodstuffs, started during the early 1980s in EU member countries, has also become more and more considerable, from the middle of the 1990s, in Hungary. Therefore, the regular set-aside of some one and a half million hectares of agricultural land from conventional food production is now expected, also in Hungary.

For these reasons, the introduction of environmentally friendly *biomass energy production* and more efficient processing and conversion technologies are intended not only for producing new energy carriers, but also to promote the solution to problems of over-production in the food industry; to promote more sustainable land use in general; the sustainable use of soils and other natural resources and a decrease in rural unemployment.

From the point of view of utilisation of biomass for energy purposes, the *direct combustion* of agricultural and forestry wastes and by-products originating from conventional agricultural and forestry production activities are already technically feasible and economically efficient. However, after completion of appropriate biological, agronomical and technological R&D activities, as well as verification of the economic efficiency of these technologies, *electricity energy* production from selected biomass resources and the production of biomass from *energy forestry* and *energy plantations* for conversion into *electricity* and *engine fuels* may also be realistic and sustainable technical-economic development alternatives, in future.

In order to ensure the long-term *ecological balance* of rural areas, the basic conditions and very first priority of the use of biomass for energy purposes should be the protection of the fertility and appropriate physical structure of soils and overall rural landscape, as well as protection of biological and ecological values of the surrounding environment. For this reason, the energetic use of biomass and the withdrawal of biomass by-products and waste materials from *ecological recycling* can be permitted only to the extent that the organic material content of soils is not destroyed and plant and animal biological resources are not jeopardised. On the other hand, for energy forestry and energetic plant production, such technologies should be developed and applied, which – on the contrary to intensive agricultural food production technologies – protect, rather than destroy, natural resources.

European experiences and tendencies

The total commercial energy consumption of EU-15 countries has a slight increasing trend. Without any particular control or co-ordination activity by the European Commission (EC) the new and renewable energy sources in most EU countries will be utilised only to a limited extent. During 1990-95, the share of renewable energy sources in EU countries has increased from 5.0% to only 5.3%. The share of renewable energies in the total energy consumption of EU countries, around the middle of the 1990s was only about 6%. This ratio is very high in Sweden (25.4%), Austria (24.3%), Finland (21.3%) and Portugal (15.7%), i.e. mostly in those countries where the practical use of biomass for energy purposes is already considerable.

For the promotion of wider use of new and renewable energy sources the EC has recently made considerable efforts. As a first step, the *Green Paper* on *Renewable Energy Resources in EU Countries* was published in 1996, followed by the *White Paper*, containing the relative S*trategic Development Programme*. The overall objective of this programme is to increase the present 6% share of renewable energy sources in the energy balance of EU-15 countries up to 12%, by 2010.

The concept of the most recent EU *Renewable Energy Development Programme* is based on the well-verified fact that an increased share of renewable energy resources within the national and EU energy balances can greatly contribute to the desired decrease in the unfavourable effects of

greenhouse gases (GHGs), whose decrease by some 15%, until 2010 has been agreed upon. One further reason to realise this EU strategic programme is to reduce the energy *import dependence* of EU member countries. At present, some 50% of the total energy demand of EU-15 countries is covered from imported fossil fuels. Without any significant measures this ratio may reach even 70% by the year 2020.

The European Council supported the working out and realisation of this strategic programme because it is obvious that the above-mentioned share of renewable energy sources within the EU energy balance cannot be realised only on the basis of conventional commercialisation of this technical development programme. Due to the present low, and sometimes decreasing, level of international fossil energy prices, which do not include the cost effects of environmental protection and energy import dependence, still prevent the competitiveness of commercial application of most renewable energy technologies in the majority of EU countries.

According to the decisions made by the European Council, such energy policy, legal, administrative, economic financial and marketing measures should be taken during the coming years, so as to guarantee the long-term executions of desired renewable energy development objectives. Carrying out the EU's renewable energy programme requires complex measures which will be extended to the sectors of energy production, environmental protection, agriculture, regional development, labour market, taxation and market control, as well as the R&D and education sectors, too.

The EU renewable energy programme has been extended to nearly all various kinds of renewable energy sources, like *solar energy* (photovoltaic, solar collectors, passive solar), *wind-energy*, *hydropower* and *geothermal energy*, mostly for heat and electricity production, and *biomass* as a resource for heat, power and engine-fuel production. According to the above-outlined development programme included in EU's *Green Paper*, through the increase of the share of renewable energy resources from 6% up to 12% the substitution of fossil fuels with renewable energies can be increased from 114.7 million toe (tonnes of oil equivalent) in 1995, up to 238.1 million toe, in 2010 and, meanwhile the yearly CO_2 emission can be decreased down to 402 million tonnes/year. The most important resources of the renewable energy programme are biomass energy carriers, which will contribute to this programme with some 90 toe/year.

Biomass for energy in Hungary

The total renewable biomass production of plant-origin in Hungary is some 55-58 million tonnes of dry matter, of which the share of main products is some 29-30 million tonnes, and that of by-products, some 26-28 million tonnes. According to various calculations, at least 3 to 3.5 million tonnes of biomass raw materials can be used for energy purposes from the 25-26 million tonnes/year of agricultural residues, and some 1 to 2.0 million tonnes/year forestry residues, without any harmful effects on the ecological balance and fertility of soils and preservation of landscape.

If the agronomical and forestry management and technical-economic conditions of energy plant production and energy forestry can be guaranteed, the yearly biomass production for energy purposes can be increased up to 6 to 7.0 million tonnes, *i.e.* up to 10-12% of total biomass production. The potential energy equivalent of *dry biomass residues for combustion* in Hungary has been calculated at some 1.5 to 2 million toe/year. The potential heat energy equivalent of biogas production from liquid manure and other high water content agricultural residues has been calculated at up to 0.3 to 0.4 toe/year: however, the realisation of this programme is hindered by the lack of economically feasible technologies.

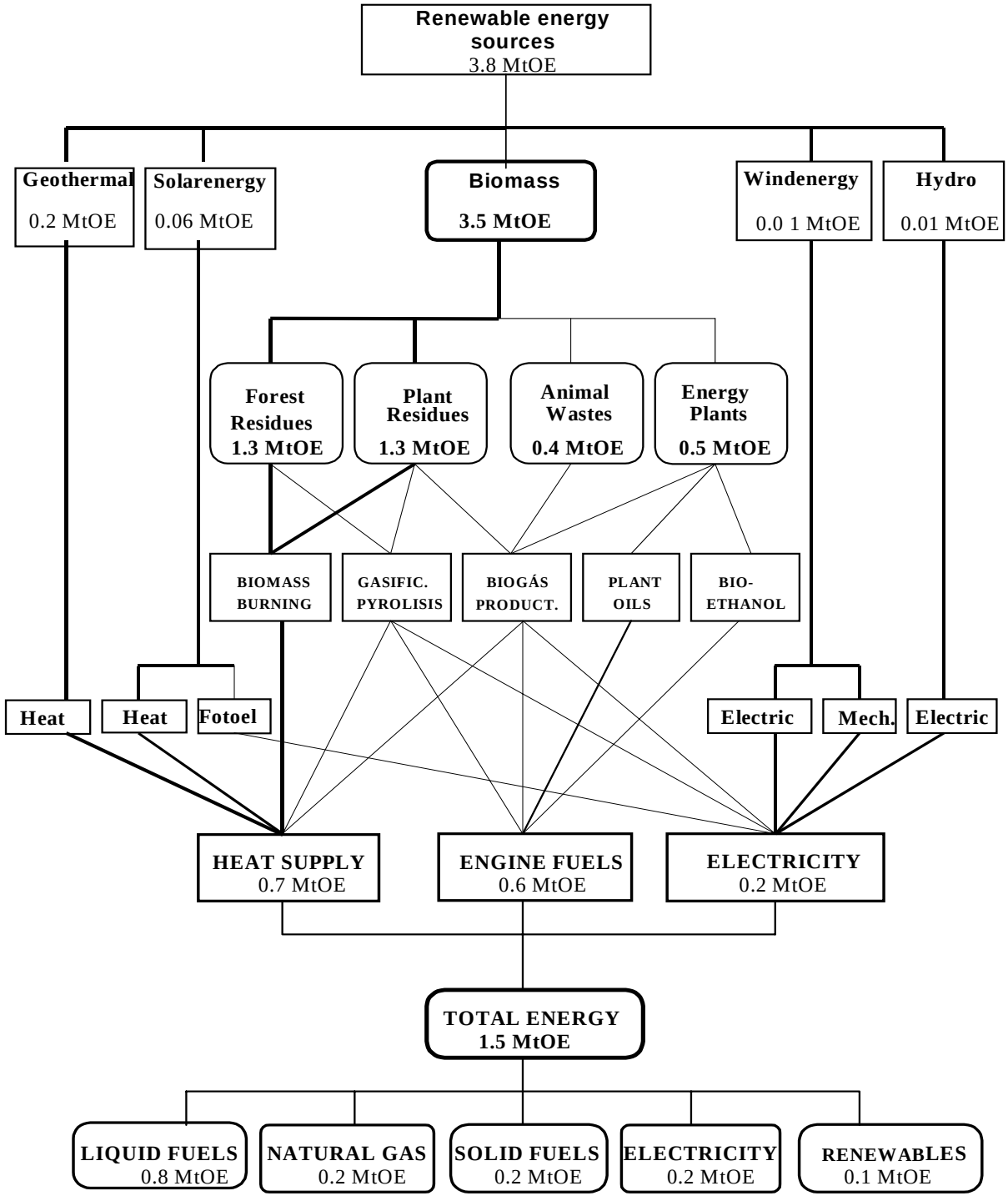
Depending on the size of conventional agricultural lands to be made available for this purpose, at present some 400-500 000 ha of land can be used for *energy forestry* and/or some other 300-400 000 ha of agricultural lands for *energy plant* production. On the basis of these figures the *biomass heat* production capacity of Hungarian agricultural sectors can easily be increased up to 0.9-1.2 million toe/year during the next decade, while *biomass engine-fuel* production can be increased up to 0.6-0.8 million toe/year. In this way, the total biomass energy production potential of rural sectors in Hungary is about 3 to 4 million toe, some 12-14% of the present total energy consumption of the country, three-quarters of which can be used for *heating* purposes and some quarter of this amount as *engine-fuels* (Figure 1).

In general, biomass energy carriers are comparatively cheap energy sources, with fairly low (15 MJ[megajoule]/kg) heat content, at low (10-20%) moisture content and their net final energy content in up-to-date *combustion* units (at 80% conversion efficiency) may reach the average values that of coal burning. One of major characteristics of biomass combustion technology is that the *energy concentration* of biomass energy carrier production measured in *dry matter yields* (t/ha) is fairly low, therefore the *total and net energy yields* (measured in toe/ha) is also moderate. The average *energy yield* in the case of conventional agricultural crops (at 1.5 to 2.5 t/ha of biomass yield) is some 2.1 to 3.5 toe/ha: however, in the case of energy plant and energy forest production technologies – through improvement of biological features of energy plants and the relative agro-technical processes – these values can be increased up to 8 to 9 t/ha and 11 to 13.0 toe/ha, respectively.

Due to the comparatively low energy density of biomass energy production, the transportation costs of raw materials on longer distances from producing lands or stores to burning units may be quite high; therefore these renewable energy sources are suitable first of all, for operation by small and medium-sized so-called decentralised (local) heat energy consumers. Apart from local utilisation of biomass energy resources through direct combustion technologies – applying special biomass energy conversion technologies – they can also be used for production of more valuable *secondary biomass energy carriers*, either as solid (*e.g.* bio-briquette) fuels or liquid and gaseous fuels for heat production or engine fuels. The specific energy demand of most of these energy transformation technologies is still comparatively high, and their energy efficiency and total energy output-input ratios still moderate, which technical characteristics, at present, may hinder their wide-scale practical applications.

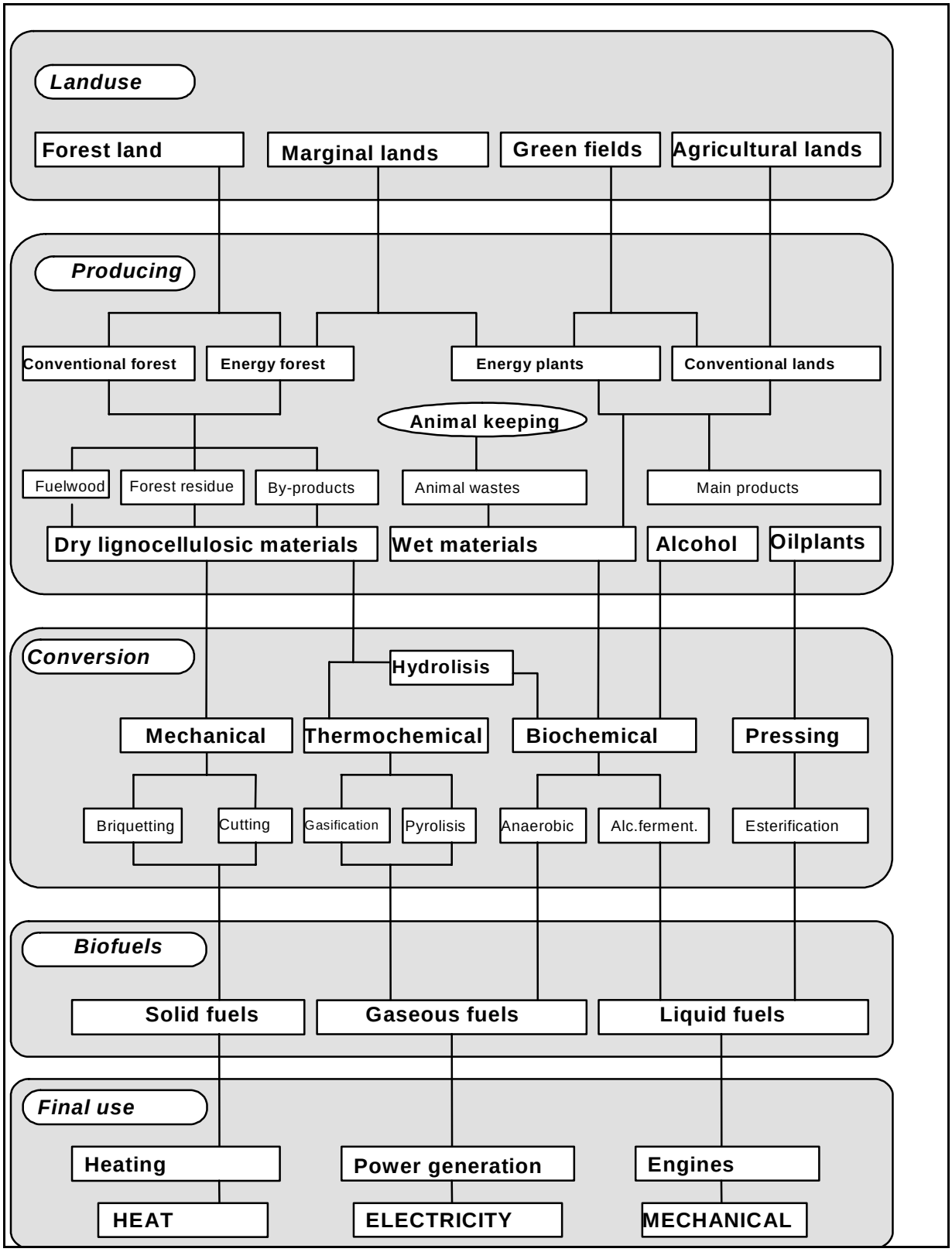
Apart from the technical-economic efficiency, the commercial use of primary and secondary biomass energy carriers depends – to a great extent – upon the biological, agro-technical and engineering characteristics of *raw material producing*, ecological characteristics and limitations of sustainable *land use* and the technical-economic characteristics of *biomass energy conversion technologies* (Figure 2). Therefore, the application and technical-economic efficiency of the practical application of any biomass energy technology can be justified only on the basis of a detailed analysis of local biomass producing, transportation and conversion conditions, and the thorough evaluation of expected local energy output-input relations as well as investment and operational costs.

Figure 1. The role of renewable energy sources in Hungarian agriculture



Source: Author.

Figure 2. Biomass production and conversion technologies



Source: Author.

Technical-economic conditions

The *energy output-input ratio* of dry biomass combustion (*i.e.* the ratio of energy equivalent of biomass yields and the energy input required for producing or collection and transportation of raw materials) in the case of plant production and forestry residues changes between 15 and 30, while in the case of anaerobic digestion of animal wastes and green plant residues of high moisture content, between 1.2 to 1.6. The energy output-input ratio of *oilseed plants* (*e.g.* rape), depending first of all, upon the specific yields of plant being produced, changes between 2.1 and 3.9, while in the case of bioethanol it is extremely low (1.0 to 2.1). The overall energy output-input ratio of secondary biomass energy carriers can be increased to a considerable extent through the utilisation of biomass processing by-products (stem-residues, oil-cakes, etc.), either for other energetic or industrial purposes or as animal feedstuffs.

It is obvious from these informative data that the energy efficiency of biomass-originated energy carriers depends basically upon the energy inputs to plant production, the utilisation of genetic capability of plant varieties, the careful selection and good organisation and efficient execution of agro-technical work processes: however, it depends above all upon the actual biomass yields (t/ha). The justification of the energetic efficiency of biomass production technologies is an extremely complex task. Therefore, the direct comparison of technical-economic parameters of selected parts of biomass production and conversion technologies may lead to wrong conclusions either in favour of or against the practical applications of these technologies. The *economic efficiency* of biomass-originated energy production basically depends upon the *prodution costs* (HUF/ha) and the specific production cost related to quantity unit (HUF/t), on *production yields* (t/ha) and/or the *market price* of primary biomass resources (HUF/t). In the case of secondary biomass energy carriers (*e.g.* bio-briquettes) the economic efficiency is further influenced by the *specific investment costs* (*e.g.* HUF/kW installed capacity), the yearly utilisation hours and nominal energetic capacity of combustion units and their energy efficiency, as well as by the accumulated energy output-input ratios of biomass energy production chains.

Today, hundreds of different biomass production, conversion and utilisation technologies are available on the national and international markets, and various biomass production technologies and farm machinery systems can be applied for the production a great variety of primary biomass energy sources (Figure 2). Therefore, the justification of the overall economic efficiency of biomass energy production is a very complex task. Simplification of economic evaluation methods and reducing the economic analysis only , for example, to the direct comparison of direct costs or actual market prices of selected biomass energy carriers, may lead to great mistakes regarding the selection of a certain biomass energy technologies.

Summing up, the most important technical-economic parameters determining the economic efficiency of production, conversion and final utilisation of biomass for energy purposes, are as follows: costs or market price of biomass raw materials, specific costs of biomass production and conversion technologies, production and conversion costs or market price of secondary biomass energy products appropriate for commercial utilisation and, the comparative costs or market prices of fossil energy carriers and fuels. These basic economic parameters should be completed with other indicators expressing the national costs of conventional energy supply and indirect contributions of national economy (either in monetary units or in other ways) which may influence the general justification of biomass use (*e.g.* environmental protection expenditures, energy import dependence, taxation, financial support to energy saving, tax exemption, national contribution to exploration of new fields, etc.).

During the past decade many agricultural enterprises, farmers, industrial firms, technical development agencies and companies, as well as local municipalities and governmental agencies, have initiated the practical application of new biomass production and conversion units and complex technologies, and many pilot projects have also been constructed in Hungary. However, all these efforts are only local and sporadic initiations and they have not yet resulted in a considerable increase of renewable energy use and significant contribution to the national energy balance. The realisation of a radical change in the structure of national energy balance requires the working out of a well-defined *strategic development programme* including governmental involvement in the execution of relative R&D activities, testing and demonstration, as well as marketing (tax exemption, investment loans, etc.) of the most advanced and feasible biomass energy production and conversion technologies.

Apart from the obviously necessary governmental involvement, in order to maintain the principle of market-driven introduction and dissemination of biomass energy technologies, the larger agro-food enterprises, national and multinational industrial companies, as well as investment banks, development agencies and non-profit organisations, should also be involved even in the preparatory phase of large-scale practical applications. Due to the complexity of this technical development programme and the wide range of institutions and commercial organisations involved in the working out of an agricultural and rural development-oriented, so-called *agro-energetic development programme*, one of the most important conditions for the wide-scale dissemination of these technologies is government acceptance.

Besides the control and co-ordination of various R&D, testing and financing of activities, the major aim of this kind of strategic development programme is the detailed justification and evaluation of the role of biomass energy resources in national and regional environment protection policies, harmonisation with agricultural and rural development programmes and analysis of the expected effects of biomass energy technologies on improvement of regional and local employment, and the working out and governmental acceptance of the necessary financing, supporting and marketing principles of programme.

Conclusions

On the basis of detailed analysis of national results and international trends of the use of agricultural and forestry biomass resources for energy production purposes, the following major conclusions can be stressed:

- Production and conversion of biomass for wide-scale energy use promote not only the *substitution of fossil fuels* with renewable energy sources, but greatly contribute to the realisation of *sustainable rural development*, solving the problems of *agricultural and food over-production*, the improvement of rural *environment management* and that of *rural unemployment.*
- The moderate use (not more than 10-12%) of the biomass resources for energy purposes reproduced year by year, does not endanger the *ecological balance* of the rural landscape and natural resources: moreover, it promotes the sustainable use of agricultural lands for non-food production, sustaining the organic material content, fertility and physical structure of soils.
- The practical use of biomass energy technologies in EU countries varies widely, but in some countries it contributes to the national energy balances to a considerable extent, with 15-27% of national energy demand being already covered from biomass resources.
- According to the most recent EU renewable energy programme, the contribution of renewable energies to national energy supply will be increased, from the present 115 million toe/year up to 238 million toe/year until 2010, resulting in considerable decrease of CO_2 emissions (402 tonnes/year).

- In Hungary, biomass energy potential is considerable, some three to four times larger than agricultural energy consumption and, ten years from now, biomass energy production can be increased to 3 to million toe/year, *i.e.* up to some 12-15% of the present commercial energy demand of the country.
- The most important condition of the dissemination of biomass energy technologies in Hungary is the preparation and gradual execution of a national strategic development programme on biomass production and conversion for energy purposes, which should be accepted and also supported financially by the government and local municipalities as part of *sustainable rural development strategy*, including concrete actions for the improvement of rural environment protection, rural unemployment, sustainable land use agro-food marketing conditions.

BIBLIOGRAPHY

Barótfi, I. (1998), *The Use of Biomass for Energy* (A biomassza energetikai hasznosítása), Handbook, The Energy Centre, Budapest, Hungary.

European Commission [EC] (1997), *White Paper on Energy for the Future: Renewable Sources for Energy*,, Brussels, Belgium.

EC (1994), *The European Renewable Energy Study, Main Report, Volume 1*, Brussels, Belgium.

Kocsis, K. (1999), "Perspectives of utilisation of biomass for energy in agriculture: Small-scale Biomass Burning", International Biomass Seminar, Gödöllő, Hungary, 1-3 July.

Kocsis, K. (1999), *The European Situation and Possible Role of Biomass in Non-Food Production and Energetical Use of Biomass in Hungary* (Az energetikai célú biomassza termelés európai helyzete és lehetséges szerepe a megújuló energiaforrások, Magyarországon), MTA Strategical Studies, Budapest, Hungary (in co-operation with Professor I. Barótfi).

Kocsis, K. (1999), *Possibilities of Sustainable Development in Energy Economy: Effects of EU Accession on the Use of Renewable Energy Sources for Development of an Energy Knowledge Based Society* (A fenntartható fejlődés lehetőségei az energetikában. Az EU csatlakozás hatása a megújuló energiaforrások alkalmazására, Energiatudatos társadalom kialakításáért), GTE Conference, Budapest, Hungary.

Kocsis, K. (1995), "Environmentally friendly production and use of energy in agriculture" (Az energia környezetbarát termelése és felhasználása az agrárgazdaságban), *Agro-21*, Füzetek, Budapest, Hungary.

Kocsis, K. (1993), *Possibilities and Economic Conditions of Renewable Energies in Agriculture* (A megújuló energia-termelés lehetőségei és közgazdasági feltételei a mezőgazdaságban), 13-9101-T OMFB Study, Budapest, Hungary.

OECD-IEA [International Energy Agency] (1995), *Energy Policies, Hungary, 1995 Survey*, Paris, France.

REVIEW OF CURRENT POLICY APPROACHES TOWARDS BIOENERGY PRODUCTION FROM AGRICULTURE IN NORTHERN IRELAND AND THE REPUBLIC OF IRELAND: A PERSPECTIVE FROM THE IRISH BIOENERGY ASSOCIATION

Michael Doran[1]

Abstract

The island of Ireland includes both the Republic of Ireland and Northern Ireland, which is part of the United Kingdom. The Republic of Ireland is an autonomous state with its own policies. Northern Ireland has been operating under both direct rule from London and under a devolved Assembly over recent years. Bioenergy production from agriculture in Ireland includes short rotation crops; anaerobic digestion; liquid biofuels and agricultural waste products, *e.g.* spent mushroom compost and chicken litter. There has been no co-ordination in the promotion of bioenergy production from agriculture between Northern Ireland and the Republic of Ireland, and co-ordination between the relevant government departments within each jurisdiction to support bioenergy production from agriculture has been poor. Recognition for the social and socio-economic benefits which can be derived from bioenergy production within rural communities has been slow.

Northern Ireland and the Republic of Ireland co-operate through electricity inter-connectors and natural gas pipelines, but do not co-ordinate bioenergy production. The island of Ireland needs to implement policies across different sectors, which can stimulate the development of bioenergy production from agriculture. This will require legislation, financial support and an increase in public awareness in Ireland, both in Northern Ireland and in the Republic of Ireland, to achieve their ambitious targets for renewable energy production.

The Irish BioEnergy Association

The Irish BioEnergy Association (IrBEA) was formed in May 1999 to promote the bioenergy industry and develop this important sector in the Republic of Ireland and Northern Ireland. The overall aim of the IrBEA is to promote biomass as an environmentally, economically and socially sustainable indigenous energy resource and also to promote its non-energy-related benefits.

The objectives of IrBEA are to:

1. Improve public awareness of biomass as a realistic option for energy supply;
2. Influence policy makers to promote the development of bioenergy;
3. Promote the implementation of bioenergy projects;
4. Network and share information amongst those interested in bioenergy development;
5. Liaise with similar interest groups.

1. Irish BioEnergy Association; and Rural Generation Limited, Londonderry, Northern Ireland.

The organisation, which is a self-governing association of voluntary members, is affiliated to the European Biomass Association (AeBIOM).

Background

The Republic of Ireland is an autonomous state with an area of 70 282 km^2 and a population of 3 917 336, equating to 55 persons per km^2. Northern Ireland covers an area of 14 138 km^2, with a population of 1 685 267, equating to 120 persons per km^2. Northern Ireland is part of the United Kingdom and is governed separately. Northern Ireland has been governed over the last three years both by direct rule from London and by a local Assembly based in Belfast. The topography, climate and agriculture are similar across the island.

Northern Ireland: farms and land use

In Northern Ireland, 80% of the total land area is used for agricultural purposes (Tables 1 and 2). In the Republic of Ireland, 62.8% of the total land area is agricultural. These figures compare with a European Union (EU) average of 42.4%.

Table 1. Land under cultivation in Northern Ireland, 1994-98

(1 000 ha)

	1994	1995	1996	1997	1998
Total Agricultural Crops	56.1	54.9	55.0	56.6	55.9
Total Horticultural Crops	3.3	3.2	3.2	3.1	3.2
Total Grass	813.0	817.4	819.3	825.1	830.6
Grazing	176.3	170.9	169.0	164.1	159.1
Woods/Plantations	8.2	8.1	8.2	8.2	8.2
Other Land	14.7	13.2	12.9	11.8	11.3
TOTAL AREA	**1 071.6**	**1 067.8**	**1 067.6**	**1 068.9**	**1 068.4**

Source: *Irish Almanac and Yearbook of Facts 2000*.

Table 2. Size of farms in Northern Ireland (1998)

Hectares	Number of farms	Hectares
0.1 - 9.9	7 837	41 898
10.0 - 19.9	7 090	103 401
20.0 - 29.9	4 871	120 130
30.0 - 49.9	5 676	219 589
50.0 - 99.9	4 719	321 779
100.0 +	1 624	261 573
TOTAL	**31 817**	**1 068 370**

Source: *Irish Almanac and Yearbook of Facts 2000*.

Republic of Ireland: farms and land use

Data on farm-size categories for 1975, 1992 and 1999 are shown in Table 3. This shows that farm numbers have declined by almost 180 000 to 143 900 since 1992. This is equivalent to a rate of decline of 1.7% per annum. This overall trend masks significant difference between farm-size categories. Most of the decline has taken place in the smaller-farms category (20 ha or less), while the number of larger farms has grown. Consequently, average farm size has increased from 26.8 ha to 29.3 ha. In relation to data on farm numbers prior to 1992 it should be noted that for the Census of Agriculture in 1991, the Central Statistical Office (CSO) revised its definition of farms and excluded from the data all farms below 1 ha in size. Therefore, difficulties arise in making comparisons between pre- and post-1991 farm numbers.

Table 3. Size structure of Irish farms 1975, 1992 and 1999

Farm size (hectares)	1975		1992		1999	
	Number	**%**	**Number**	**%**	**Number**	**%**
<5	34 400	15%	16 600	10%	11 300	8%
5-9	37 700	17%	22 200	14%	17 300	12%
10-19	70 600	31%	46 100	29%	38 700	27%
20-29	35 800	16%	29 900	18%	28 500	20%
30-49	29 800	13%	27 600	17%	27 900	19%
50-99	15 900	7%	15 400	10%	16 300	11%
>100	3 700	2%	3 900	2%	4 0	3%
Total farms	227 900	100%	161 700	100%	143 900	100%
Average farm size	**22.3**		**26.8**		**29.3**	

Source: CSO *Agricultural Labour Input Survey*.

Total land area in Ireland is 7.01 million ha, of which agriculture accounts for around 4.41 million ha and forestry, 6 000 ha (Figure 1). Apart from an increase in forest cover there has been little change in land usage in recent years. Over 90% of agricultural land area is used for pasture, hay, silage or rough grazing, with the remaining 10% under cereals and other crops.

Bioenergy production from agriculture

The Republic of Ireland has its own energy and bioenergy policies, which have been developed in isolation from the policies in Northern Ireland.

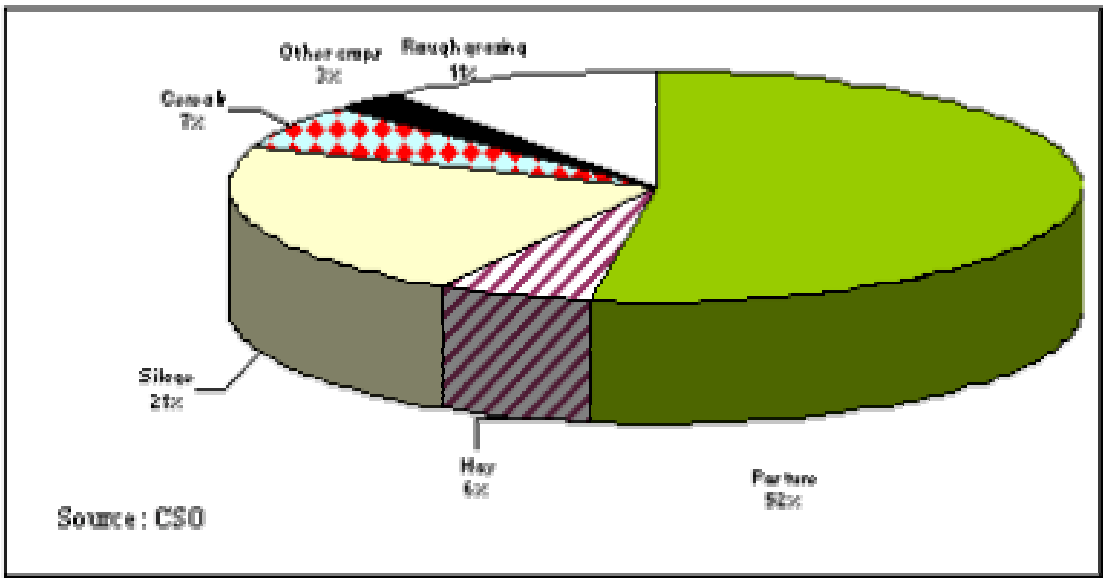
Northern Ireland has, to a large extent, imported UK policies and schemes but there are several specific schemes which do not apply in Northern Ireland, and the level of grant support, for some of the schemes, is different between England and Northern Ireland.

Renewable energy usually refers to sources such as wind, hydro, biomass, wave or solar. This paper refers specifically to bioenergy production, which includes the following:

- Short rotation crops (not commercial forestry);
- Organic wastes *e.g.* chicken litter or spent mushroom compost;
- Anaerobic digestion; and
- Biofuel.

Policy development within both the Republic of Ireland and Northern Ireland has been "broad-brush" with little focus on bioenergy from agriculture. It is therefore necessary first to review the policies in their entirety, and then to examine the impact that they have had upon bioenergy from agriculture.

Figure 1. Agricultural land use in Ireland, 1999



Source: www.agriculture.gov.ie/index.jsp?file=publicat/review2000/files/chapter10/chapter10-5.xml.

Policies

The development of energy policy

Northern Ireland

In 1996 the UK government published the National Biomass Energy Strategy, which set out its plans for encouraging the development of energy production from biomass to the year 2001. The strategy focused on identifying the research required to develop the commercial deployment of energy crops, and the development of conversion technologies that could improve the efficiency and competitiveness of biomass energy in the longer term. This strategy was developed by the Ministry of Agriculture Fisheries and Food (MAFF) in London, but was not implemented regionally within Northern Ireland.

In December 1997 the United Nations Framework Convention on Climate Change was signed, in Kyoto, by 171 countries, including the United Kingdom, of which Northern Ireland is a part. The EU has agreed to reduce greenhouse gas emissions by 8% by 2012, using 1990 as a baseline. Following

the publication of a Green Paper, the European Commission issued a White Paper in 1998 entitled "Energy for the Future – Renewable Sources of Energy" (EC, 1997). This proposed a doubling of renewable energy production from 6% to 12% of the EU's total primary energy need by 2010. Political agreement on the targets was reached at the Energy Council in December 2000, and these targets were subsequently included in EU Directive 2001/77/EC.

The UK launched a consultation paper in March 1999 entitled "New and Renewable Energy – Prospects for the 21st Century". This, together with measures proposed within the Royal Commission on Environment Pollution (2000) "Energy – The Changing Climate" led to the publication of an energy *White Paper* "Our Energy Future – Creating a Low Carbon Economy" which was published in February 2003.

Northern Ireland began reviewing its overall energy strategy in 1992 with the publication of a document entitled "Energy in the 90's and beyond". This document was concerned with energy efficiency, clean energy, lowering costs, diversification of supply, and security of supply. It acknowledged that renewable energy could help achieve the objectives of clean energy production, supply diversification, and security of supply.

The Department of Economic Development published a consultation document in 2000 entitled "Vision 2010 – Energy Action Plan". Again, the document highlighted the value of developing renewable energy, the opportunities that this would provide for new business and the fact that regional competitiveness and innovation would be stimulated. In October 2001 the Department of Enterprise Trade and Investment (DETI) published "Renewable Energy in Northern Ireland – Realising the Potential".

While specific targets for the production of renewable energy in Northern Ireland were not identified, it was recognised that Northern Ireland should contribute towards achieving the same results as the rest of the UK. The focus of government policy with regard to renewable energy was still on licensed electricity supplies and little consideration was given to heat energy or to other energy sources, which were beyond regulatory control.

At present the DETI has a further consultation paper in the public domain for which the consultation period ends on 30 June 2003. It is entitled "Towards a New Energy Strategy for Northern Ireland" (DETI, 2003). The consultation document identifies electricity costs (which are particularly high in Northern Ireland) as a major concern. However, it also recognises that "a comprehensive, coherent and credible energy strategy must address other issues including security and diversities of supply, progressive market liberalisation and competition, and – increasingly – concern for a sustainable environment". It remains to be seen how this balance can be achieved. It is useful to note that the DETI consultation document highlights that the Northern Ireland strategy cannot be developed in isolation from the wider UK, all-island and European markets.

Republic of Ireland

Energy policy (renewable energy included) became part of Irish economic policy in 1973-74, when the world was confronted with the first oil crisis. Energy saving was one of the main themes in 1974, in which the finiteness of sources of fossil fuel played an important role. After the second oil crisis in 1979-80, energy saving and diversification of energy sources for electricity production were the leading themes. In the period 1985-94, Irish government support for energy saving and renewable energy decreased, particularly because of low energy prices, diversification of fuel mix and suppliers and the discontinuation of subsidies.

After this period new policy publications were issued, such as "Renewable Energy – A Strategy for the Future", in 1996. Following publication in 1997 by the EC of *The White Paper & Action Plan for Renewable Energy – Energy for the Future: Renewable Sources of Energy* in 1997 (EC, 1997), the Irish government published its *Green Paper on Sustainable Energy* in 1999 (Department of Public Enterprise, 1999).

This Green Paper called for a significant increase in the contribution of renewable energy to meeting Ireland's energy needs and set targets for new renewable electricity-generating capacity, which would see a doubling of the contribution from renewable energy from 2% in 2000, to some 4% by 2005.

This 1999 Green Paper also reflected the government's concerns about the need for the balanced development of Ireland's large renewable resources as well as the need to reduce delays in their deployment. Further government recommendations followed in 2000, setting out an integrated approach to wind energy deployment in "A Strategy for Intensifying Wind Energy Deployment" (Department of Public Enterprise, 2000). Also in 2000, the Department of Environment issued the "National Climate Change Strategy" that called for the significant further expansion of renewable energy to make a meaningful Irish contribution to overall EU targets. The climate change strategy also indicated that a carbon/energy tax would be introduced to improve the competitiveness of renewable energy technologies.

Security of energy supply is now a major issue for Ireland. In 2000 Ireland imported 86% of its energy needs and this will increase to 94% by 2010 unless there is a major increase in the deployment of renewables (Figure 2 and Table 4). The Irish economy is currently over 50%-dependent on oil products, with only 3% coming from its own renewable resources. Adding to this existing over-reliance on energy imports and fossil fuels is the fact that Irish electricity demand is rising by 20% every 5 years. Renewable energy will have to play a major part in the energy supply system in future if this situation is to change. Not until recently have the Irish government and the Irish energy sector taken up renewable energy as an integral sustainable theme and challenge. Because of the ample availability of cheap natural gas and the relatively clean character of this fuel, the development of renewable energy in Ireland has been characterised by a very slow start.

Renewable-energy targets

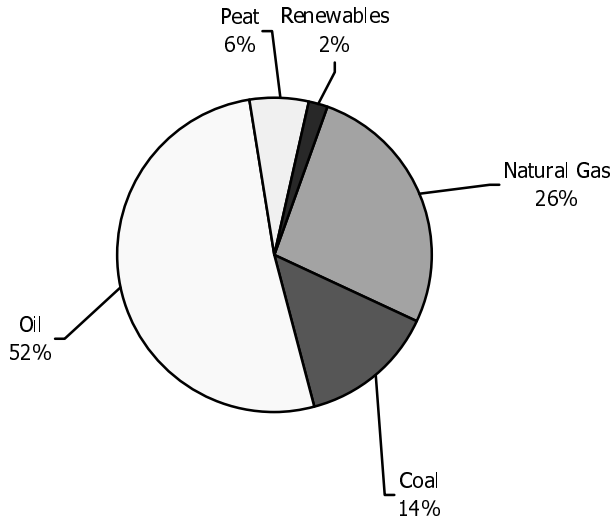
Northern Ireland

The UK and, in turn, Northern Ireland, supports the European policy of doubling renewable-energy consumption from 6-12% in the EU by 2010. Northern Ireland currently produces 3.1% of its total energy requirement from renewable sources, primarily wind.

A study commissioned in 2002 by Northern Electricity and DETI identified a number of potential sources of renewable energy that should be available for use by 2010 (Figure 3).

There are well-developed plans that could increase generating capacity for on-shore wind farms from 37 MW to 140 MW within the next three years. A further proposal for an off-shore wind farm with capacity of up to 250 MW is currently being considered. The focus of government attention is on electrical energy and, as wind technology is more developed than biomass or anaerobic digestion, the contribution that bioenergy from agriculture could make is largely unidentified within government projections. There are no reliable figures available at present for bioenergy production for heat in Northern Ireland and the only figures available for electrical generation come from an analysis of the commissioned Non Fossil Fuel Obligation Orders (NFFO) Schemes.

Figure 2. Ireland's energy supply situation in 2000



Source: Department of Public Enterprise, 2002.

Table 4. Energy balance in 2000

(ktoe*)

	Oil	Natural gas	Solid fossil fuels	Nuclear	Hydro**	Renewables	Electricity	TOTAL
Primary production	0	960	970	0	72	182	0	2 183
Net imports	7 827	2 483	1 964	0	0	0	7	12 281
Total energy supply	7 869	3 059	2 794	0	72	182	0	13 976
Of which electricity generation fuel	1 051	1 828	1 968	0	72	42		4 961
Gross inland consumption	6 713	1 203	707	0	0	140	1 726	10 613

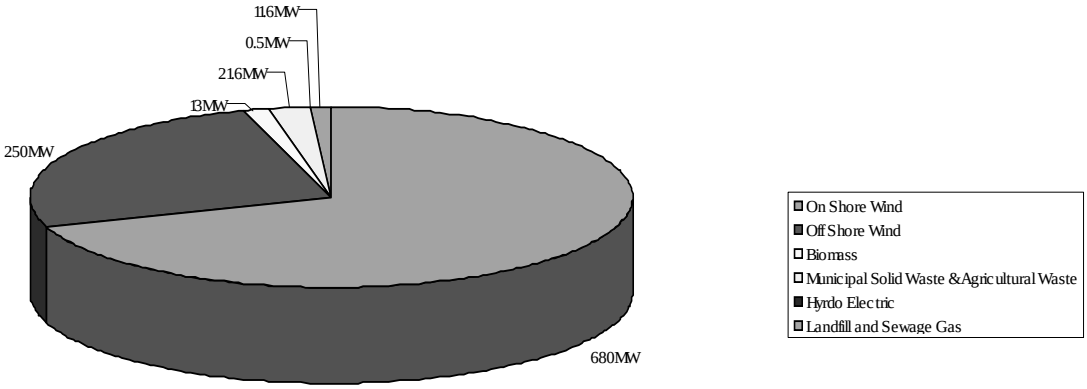
* Thousand tonnes of oil equivalent.
** Mixture of large hydro (62 ktoe) and small hydro (10 ktoe).

Source: Department of Public Enterprise Statistics, 2002:

NFFO Schemes supported the creation of electrical generating capacity from renewable sources in Northern Ireland. NFFO 1 should have delivered 14.8 MW of electrical capacity, most of it coming from wind, with approximately 1.4 MW from hydro. NFFO 2 should have produced 2.8 MW with a mixture of hydro, wind and biomass. However, only 0.3 MW of this came from biomass. It is difficult to be certain if all of the above schemes are continuing to generate at their declared capacity. There is also approximately 1.4 MW produced from non-grid-connected renewable-energy projects, including production from wind, hydro, solar and municipal waste. However, little of this generation comes from bioenergy from agriculture.

Figure 3. Potential generating capacity from renewable-energy sources in Northern Ireland by 2010

(Figures are in MW [megawatts] for grid supply only)



Source: Northern Electricity and DETI, 2002.

Republic of Ireland

Irish government policy supports the EU policy of doubling renewable-energy consumption from 6-12% by 2010. However, Irish usage of renewable energy – currently standing at just 2.8% – is well below the EU average of 7%. Irish targets to 2005 aim to increase this 2.8% contribution to 3.75% of consumption. Bioenergy, wind energy, hydro and heat pumps will provide the main sources of renewable energy (Figure 4).

Government efforts presently concentrate on the electricity market, with wind energy deployment a priority. Only 1.5% of Irish electricity came from wind energy in 2000, but government targets are to reach a minimum of 7% by 2005. Figure 5 shows government renewable-electricity targets and projections to 2010 (MW).

Specific policy measures relating to renewable energies

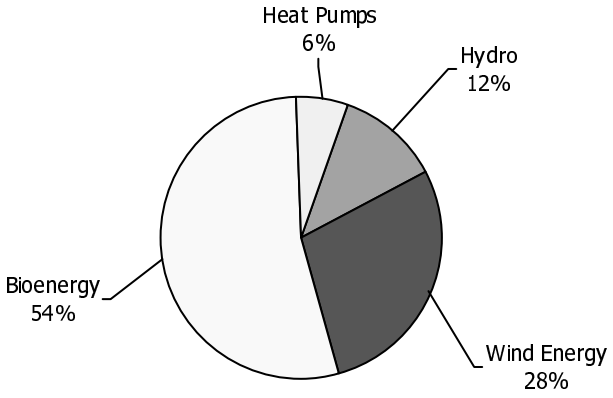
Northern Ireland

Northern Ireland relies heavily on renewable-energy policy initiatives generated by the DTI in London. Northern Ireland's key policies and programmes are therefore as follows:

- Bioenergy Capital Grant Scheme (launched in 2002), focusing on deployment of combined heat and power (CHP) from biomass and the demonstration of advanced power generation from energy crops;

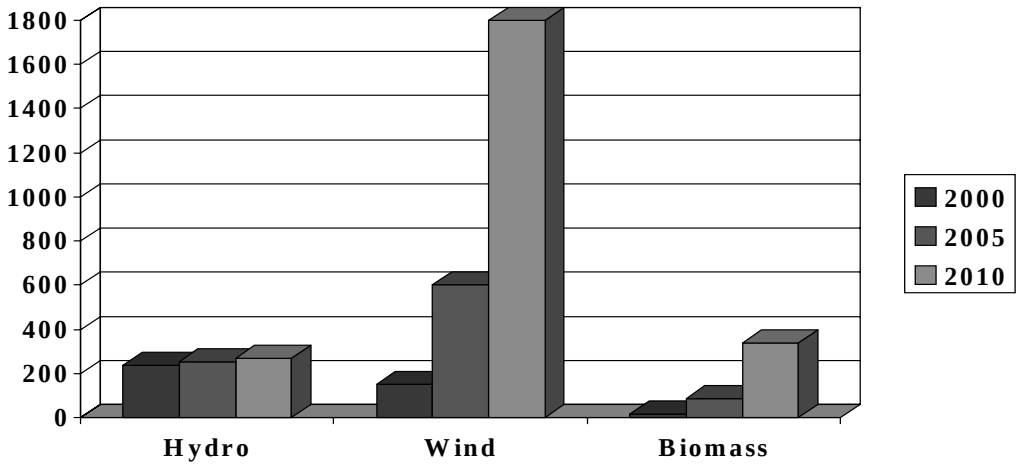
- Community and Household Capital Grants Scheme, focusing on renewable energy at household level;

Figure 4. Breakdown by technology of the Irish government 2005 renewable energy sources target of 3.75%



Source: Department of Public Enterprise, 2000.

Figure 5. 12% of Irish electricity from renewables by 2005, 30% possible by 2010



Source: Sustainable Energy Authority of Ireland (formerly the Irish Energy Centre), 2002.

- Bioenergy Infrastructure Scheme, focusing on supply chains to harvest, store and supply energy crops (as well as forestry wood fuels);

- Woodland Grant Scheme, focusing on establishing plantations of poplar and willow for energy production;

- Farm Woodland Premium Scheme, which encourages the creation of new woodlands on farms (short rotation coppice is not eligible under this scheme);

- Eco Energy Tariff (launched in 1988), promoting electrical generation from renewable sources;

- NFFO Schemes (see above, under "Renewable-energy targets");

- Support from Northern Ireland Electricity through "Transmission Credits", and the purchase of excess generation that small renewable generators may have.

- The Finance Bill 2000 – Climate Change Levy. The Climate Change Levy is a UK tax on supplies of electricity, gas and certain other commodities. Its aim is to encourage energy efficiency: some exemptions to the levy are available, including renewable biomass technologies, incorporating agricultural waste and energy crops.

- The Enhanced Capital Allowances (ECA) Scheme gives allowances on plant and machinery that meet energy-efficiency criteria (this includes biomass boilers).

- "Forestry in Northern Ireland" a Consultation Paper, was published by the Department of Agriculture and Rural Development in June 2002. It virtually ignored the opportunities for agri-forestry, and reflected the lack of interest expressed by the Department for the pro-active establishment of energy crops.

Republic of Ireland

The following is a summary of key objectives identified in the Green Paper and other government policy documents, programmes and acts.

The *Green Paper on Sustainable Energy* sets the following targets for renewable energy in Ireland:

- Increasing the percentage of Total Primary Energy Requirement (TPER) to be derived from renewable sources to 3.75% by 2005, from 2% in 2000;

- Increasing the percentage of electricity generated from renewable sources from 6.3% in 2000, to 12.39% by 2005. This includes an extra installed capacity of 500 MW of electricity generated from renewable sources by 2005.

- The "National Climate Change Strategy" outlines the strategy to meet Ireland's commitment to limit greenhouse gas emissions to a 13% increase over 1990 levels by 2008-12. Some of the key points relating to renewable energy in the strategy include the reduction of annual CO_2 emissions by 1 million tonnes by 2010 through increased deployment of renewable energy:

  - review of the rate and structure of energy taxes;
  - fuel switching from coal to renewable energy.

- The "National Development Plan" allocates a total investment of EUR 67 million for renewable energy in the period 2000-06. The main items are:
  - Re-enforcement and up-grading of the electricity grid to accommodate increased use of renewable energy;
  - Providing support for the delivery of additional renewable-energy supply (including this programme);
  - Encouraging new entrants to the renewable-energy market by support for small-scale projects.
- The "Electricity Act 1999" contains the following measures:
  - Full deregulation of the market for electricity generated using renewable forms of energy as its primary source;
  - Priority dispatch of electricity generated from renewable-energy sources;
  - Establishment of the Commission for Energy Regulation (CER) with a duty to encourage research and development (R&D) into methods of generating electricity using renewable, sustainable and alternative forms of energy.

The Kyoto Protocol indirectly contains Ireland's commitment to limit greenhouse gas emissions to a 13% increase over 1990 levels by 2008-12 and which calls for R&D in the areas of renewable energy. Furthermore, the EC Directive 2001/77/EC (EC, 2001) on the promotion of electricity produced from renewable-energy sources converts a component of the Kyoto target into a requirement for Ireland to generate a minimum of 13.2% of its electricity from renewable-energy sources by 2010.

One of Ireland's energy objectives is to produce as much of national energy requirements from indigenous sources as is economically possible. The government sees development of renewable sources of energy as an appropriate strategy to meet this objective, as well as providing opportunities for rural development. Environmental considerations, specifically CO_2-free electricity production, are also becoming increasingly important.

Important instruments for the development of renewable-energy technologies in Ireland are supporting capital funds from the EU. EU policy and support towards renewables has had a strong influence on Irish policy and Ireland has been successful with a number of projects under the JOULE, THERMIE and ALTENER Programmes. Successful EU projects continue to have guaranteed electricity market access.

A number of national support measures for renewable-energy projects has now been set up, including:

Direct promotion measures:

- The Alternative Energy Requirement – AER (Electricity Market) (Public Service Obligation, Guaranteed Market using Tender Approach);

- Third Party Access – (Regulated Electricity Market). From February 2000, all electricity customers have been able to purchase electricity produced using a renewable or alternative form of energy (Art. 27, Electricity Regulation Bill 1998).

Indirect promotion measures:

- Electricity Grid Access Support. A rolling investment budget of EUR 50 million to support clustered renewable electricity projects has been agreed for the period 2001-06. The budget will support the grid connection of groups of renewable-electricity projects in a strategic manner.

- The Renewable Energy Research & Demonstration Programme 2002-06. Following the publication of the government's policy on renewable energy in 1999, EUR 16 million has been made available to provide for renewable-energy R&D.

- Corporate tax relief for equity investment;

- The 1998 Finance Act provided a tax incentive for companies wishing to invest in renewable-energy projects. Company profits invested in wind, hydro, biomass and solar projects are not subjected to tax under certain restrictions. This measure is currently in force until 2004.

Impact of policies

It is evident that the generation of energy from agricultural sources has been vastly over-shadowed by the generation of electrical energy from wind sources within Ireland, both Northern and Southern. The renewable-energy policies mentioned previously have stimulated a remarkable growth in wind energy, but have had little effect on energy production from agricultural sources.

Ireland has the capability to produce energy from short rotation forestry, wood wastes, sugar crops, starch crops, herbaceous lignocellulosic crops, oil crops and agricultural wastes (Table 5). It has the potential to produce a theoretical maximum of 900 MW per annum from agricultural sources, but at present this figure is only approximately 5 MW (a figure of 100 MW is probably a more realistic figure in the next 10 years). The EU hopes to produce 6% of its total energy requirement from biomass by 2010 and 10% of its total energy requirement by 2015. Ireland currently produces approximately 0.18% of its total energy requirement from agricultural sources, and it is difficult to see how this figure can rise significantly without a focused strategy, with direct mechanisms of delivery.

Table 5. Agricultural wastes for potential use as energy

	Northern Ireland	Republic of Ireland
Spent mushroom compost	353 000 tonnes	66 514 tonnes
Chicken litter	180 000 tonnes	115 000 tonnes
Short rotation willow coppice	45 ha	30 ha

Source: Author.

The way forward

To date, Northern Ireland and the Republic of Ireland have developed separate policies for the encouragement of renewable-energy generation. There has been some co-operation on the harmonisation of legislation affecting electricity generation and supply, and an electrical inter-connector has been set up. The inter-connector is capable of operating two circuits with a theoretical capacity of 1 500 MW; however, this usually operates at around 900 MW, for security reasons. Again, the focus of policy co-operation has been on electrical generation and transmission. There has been virtually no co-operation on policy initiatives between Northern Ireland and the Republic of Ireland on biomass or bioenergy from agriculture, despite the fact that the agricultural conditions are broadly similar. There has also been a distinct lack of co-ordination between the relevant government departments within each jurisdiction. Sustainable Energy Ireland, which was originally the Irish Energy Centre, has been largely successful in promoting the environmentally and economically sustainable production of energy in the Republic of Ireland. Unfortunately a similar organisation does not exist in Northern Ireland. Sustainable development and the establishment of a secure energy infrastructure cuts across the Departments of Finance, Regional Development (NI), Agriculture, Energy and Environment within both countries. However, there is no long-term focused strategy in either country to develop bioenergy from agriculture.

Bioenergy from agriculture can, and should, play a significant part in the development of renewable-energy production in Ireland, both North and South. This can only be brought about using all of the following:

- Legislation to ensure compliance and create a regulatory framework that recognises the value of bioenergy as a sustainable contributor;

- Financial inducement to encourage the establishment of a market infrastructure that will support the development of a bioenergy from agriculture;

- Increase in public awareness that highlights the opportunities that exist to use waste agricultural products as an energy source, and the socio-economic benefits that can be derived from generating energy from crops such as short rotation willow.

Specifically, it is recommended that the following basic requirements for strategies are required, regardless of which strategy is chosen (Figure 6), including setting targets and actions for these strategies (Figure 7).

Figure 6. Basic requirements for agricultural bioenergy strategies in Ireland

No.	Basic requirements for strategies
1	Pro-active education and communication of the delivery mechanism to the target audience is important
2	Stress the environmental creditability of the policy both as a waste management exercise and as an energy generating activity.
3	Plan long-term. Predictability and continuity of policy is particularly important, (a) because of the relatively long time required to produce energy crops and (b) to ensure that the initial capital investment is protected by a mid-term commitment.
4	The policy should ensure that the eventual outcome secures a sustainable position, either for waste management or for income generation from energy crops.
5	With respect to financial incentives they should show a decreasing characteristic over time *i.e.* pump priming may be required at an early stage but this should reduce to an economically viable position over time.
6	Recognise the maturity of the market in Ireland and benefit from international experience from more advanced and developed markets.
7	Dissipate the current focus on electricity markets that currently predominate the energy sector.

Summary

Northern Ireland and the Republic of Ireland do not have a co-ordinated strategy for the development of bioenergy from agriculture. The focus of energy production within both countries over the last ten years has revolved around the electricity market, including liberalisation and regulation. As the heat market is not regulated, its contribution has been largely ignored.

The drive for renewable energy on the island of Ireland has centred on electrical energy from wind. Ireland has a tremendous potential to produce relatively inexpensive electrical energy from wind. To date, this has been achieved with on-shore wind farms and several schemes are developing both North and South to produce substantial energy from off-shore wind locations. It is generally accepted that, at present, wind can only contribute up to approximately 15% of total electrical production to the grid before the security of the grid is jeopardised by intermittency of supply. Above 15% the "spinning reserve" becomes expensive to maintain and there are practicalities associated with ensuring security of supply in the short term.

Bioenergy from agriculture has the potential to deliver considerable benefits. These include security of supply, diversity of supply from a range of sources including short rotation crops, chicken litter, spent mushroom compost and anaerobic digesters, etc. It can also have the added benefit of using a waste stream to produce energy.

The creation of bioenergy from agriculture necessarily involves the co-ordination of different government departments, primarily those involved in agriculture, waste management and energy production. To date, there has been no "joined up" or long-term strategy to exploit this market. Bioenergy from agriculture is generally considered to be a component part of "renewable energy", but little support is given to provide holistic solutions, which can solve environmental problems, create employment opportunities and provide energy at the same time.

Figure 7. Targets and actions for an Irish agricultural bioenergy strategy

No.	Target	Action	Action by
1	Co-ordinate strategy between government departments in Northern Ireland	Set up cross-departmental group with policy focus in Northern Ireland	DARD, DETI, DRD, DFP
2	Co-ordinate strategy between government departments in the Republic of Ireland	Set up cross-departmental group with policy focus in the Republic of Ireland	DAF, DCMNR, DCRGA, DELG, DF, DETE
3	Co-ordinate bioenergy from agriculture policy between NI and ROI	Establishment of a cross-border strategy group to co-ordinate	Ministers
4	Develop vision for bioenergy from agriculture across Ireland	Develop long-term plan *i.e.* 10/15 years with reviews at 3- or 5-year intervals	Cross-border strategy group
5	To identify realistic targets for bioenergy production from agriculture	Set specific targets, monitor and review	Cross-border strategy group
6	Identify the most appropriate delivery mechanisms to assist bioenergy production from agriculture	Quantify sectoral contribution from biomass, AD, agricultural wastes etc.	Cross border strategy group
		Assess extent of market development/technology for each bioenergy source	
		Set target dates for production	
7	Make bioenergy from agriculture financially sustainable	Educate financial institutions and incorporate them in delivery mechanisms	Cross-border strategy group, green banks, financial institutions
		Develop appropriate government support mechanisms	
		Identify "critical mass" that is required to achieve sustainability for each market/technology.	
8	Ensure market structures are robust for bioenergy production from agriculture	Enact legislation compatible with appropriate market development	Cross-border strategy group, bioenergy industry
		Reduce barriers to market entry	
		Encourage appropriate technologies	
9	Provide range of proven production and conversion technologies	Assess/encourage most promising technologies	Cross-border strategy group, research institutes, educational establishments, industry
		Allocate resources to R&D	
		Draw up codes of best practice, controlled by legislation, encouraged by financial support	

Northern Ireland and the Republic of Ireland have co-ordinated the liberalisation of the electricity market and have constructed an inter-connector. They have not co-ordinated on the development of a market infrastructure that would support a biomass industry or an industry reliant on bioenergy from agriculture. Both Northern Ireland and the Republic of Ireland are relatively small in EU terms and their geographical location, at a distance from other European markets, but sharing a land boundary, would indicate that a co-ordinated strategy to develop the bioenergy market would be advantageous.

Northern Ireland has suffered recently because strategy implementation has been impeded by the uncertainty surrounding political governance. Having said this, the author is still of the opinion that there is a distinct lack of long-term framework delivery within Northern Ireland which will eventually result in an under-delivery on renewable-energy production and a continued reliance on imported fossil fuels.

The Republic of Ireland has been more pro-active in its long-term policymaking, but has already fallen short of its own targets for delivery, particularly on its commitment to reduce greenhouse gas emissions. By 1999 the EU, as a whole, had reduced its greenhouse gas emissions by 4%, on 1990 levels. In the same period, Ireland's greenhouse gas emissions were up by 22%. This tendency to fail on delivery is also apparent throughout the National Development Plan and, with recent cutbacks in government spending, it is doubtful whether the Republic will achieve any of its ambitious targets relating to renewable-energy generation, or to environmental improvement.

Ireland has a tremendous opportunity to use agricultural waste to generate energy, and to develop a sustainable biomass industry based on short rotation coppice. The growing conditions within in Ireland are generally ideal for short rotation coppice, while the agricultural wastes, which are increasingly creating a waste management problem, could be employed to generate heat and power.

BIBLIOGRAPHY

Northern Ireland

Cabinet Office PIU *Energy Review* (February 2003): www.cabinet -office.gov.uk/innovation.

Central Statistical Office:
www.agriculture.gov.ie.index.jsp?file=publicat/review2000/files/chapter10/chapter10-5.xml.

DETI [Department of Enterprise Trade and Investment] (2003), *Towards a New Energy Strategy for Northern Ireland:* www.nics.gov.uk/deti/energy.

DETI (2002), *Towards a New Energy Market Strategy for Northern Ireland*, March: www.nics.gov.uk/deti/energy.

DETI (2001), *Renewable Energy in Northern Ireland – Realising the Potential*, October: www.detini.gov.uk/energy.

IPA Energy Consulting, P.B. Power Limited, Energy Links Consultancy (2001), *Final Report on North-South Energy Studies*, August: www.detini.gov.uk/energy.

Irish Almanac and *Yearbook of Facts 2000* (1999), DND Publications, Local Ireland, Northern Ireland.

Republic of Ireland

Department of Public Enterprise (2000), *A Strategy for Intensifying Wind Energy Development*.

Department of Public Enterprise (2000), *Energy Balance 2000*: www.dpe.ie.

Department of Public Enterprise (2001), *Alternative Energy Requirement* V 2001: www.dpe.ie.

Department of Public Enterprise (1999), *Green Paper on Sustainable Energy 1999*. ISBN 0707 66263X: www.dpe.ie.

EC [European Commission] (2001), *European directive on the promotion of electricity produced from renewable energy sources in the internal electricity market* (Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001): www.agores.org.

EC (1997), *Energy for the Future: Renewable Sources of Energy, White Paper for a Community Strategy and Action Plan* (COM(97),599 FINAL), Brussels, Belgium.

EC (1997), *The ATLAS Project:* http://europa.eu.int/comm/energy_transport/atlas/.

IEA [International Energy Agency] (1999), *Energy Policies of IEA Countries*, Ireland 1999 Review. ISBN 92 64 17103-7: www.iea.org.

Irish Energy Centre (2001), *Renewable Energy Research Development & Demonstration Programme*, Consultation Document 2001: www.irish-energy.ie.

Irish Energy Centre – Renewable Energy Information Office (2001), *Renewable Energy Overview Factsheet 2001*: www.irish-energy.ie/reio.

National Development Plan 2000-2006: www.ndp.ie.

Sustainable Energy Authority of Ireland (formerly the Irish Energy Centre) (2002), "The Energy Show 2002".

URL sources:

Irish Energy Centre: www.irish-energy.ie/.

CER [Commission for Energy Regulation]: www.cer.ie.

Department of Public Enterprise Statistics: www.irlgov.ie/tec/.

Department of Finance: www.irlgov.ie/finance/publications/tsg01/tsg01index.htm.

Department of Agriculture and Rural Development (Northern Ireland): www.dardni.gov.uk.

Department of Enterprise Trade and Investment (Northern Ireland): www.detini.gov.uk.

Department for Regional Development (Northern Ireland): www.drdni.gov.uk.

Assemblies Enterprise, Trade and Investment Committee (Northern Ireland): www.ni-assembly.gov.uk/enterprise/enterprisehome.htm.

NI Statistics Research Agency: www.nisra.gov.uk.

International Energy Agency Statistics: www.iea.org/stats/files/renewables.htm.

Publications:

"Energy for the Future – Renewable Sources of Energy": http://europa.eu.int/comm/energy/library/599fi_en.pdf.

"New and Renewable Energy – Prospects for the 21st Century": www.dti.gov.uk/renew/condoc/.

"Energy – the Changing Climate: www.recep.org.uk/pdf/title.pdf.

"Our Energy Future – Creating a Low-carbon Economy": www.dti.gov.uk/energy/whitepaper/ourenergyfuture.pdf.

"Energy in the 90's and Beyond": www.edfni.com/strategy2010/WGReports/energy.pdf.

"Vision 2010 – Energy Action Plan": www.vision2010.org/downloads/Vision%202010%20Report%20-20Implementation%20Action%20Plant.pdf.

"Renewable Energy in Northern Ireland – Realising the Potential": www.detini.gov.uk/cgi-bin/moreutil?utilid=242.

"Towards a New Energy Strategy for Northern Ireland": www.rtpi.org.uk/resources/policy-statements/2003/jun/ol20030646.pdf.

"National Climate Change Strategy": www.environ.ie/DOE/doeipub.nsf/0.fecdecefd52bc7bc80256b7005db5ee/$FILE/pccexsuminside%5B1%5D.pdf.

"Forestry in Northern Ireland": www.forestserviciceni.gov.uk/consultations/policy/consult/pdf.

Electricity Act 1999 (Republic of Ireland): www.dcmnr.gov.ie/files/SI%20632%20signed%20by%20Minister%20-%2021%20Nov%202003.doc.

1998 Finance Act (Republic of Ireland): www.finance.gov.ie/viewdoc.asp?fn=/documents/Publications/legi/indexfinanceact.htm.

FAVOURABLE POLICY CONDITIONS TO THE DEVELOPMENT OF BIOGAS PRODUCTION AS A SUSTAINABLE FORM OF ENERGY IN LUXEMBOURG

Gérard Conter[1]

Abstract

In addition to their traditional agricultural business, farmers are developing other activities today. Biogas production presents one possibility for the farmer to diversify his activities in the range of sustainable energy production and to create an additional source of income on the farm. In Luxembourg, biogas production became established only a few years ago but, due to favourable policy conditions, it has been developing very rapidly in recent years. Apart from a number of small on-farm plants, some co-operative projects have been planned and realised. A first and interesting co-operative project, which is also part of an EU promotion project, is described below, with special focus on economic aspects, financing and subsidies in regard to given policy conditions.

General information

Reasons for developing biogas

In many European Union (EU) countries, biogas technology is developing very quickly at the moment. Various reasons are the cause of this development:

- There are many environmental advantages that, today, are of increasing relevance: indeed, thinking in nutrient cycles is rather new; moreover, the biogas procedure is CO_2 neutral. In contrast to the result of burning fossil energy sources, the greenhouse effect is not intensified.

- The anaerobic liquid manure treatment in a biogas plant is a practicable possibility to minimise the emissions of methane and ammonia during the storage and spreading of liquid manure.

- Advanced technologies are at the basis of cheaper and more operator-safe plants that permit improved economic exploitation than was the case some years ago.

- High-quality consultation and planning are available.

- Increased financial aids are offered, in Luxembourg.

1. Ministry of Agriculture, Luxembourg.

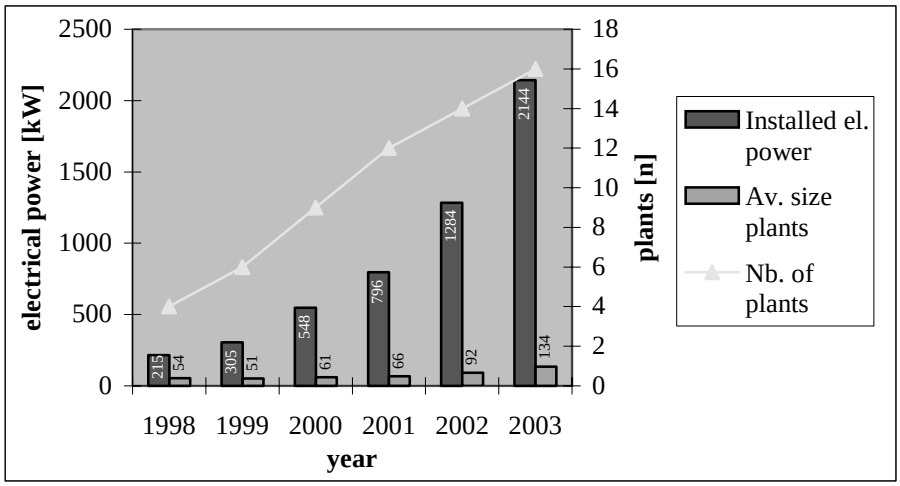
- Favourable remuneration exists for electricity from renewable energies.
- The new plants permit co-fermentation of organic wastes. Thus, nutrient cycles are additionally closed, and the profitability of the plant improves.
- Agronomic advantages are created by the higher value and easier manipulation of the fermented liquid manure.

Biogas in Luxembourg

Recent developments

As a consequence of a specialised seminar organised by the young farmers' organisation, *Jongbaueren a Jongwënzer*, in co-operation with the donation of *Oeko-fonds* on the topic "Biogas in Luxembourg: Decentralised Energy Source as a Chance for Agriculture", the first four plants were planned in 1997 and constructed in the subsequent year. Since this pioneering work, biogas has continued to develop rapidly (Figure 1). At the moment all plants in Luxembourg are run by farmers.

Figure 1. Fast development of biogas technology in Luxembourg

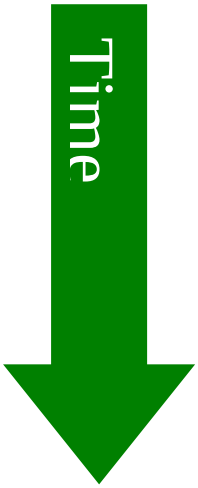


Source: Personal communication by ASTA (Administration des services techniques de l'agriculture); LEE (s.à.r.l. Landwirtschaft-Energie-Emwelt).

Suitable economic results by favourable policy conditions

Favourable policy conditions

Taking into account all the ecological advantages, biogas should have great development perspectives. Without suitable economic results, however, development of biogas technology will not be possible. This is why the government has made considerable efforts in recent years to assure the economic viability of biogas production in Luxembourg.



- 1998: Establishment of the first 4 biogas plants in Luxembourg (Figure 2):

  ⇨ Investment grants: 45% subsidies on total investment (excluding VAT) by the Ministry of Agriculture + EUR 15 127 (= 25% of maximum EUR 37 184) by the Ministry of Energy.

  ⇨ Market price of electricity: EUR 0 07585/kWh (kilowatt-hour).

- 2001: The law concerning the support of rural development (24 July 2001) assigns investment grants of 40-50% (for less-favoured areas) of total investment costs (excluding VAT) to farmers (these subsidies are limited to farm buildings and total investment costs of EUR 375 000 per farm for a period of six years [2001-07]). For biogas plants, additional subsidies of 60% on total investment costs of EUR 150 000 (excluding VAT) are offered.

  In order to promote renewable energies, a special programme created by the Ministry of Environment *(Marktanreizprogramm zur Förderung erneuerbarer Energien des Umweltministeriums)* guarantees an ecological support premium of EUR 0.025/kWh for electricity produced in biogas plants with an electrical capacity between 1 and 3 000 kW (kilowatts).

Economic results

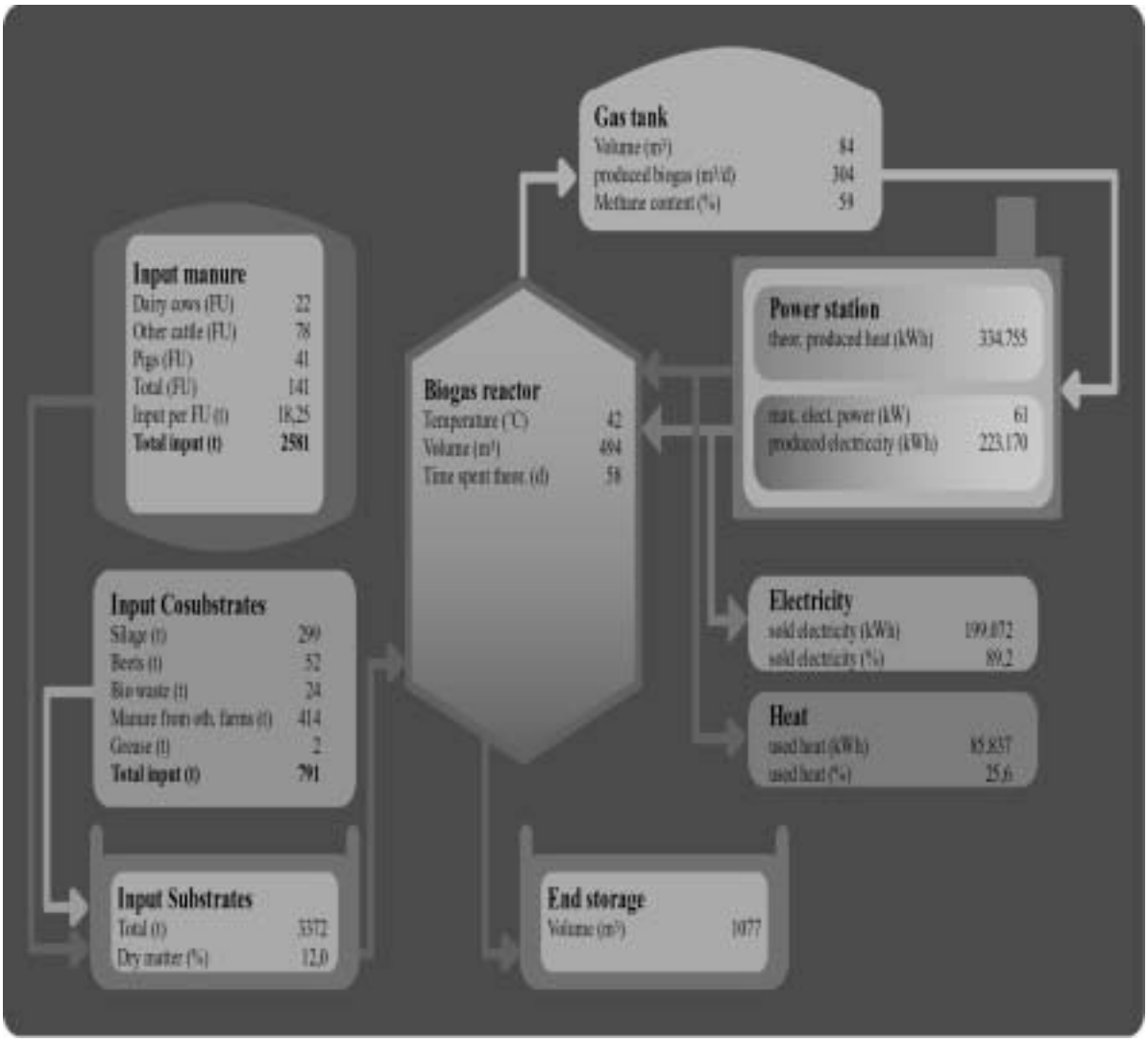
An economic study (Conter, 2001) based on the economic results of the first plants installed in the years 1998-2000 proves that the subsidies offered were justified and necessary in order to assure the sufficient profitability of biogas production in respect to the prevailing economic conditions.

The core of each economic study consists of a comparison of costs and receipts of a given system. The receipts of a biogas plant consist of different components. As the goal of the gasification is electricity production, this is the most important component from an economic view.

Biogas is a water-saturated gas mixture containing about 50-70% methane, 30-40% CO_2 and small quantities of hydrogen sulphide and ammonia. The energy content of biogas is dependent on the content of methane and varies between 4 and 7.5 kWh/m^3. As a consequence, profitable running of the plant depends very much on gas quantity and quality.

Modern plants convert up to 40% of the gas energy into electricity. More than half of the energy contained in the gas is released as heat. Some of the generated heat is used in the fermenter, but the rest is available for other purposes and thus represents further possible receipts from the gasification process. In Luxembourg only about 25% of the produced heat is used, consequently substantial reserves are available. In order to increase the profitability of the plant, the biogas farmer has to try to use these reserves. In connection with a central heating system, this is usually possible on the farm without incurring significant additional costs. As the plants tend to become larger and larger, heat sales by long-distance heating nets are another possibility. Other sources of income, although of less importance, consist of disposal receipts as well as the increased fertilising value (+EUR 10 per FU [fertilising unit]) of the treated manure.

Figure 2. Technical data of the first biogas plants in Luxembourg (1998-2000)



Source: Conter, 2001.

Expenditure on a biogas plant is composed of capital costs (depreciation, interest, etc.) and running costs (maintenance, ignition oil, etc.) (Table 1). The capital costs are in direct relation to the value of the plant and they are subject to substantial differences: for plants of the same size there can be a price difference of up to 100%, which consequently has a noticeable impact on the profitability of the system. The running costs are primordially related to the gas quality (=> consumption of ignition oil) and the percentage of co-fermented material (higher wear => maintenance costs).

The profit realised by the system equals the remuneration for invested work and owner capital. According to the indications of the concerned farmers the necessary work input varies considerably. It depends on the chosen procedure: fresh liquid manure put directly into the fermenter from the stable requires little work and provides suitable gas yields. Co-substrates may increase the gas yield substantially, but they are always a source of additional work and specialised knowledge. Biogas plants are in a certain way windowless stables with millions of small animals that have to be fed, observed and cared for on a daily basis. Similarly to a stable it has to be run methodically. Constant feeding (filling) of the fermenter is vital for the production of large, high-quality gas yields.

Table 1. Economic results of the first biogas-plants in Luxembourg (1998-2000)

Receipts	
sold electricity [kWh]	152.543
price [EUR/kWh]	0,102
internal used elec. [EUR]	1.939,10
electricity receipts (total) [EUR]	17.556,48
heat receipts [EUR]	2.083,77
disposal receipts [EUR]	398,68
add. fertiliser value [EUR]	991,57
entire solves [EUR]	21.030,50
Investment costs	
Total costs [EUR]	159.222,82
Financing	
own capital funds [EUR]	29.561,29
own work [EUR]	12.784,01
investment subsidies [EUR]	83.072,78
external funds [EUR]	33.804,75
interests [EUR]	1.864,60
Running costs	
ignition oil [EUR]	2.289,88
maintenance [EUR]	1.097,99
insurance [EUR]	353,59
co-substrates [EUR]	1.991,24
Total costs [EUR]	5.732,70
SURPLUS OF MONEY (EUR)	**14.034,32**
depreciation [EUR]	11.150,13
Profits [EUR]	**2884,19**

Source: Conter, 2001.

- ⇨ Average figures of 6 biogas plants
- ⇨ For a better comparability all values have been converted to an average plant size of 100 FU

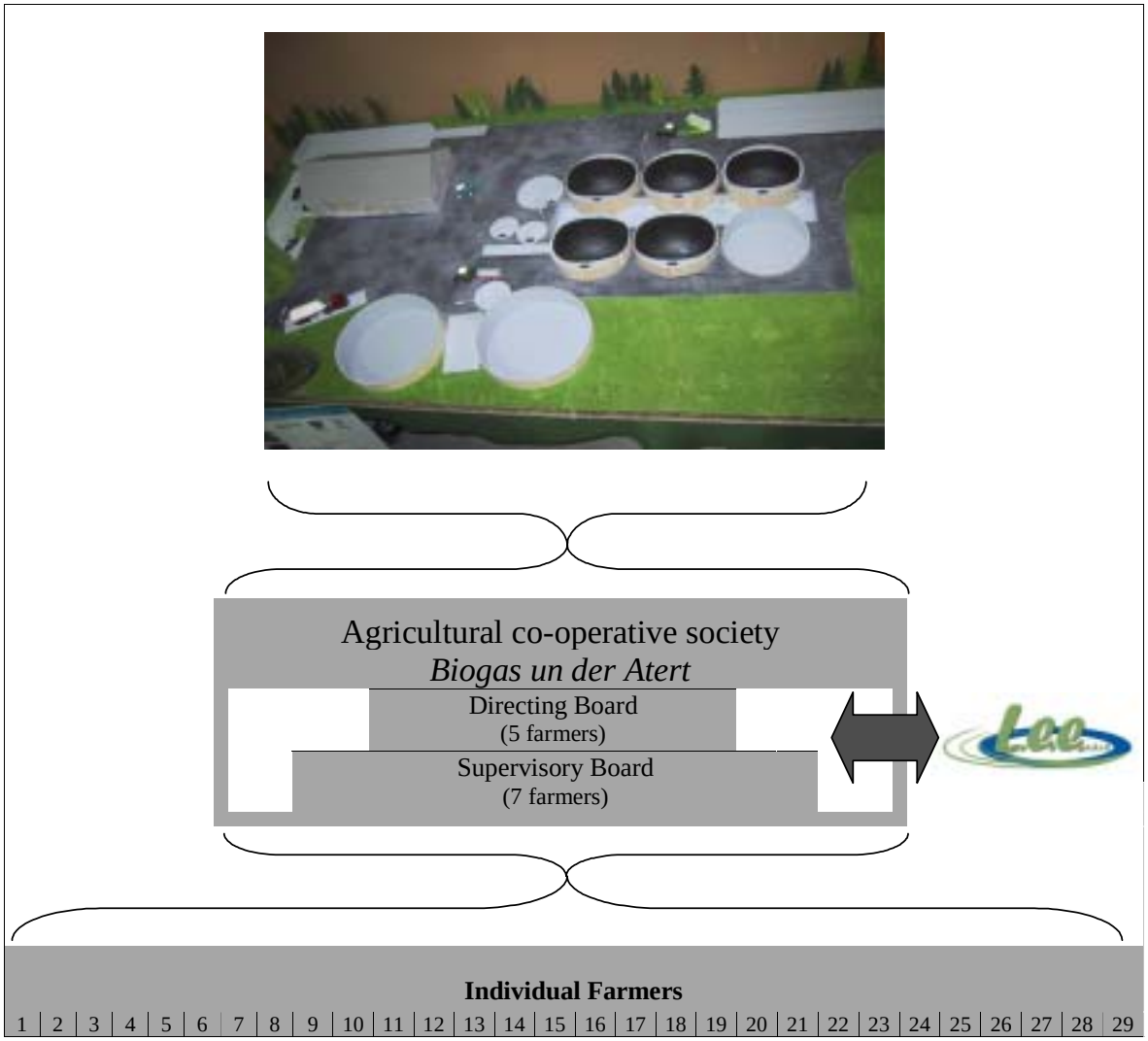
Suitable conditions on the farm (available working time, ...) in combination with the necessary know-how are a good basis for decentralised biogas production on the individual farm. With regard to the given energy prices, biogas production in Luxembourg would not, however, be profitable today in the absence of the public aid described above.

The co-operative project: *"Biogas un der Atert"*

Introduction

A large biogas plant has been constructed in Rédange. The goal of the project is to utilise as efficiently as possible the energy generated from manure (and other organic wastes) from farms in and around Rédange. The electricity produced is sold to the local electricity distributor, and the generated heat is distributed by a local heat supply grid to various consumers (such as public swimming pools or schools). The project is under the responsibility of the agricultural co-operative society, *Biogas un der Atert*, which consists of 29 farmers from Rédange and its neighbouring villages (Figure 3).

Figure 3. Organisation of the co-operative *Biogas un der Atert*



Source: Personal communication, LEE.

The project is managed independently by the co-operative, and receives support in planning, permission procedures, construction and supervision from LEE, an advisory consultancy firm specialising in biogas concerns.

The EU's LSDN promotion project

The biogas plant at Rédange is part of an EU project, the Local Sustainable Development Network (LSDN), which is part of the RECITE II Programme, promoting AGENDA 21.

LSDN is regrouping project partners in four countries (Germany, Spain, Austria and Luxembourg) and 25 associated partners in approximately 200 single projects, in order to create a network for sustainable development on a local basis. Each partner region has to realise an innovative project focussed on the energetic use of biomass and will participate in an exchange of experiences between European regions and municipalities by means of conferences, seminars, internet-chats, tele-teaching and youth exchanges, which will have the effect of widely disseminating specific expertise, and also contributing towards the protection of the environment. The creation of around 50 jobs under the EU project is another positive consequence. The national biogas project is generating four local job opportunities.

Processed biomass

Liquid and solid manure

As the main source of biomass, organic fertiliser from all 29 participating farmers is utilised, as shown below:

- Liquid and solid manure, equal to 3 500 FU, consisting of:
    - ⇨ 27 600 m^3 liquid manure
    - ⇨ 14 500 tonnes of solid manure.

As most of the farmers specialise in milk production, the volume of biomass available varies considerably throughout the year. As it is not possible to store the manure without losing efficiency, other forms of biomass have to be provided in order to run the plant at full capacity during the summer months.

Energy plants

The biogas plant must be supplemented with approximately 15.5 tonnes per day of organic dry matter if it is to run at maximum efficiency throughout the summer. Energy plants can offer a solution to this problem. With regard to sustainable production, energy plants have to be carefully selected. For example, maize provides high energy yields but entails a range of environmental problems (erosion, soil protection, etc.), whereas grassland assures all-season soil cover and normally never requires chemical treatments. In terms of sustainability and especially water protection (the described plant is situated in a water protection zone), grassland or other extensive crops are to be preferred.

The cultivation of energy plants on set-aside land is approved by European legislation. Farmers can grow energy crops on their farms on an individual basis. The local co-operative remunerates its members for the biomass produced, per tonne of dry matter.

Organic wastes

The fermentation of organic wastes and the related disposal receipts may increase the profitability of the biogas plant. Moreover, from an ecological point of view, the integration of biogas production into the process of waste management assures an optimum ecological balance, and this is the reason for the collaboration between the co-operative and the responsible local waste syndicate. According to the syndicate, about 4 000 tonnes of organic waste are collected annually in the immediate surroundings of the biogas plant which could, theoretically, be fermented.

The co-operative has to assure perfect operation systems on the plant – and energy efficiency is important. The integration of agriculture into waste management thus has multiple advantages: it ensures not only maximum biological efficiency but also safeguards process security via input control, as the output products are used on land belonging to the farmers taking part in the scheme.

Transport optimisation

Most co-operative biogas projects fail due to the lack of an efficient transport system, but an important issue in the Rédange project from the outset was to achieve the highest possible energy yields and to minimise transport costs.

Minimisation of transport costs

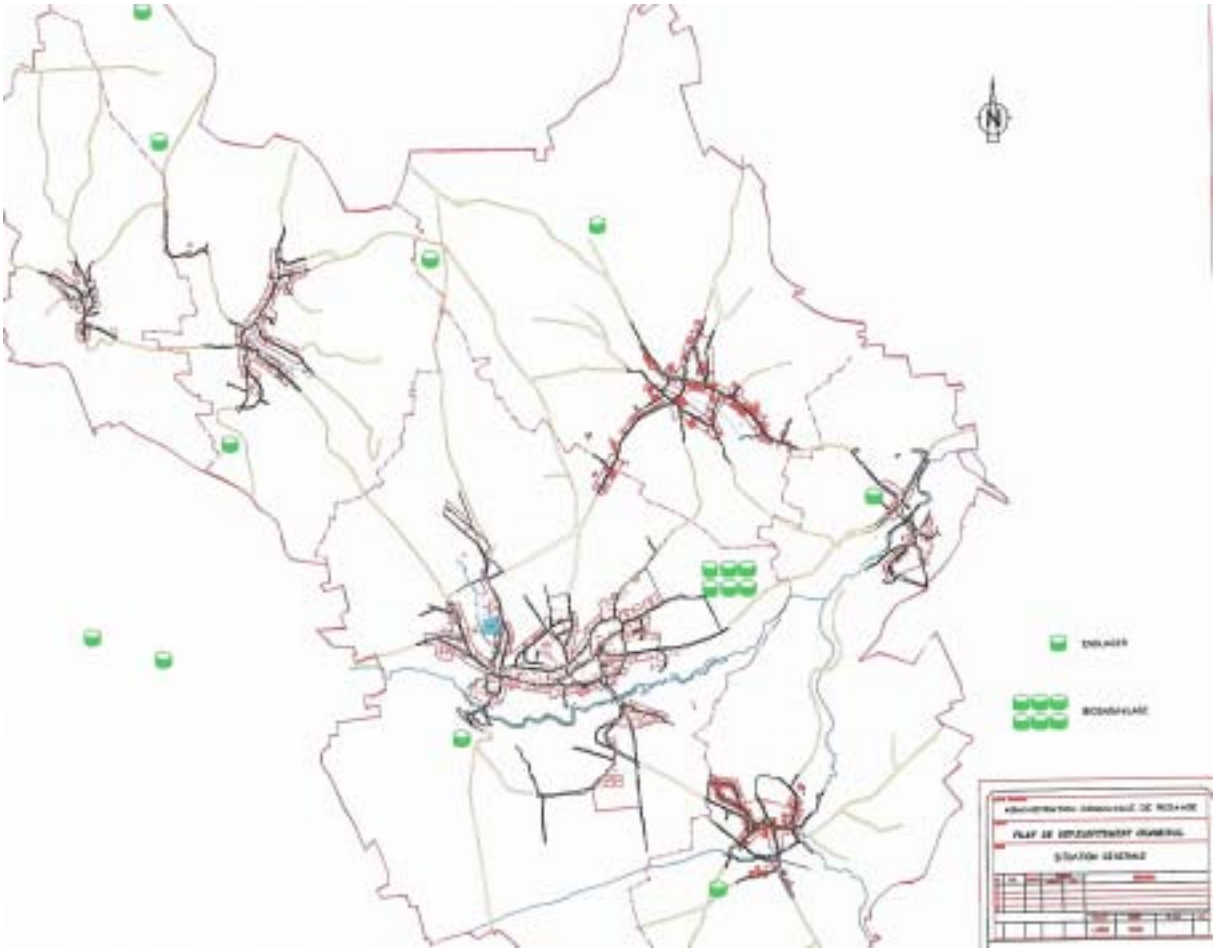
The co-operative's transport pool consists of a truck equipped for the transport of liquid manure and tractor equipped with a slurry tanker and trailer.

- The transport of the liquid manure from the storage tanks to the plant and back is effected with the truck or the tractor.
- Solid manure may be transported to the plant by the co-operative, or the farmer may transport it independently. In the latter case, remuneration is made. Prior to being put into the fermenter, the solid manure is stored temporarily on a special concrete surface.
- Immediately after harvesting, energy plants are transported to the biogas plant, where they are stocked in silos.
- The transportation and sorting of the collected organic waste are assured by the local waste syndicate.
- In order to reduce the volume of transport, decentralised end-storage tanks were introduced.

The advantages of decentralised liquid manure end storage are multiple:

- As a truck or tractor has to collect the liquid manure from the 29 farms on a regular basis, it can also transport the processed manure from the plant to the decentralised end-storage tanks situated in the villages on the way back to the farms, instead of travelling half the distance unloaded. In this way, the transport volume can be reduced by half, without incurring any extra cost.
- As the storage tanks are sufficiently large, and as they are outside the villages, the distances for distributing in the field are very low. As a consequence, the volume of transport is further reduced and the distribution equipment can work efficiently in the field, without having to travel much of the time on the roads (Figure 4).
- Another advantage is the large and modern transport vehicles which can carry larger loads than the existing conventional equipment.

Figure 4. The location of the central plant and of the different end-storage tanks



Source: LEE, personal data

Increased energy yields by an optimised material flow management

Practical experience has demonstrated that the energy yield of fresh liquid manure is substantially higher than the yield of stored slurry. By optimising transport logistics it is possible to collect the liquid manure regularly from the different farms and attain high energy yields comparable to those of on-farm plants. Gas yields of about at least 1.3 m^3 biogas/FU/day are expected in the co-operative plant. Under ideal conditions, when manure from the stable is put directly into an on-farm fermenter, yields of about 2 m^3 biogas/FU/day are possible.

The energy losses that result from storing solid manure are less important. It is therefore possible to make provision for the summer months by storing a certain quantity of solid manure from the winter season on the plant.

Economic aspects

The profitability of the plant is positively influenced by certain favourable basic conditions:

- The price of the energy sold;
- High investment subsidies;
- Disposal receipts.

An optimised use of all resulting energies (electricity, heat) is further improving the profitability of the plant.

Energy sales

Electricity

The utilisation by the local electricity supplier of the electricity produced is regulated by the 1994 energy law. At the present time the basic price for "green" electricity is fixed at EUR 0.0775/kWh. In order to promote renewable energies, the Ministry of Environment guarantees an ecological support premium of EUR 0.025/kWh for electricity produced in biogas plants with an electrical capacity between 1 and 3 000 kW (*cf.* sub-section on "Favourable policy conditions").

Heat

The utilisation of the heat resulting from biogas production is often problematic. In this project the renovation of the local swimming pool (at a distance <1 km) was a good opportunity for selling the produced heat. Further selling opportunities are currently being discussed (*e.g.* secondary schools, other communal buildings).

In Luxembourg heat selling prices of EUR 0.030/kWh for surplus heat and EUR 0.054/kWh for heat in exclusive heating contracts are under discussion. The prices are coupled to the development of the selling price of fossil energy sources and thus regularly adapted to market conditions.

Investment grants

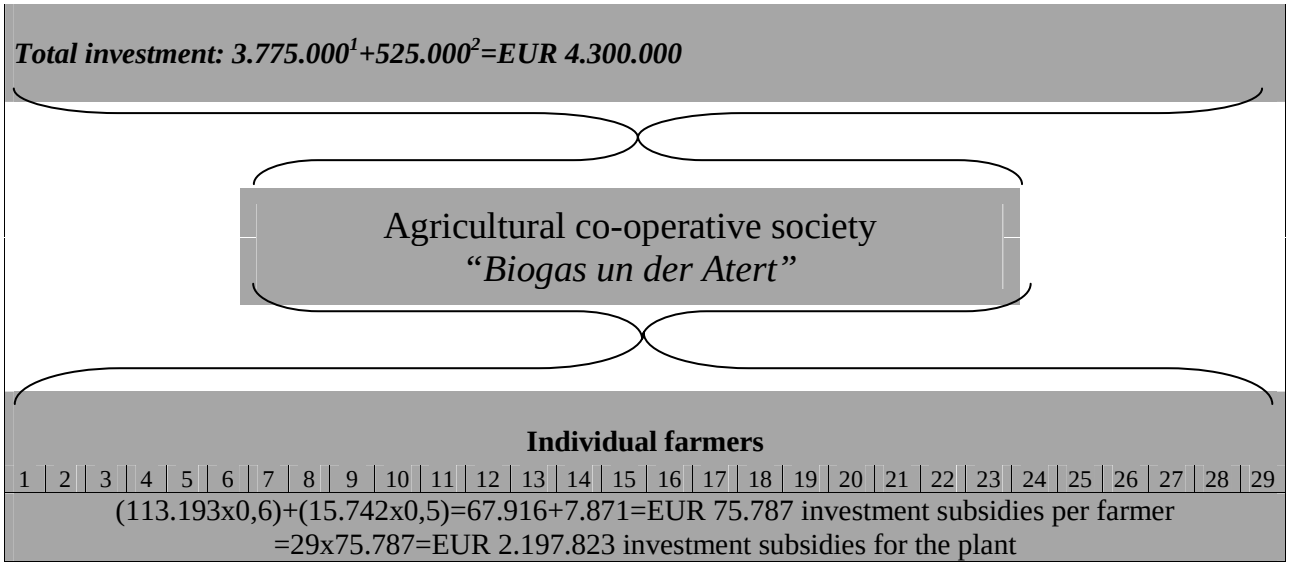
The investment subsidies available for biogas plants are very favourable in Luxembourg. The application of the law concerning the support of rural development provides subsidies of up to 60% of total investment costs (< EUR 150 000, excluding VAT) to each investing farmer (except for end storage, which has a limit of 50%). As the Rédange project is run by a co-operative of individual farmers, a multiplication of the investment subsidies is possible.

In order to profit from the favourable subsidies offered to individual farmers investing in biogas production, it is necessary for each member of the co-operative to make a personal request for financial aid at the Ministry of Agriculture (Figure 5).

Disposal receipts

The fermentation of organic waste causes additional investment and running costs. As a consequence, the responsible waste syndicate has to pay disposal proceeds to the co-operative. The exact tariff has not yet been fixed, as negotiations have not been concluded.

Figure 5. Investment subsidies for the biogas plant



Notes:
1. Biogas plant: 3.775.000/29 = EUR 130.172 per farmer = EUR 113.193 excluding VAT.
2. End storage: 525.000/29 = EUR 18.103 per farmer = EUR 15.742 excluding VAT.

Source: Personal communication ASTA; LEE.

Financing

Given the favourable investment conditions, the project has been financed with a minimum amount of private capital being contributed by the 29 farmers (Table 2).

Table 2. Financing of the co-operative biogas plant

Source	Amount [EUR]
Investment subsidies (29 x EUR 75.787)	2 197 823
Capital of the co-operative (29 x EUR 4.000)	116 000
External funds (29 x EUR 68.488)	1 986 177
TOTAL INVESTMENT	**4 300 000**

Source: Personal communication, LEE.

Due to the generous investment subsidies and the fixed proceeds, local banks are willing to supply the necessary external funds without personal guarantees from the members of the co-operative. Thus, the element of personal risk for the investing farmer is very low.

Remuneration of the participating farmers

The co-operative pays its members for the biomass they provide. The amount of remuneration depends on the content of the organic dry matter in the substrates. This is a practicable possibility to consider in terms of the different energy content of the biomass supplied.

If the co-operative makes additional profits, they are distributed to members in accordance with their business shares.

Progress of the project and perspectives

At the moment, the project is progressing very well (Figures 6 and 7). Work on the plant is nearly finished and in July 2003 it will be launched.

Figures 6 and 7. The construction of the co-operative biogas plant is progressing well





Source: LEE.

As the conditions for biogas production in Luxembourg are so advantageous, and present an excellent opportunity for farmers to multiply their activities and to create new sources of income in the field of sustainable energy production, biogas production in Luxembourg continues to develop: another co-operative project of similar size to the Rédange plant has recently been set up, and other farmers are planning their own system on the farm level.

BIBLIOGRAPHY

Conter, Gérard (2001), "Wirtschaftliche Aspekte der Biogaserzeugung", Service d'Economie rurale, *De Beroder,* No. 13, Luxembourg.

Ministry of Agriculture, Grand-Duchy of Luxembourg (2001), "Loi du 24 juillet 2001 concernant le soutien au développement rural", Memorial, Luxembourg.

Heck, Christian and Jang Schummer (2002), *Gemeinschaftliche Biogasanlagen in Luxemburg*, Landwirtschaft-Energie-Emwelt [LEE], Luxembourg.

Ministry of the Environment (2000), *Förderung von Massnahmen zur rationellen Nutzung der Energie und zur Nutzung erneuerbarer Energien,* Emwelt-Info, Luxembourg.

BIOENERGY AND AGRICULTURE – THE NORWEGIAN POLICY PERSPECTIVE

Frode Lyssandtrae[1]

Abstract

Norway is the northernmost country in Europe and has only 3% agricultural land. This means that the potential for bioenergy production from agriculture is limited. The Norwegian Industrial and Regional Development Fund has estimated the potential from agriculture to be 5.0 TWh (this includes energy crops, biowaste, straw and manure). The current potential for biofuel is estimated to be 3.1 TWh.

The government has no single political target for an increase of bioenergy production, but there are targets for renewable energy and for water-based heating systems. The government has introduced several instruments to increase the use of renewable energy, and bioenergy is a part of this strategy. If a larger share of agricultural land is going to be used for energy production instead of food production, extensive discussion on agricultural subsidies, environmental and regional goals for agriculture, etc. will need to be conducted. These discussions should be instigated in the coming months and years.

Introduction

Norway is the northernmost country in Europe, reaching from 58° to 71° Northern latitude, a distance of 1 750 km. That is longer than the distance from Oslo to Rome. Norway measures 323 758 km^2 (385 155 km^2 including Svalbard and Jan Mayen), which is about the same size as the state of New Mexico in the United States of America. It has the second-lowest population density in Europe after Iceland, with a population of 4.5 million (Statistics Norway, 2003).

Land use

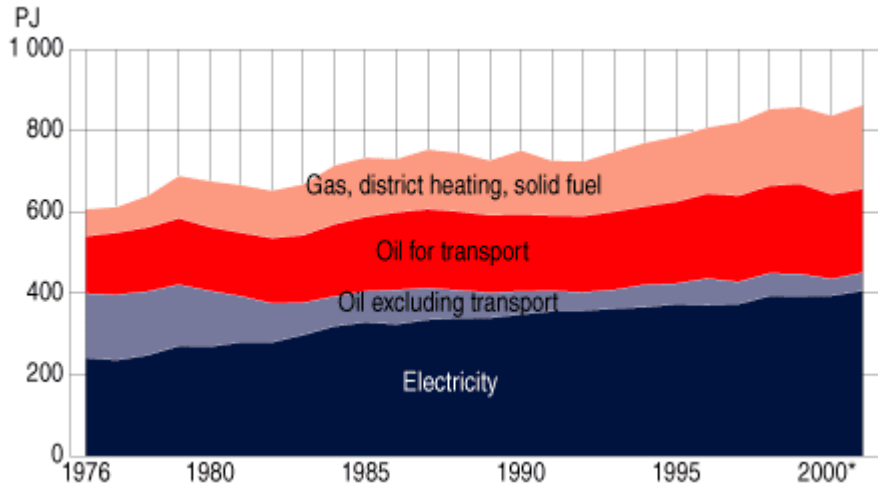
Approximately 3% of Norway's land area is fully cultivated agricultural land. Productive forest area covers 23% and the rest consists of mountains, unproductive forest, lakes, built-up areas, etc. About 30% of the cultivated land can be used for grain production (with a reasonable yield).

1. Ministry of Agriculture, Oslo, Norway.

Energy supply

Norway has a coastal climate and a mountainous landscape, making it ideal for hydroelectric power production. Figure 1 shows the energy use for Norway from 1976-2000, measured in petajoules (PJ) (3.6 PJ = 1 TWh [terawatt-hour]) and divided into different energy sources. Because of the high production of hydroelectric power, Norway has a relatively low use of fossil fuels for heating, even though it is the third-largest oil exporter in the world.

Figure 1. Energy consumption, excluding the energy sector and ocean transport



Source: Statistics Norway, 2003.

Bioenergy

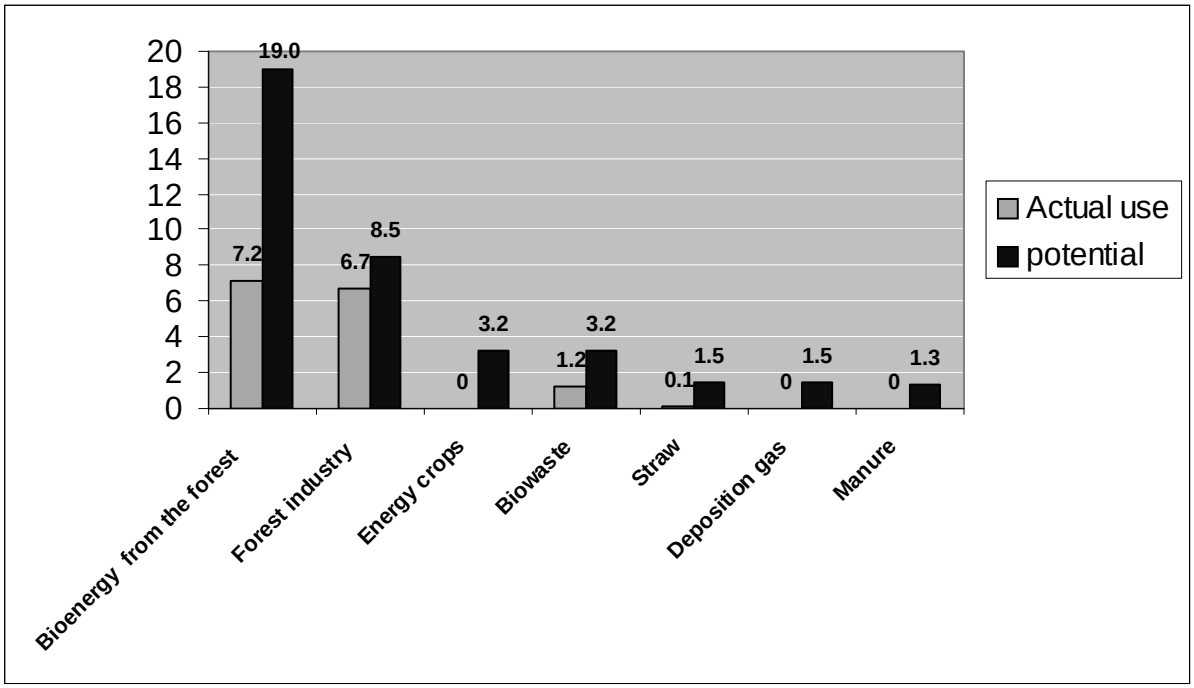
Historically, firewood has been the most important energy source for heating in Norway. Before the introduction of cars and tractors 10-20% of the agricultural land was used to feed the horses required for transportation and farm work (Energigården, 2003). Early in the 20th century Norway began to build up large-scale electricity production based on hydroelectric power from waterfalls. This, together with oil, has reduced the importance of bioenergy.

Today, Norway's annual use of bioenergy is approximately 15 TWh, which is 6% of its total yearly energy use. Of this figure, 6 TWh comes from firewood, 7 TWh comes from the forestry industry and 2 TWh is based on waste (Norwegian Industrial and Regional Development Fund [SND], 2002).

Norway has great potential for increasing the production of bioenergy based on wood but, because of the very restricted extent of agricultural land, the increase of bioenergy from agriculture is limited. Figure 2 illustrates the potential in Norway for increased bioenergy production divided into different areas (SND, 2002).

Even though bioenergy production from agriculture is limited, agriculture does have the potential to increase its energy production. This potential is very dependent on electricity and oil prices (as is the case with bioenergy from forestry). It is also highly dependent on Norwegian agricultural policy and international trade agreements.

Figure 2. Bioenergy potential in Norway (TWh)



Source: SND, 2002.

Norwegian grain production cannot meet the prices on the world market, and therefore the bioenergy potential from straw is reliant on profitable grain production. The energy value of the straw will most likely always be of marginal influence on the production volume of the grain.

Energy crops include a range of different crops. The main production today is oilseeds. Oilseed production is small because of the climate and because grain production for human consumption and for feed is more profitable. Current production is about 10 000 ha, and can potentially be increased to about 40 000 ha (Energigården, 2003).

An increased use of biowaste from the food industry for energy purposes is likely to emerge in the coming years, but this is also very dependent on energy prices.

Bioenergy from manure has a potential in areas where animal density is high. On average, Norwegian agriculture has very small farms compared with most other OECD countries, and this increases the cost of using manure as a source of energy. However, if several farmers join together to build a manure energy plant, such systems may become more profitable. Today, there is only one large farm in Norway possessing the necessary equipment, and this farm is connected to a prison facility that uses the energy for heating.

Biofuel for transportation is a segment of bioenergy that has not attracted great attention in Norway until now. Norway is at the moment considering implementation of the EU directive on biofuel as part of the Norwegian agreement with the EU. As part of this consideration, the Ministry of Agriculture has engaged the consultancy company, Energigården, to assess Norway's potential for

biofuel production. Energigården calculated the current potential for biofuel to be 3.1 TWh, (assuming that biofuel cannot have a production and transportation cost above 5 NOK/l [1 USD = 6.6 NOK; 1 EUR = 7.9 NOK]). At present, bioethanol and biogas have the largest potential (Energigården, 2003).

Norwegian policy targets

Today Norway has no defined policy targets for bioenergy alone. The Ministry of Petroleum and Energy, which is responsible for Norwegian energy policies, including bioenergy, operates with a target of a 10 TWh increase in the production of renewable energy, apart from hydroelectric power (or a documented reduction of use because of energy-saving measures) by 2010. The Ministry of Petroleum and Energy has also set a policy target of a 4 TWh increase in water-based heating systems by 2010. Both targets involve bioenergy, and they are likely to stimulate an increase in the use of bioenergy (Ministry of Petroleum and Energy, 1998).

Norway has signed the Kyoto Protocol and has a +1% target. Because of the large increase in Norwegian oil production during the 1990s, measures have to be introduced in order to reduce CO_2 emissions and meet the target. Norway is in the process of creating a quota system for emissions, and bioenergy production can play a role in this system. However, it still has to be competitive with other reduction possibilities.

Norway has not yet taken a final decision on whether or not it will implement the EU's biofuel directive. The aim of the directive is that 2% of all fuel should be biofuel by 2005, and 5% by 2009. Implementation of the directive would increase the interest for Norwegian biofuel production. Today, the biofuel used for transportation is mostly imported biodiesel from Germany. Under the directive it is likely that prices for biofuel in Europe will rise, which will act as an incentive to increase Norwegian biofuel production.

Policy instruments

Norway imposes a general tax on electricity and oil for heating at 0.09 NOK/kWh (kilowatt-hour). This is relatively low compared to many other European countries, but it is still an important measure for stimulating alternative energy production such as bioenergy (SND, 2002). There are plans for removing the electricity tax for the industry over a period of 5 years.

The government gives financial support to heating installations, amounting to 100 million NOK/year. This has resulted in growth of 1.6 TWh over the period 1997-2001 (Ministry of Petroleum and Energy, 2002). This is financed from the Energy Fund, which receives the revenues from a levy on the distribution tariff (NOK 0.003 per kWh). The fund is managed by ENOVA, a state-owned company established to stimulate a shift in energy production and use.

The Ministry of Agriculture has, for several years, offered some financial aid to farmers and forest-owners wishing to start up bioenergy businesses. From 2003 this has become a separate support scheme, with 15 million NOK allocated for 2003. The support is provided for the establishment of supply systems for heating, and a set of rules for how the support should be distributed has been established (SND, 2002). Farmers and the forestry business have shown great interest in the scheme, but as yet it is too early to see any results.

As an incentive to production, biofuels have been exempted from the tax applied to fossil fuels. This is an important measure to aid the introduction of biofuel. During 2002, biodiesel went on sale in Norway at a lower price than regular diesel. However, there are only two petrol stations selling pure biodiesel in the country.

Discussion and conclusion

This document shows that Norwegian energy production from agriculture is limited, mostly because of the very restricted agricultural land area. Increases in Norwegian bioenergy consumption will most likely come from an increase in the consumption of different bioenergy products from the forest (firewood, pellets, etc.). This potential will be exploited in preference to the possibilities agriculture can offer, mainly because energy derived from forestry is the less expensive option.

However, the EU's biofuel directive could change this picture. A clear political target for the production of biofuel would increase the interest for energy from agriculture. Waste from the food industry is probably the cheapest bioenergy product from agricultural sources. Ethanol produced from grain, or biodiesel produced from oilseeds are also possibilities, but the cost involved is higher.

The production of biofuel from grain and oilseeds raises discussion of the general agricultural policy in Norway. There is widespread support in Norwegian society for subsidising Norwegian food production. There are several different reasons for this, such as food security, landscape, rural employment, etc. Is the willingness to pay the same if the product goes to fuel and energy production? Clearly, the arguments for food security do not stand, but are the landscape and rural employment factors the same? Since Norway is a large exporter of mineral oil and gas there are no energy security issues involved for Norwegian biofuel production, as is probably the case for several other countries. Energy security cannot, therefore, take the place of food security in the argument.

These questions need to be discussed in Norway the coming months and years. The potential for biofuel and bioenergy in general does not fully depend on agricultural polices, but it will be much more difficult to initiate bioenergy production from Norwegian agriculture if it is introduced without any help from the established agricultural support system.

BIBLIOGRAPHY

Energigården (2003), *Biodrivstoff – produksjonsmuligheter for landbrukssektoren i Norge* (a study of production possibilities of biofuel production in Norwegian Agriculture, prepared for the Norwegian Ministry of Agriculture, Oslo).

Ministry of Petroleum and Energy (2002), "The Energy Sector and Water Resources in Norway 2002": http://odin.dep.no/oed/engelsk/p10002017/index-b-n-a.html, or: www.odin.dep.no./oed/engelsk (click on "Publications").

Ministry of Petroleum and Energy (1998), St. meld No. 29, 1998-99, "Norwegian Energy Policy" (Report to the Storting [White Paper]): www.odin.dep.no/oed/engelsk (click on "Publications"; then "Reports to the Storting" [White Papers]), or: http://odin.dep.no/oed/engelsk/p10002017/p10002306/index-b-n-a.html.

Norwegian Industrial and Regional Development Fund [SND] (2002), *Program for økt verdiskaping innen bioenergi fra landbruket*, Oslo, Norway.

Statistics Norway (2003), www.ssb.no/english/.

STATE OF THE ART OF BIOENERGY IN POLAND – BARRIERS AND OPPORTUNITIES

M. Rogulska, A. Oniszk-Popławska, M. Pisarek and G. Wisniewski[1]

Abstract

Poland is the largest country in Central Europe – with a surface area of 312 680 km^2 and a population of 38.7 million. Forests cover 28.1% (8.8 million hectares) of the country, the extent of area under forest varying from one *voivodship* (or administrative unit) to another, from 11-48%. Rural areas are a vital element of the Polish economy, with agricultural land occupying approximately 60% of the surface area. About 38% of the population lives in rural areas. Agriculture and forestry contribute only 4.8% of GDP, yet 27% of the Polish workforce is employed by the agricultural sector (0.4% in forestry).

Local renewable energy sources can play a significant role in the development of Poland's rural areas. Biomass energy is recognised as the country's most important potential source of renewable energy and can be brought into use in the near future. Poland has the potential to produce large amounts of several types of bioenergy resources. The total technical potential from biomass has been estimated at 750 PJ, with the largest amount of resources coming from agriculture (agricultural residues) and forestry (residues and wood). Energy crops have a more important role to play over the mid and long-term perspective. Several pilot schemes and research programmes (such as short rotation coppice willow plantations) are being conducted on areas of up to 1 500 hectares. The development of biomass technologies is the fastest-growing branch of renewable energy in Poland. This paper presents the current situation in Poland, and reviews development trends over the short and mid-term perspective.

Background

Rural areas are of fundamental importance in Poland. There are some regions where agriculture is still the major sector of the economy. The share of agriculture in gross domestic product (GDP) (including hunting and forestry) was 4.8% in 2001, with a continuous downward trend (in 1988, it was 11.8%, compared with 6.4% in 1994). This fall in agriculture's share of GDP is the result of declining prices and volume of agricultural output, accompanied by rapidly increasing prices and output volume in other sectors of the economy, especially industry. Agriculture (including hunting and forestry) is the main source of income for 4.4 million of the workforce, 27% of the Polish workforce, with 38% of the population living in rural areas. Rural areas have a very high unemployment rate – as high as 50% in certain areas. In addition, rural areas show a negative economic balance – a large part of agricultural incomes often flow out to urban areas (*e.g.* as with expenses related to energy costs [GUS, 2002]).

1. EC Baltic Renewable Energy Centre (EC BREC/IBMER), Centre of Excellence and Competence in Renewable Energy in Poland RECEPOL, Warsaw, Poland.

The Polish agricultural sector encompasses many farms which are highly variable in terms of organisational structure, type of ownership, size and volume of output. Unpredictable weather conditions and the fluctuating profitability of various production lines result in a lack of production stability. Agricultural production in Poland is not regulated with a quota regime, and the entire production risk is borne by the farmer, with the exception of a few crop deliveries based on supply contracts between the producer and the food-processing plants such as those for sugarbeet, rapeseed, flower and vegetable seeds.

Most Polish farms are mixed, producing both crops and livestock. The majority lack clearly defined areas of specialisation. Within the group of larger farms, with acreage of over 50 ha, more than 38% cultivate crops exclusively; 17% produce livestock; and 45% are mixed farms. Only 16.2% of farms maintain no livestock. Of the total number of farms, 64% keep cattle and over 50%, pigs. The total area under crops in 2000 was 12.4 million hectares. In total, basic cereals occupied 8.8 million ha (71.0%); potatoes: 1.3 million ha (10.1%); and industrial crops: 0.8 million ha (6.5%). Crop areas changed to some extent over the last decade, with acreage for cereals increasing from 59.9% in 1990, to 71% in 2000, and decreasing for other crops.

In Poland animal production is largely traditional, with smaller farms requiring high labour inputs, and larger farms consuming considerable amounts of energy. Annual quantities of cattle and swine wastes estimated on the basis of analysis of the current state of animal production and on Ministry of Agriculture and Rural Development forecasts, are approximately 38 million m^3 of liquid manure and 51 million tonnes of solid waste. These data reveal a general need throughout the country for improvement in the storage and management of animal wastes. The rational management of agricultural wastes, based on appropriate removal from livestock buildings, storage and subsequent utilisation, can have enormous implications for the natural environment. Moreover, development of complementary sanitation systems in agriculture, including treatment installations for anaerobic wastes, is necessary for solving the problems that arise in rural regions in connection with three main types of organic pollution sources: human liquid and solid wastes, animal production wastes and wastes from small agro-food industries.

Agriculture is the branch of the economy with the greatest potential for the practical realisation of the principles of sustainable development (*i.e.* by producing wholesome food, managing the environment efficiently and implementing technologies that utilise renewable sources of energy). Conventional methods of cultivation are, to an increasing extent, coming to be regarded as unfavourable to sustainable development. Technological progress and intensive farming methods lead to increased production and waste, leading to adverse effects on the environment. On the other hand, agriculture is a producer of a large volume of biomass which farmers do not normally exploit as an additional source of income. The creation of employment, together with the generation of additional income, is one of the priorities of sustainable regional development. The utilisation of local sources of energy to satisfy local energy requirements strengthens the local market, and the extra income generated benefits the local community.

National policy supporting bioenergy

Policies related to renewable energy sources (RES) encompass issues that have traditionally fallen within the scope of several different ministries – thus, work on the various aspects of RES utilisation originates in separate institutions.

Poland's programmes are of a strategic nature and deal with specific areas of Poland's development. Important programmes which touch upon RES development include: the "National Development Plan" (Council of Ministers, 2003); "Initiative, Development, Labour" (Council of Ministers, 2002*a*); "Development Plan of the Polish Rural Areas 2004-2006" (Ministry of Agriculture and Rural Development, 2002*a*); and "National Environmental Policy for the Period 2003-2006 with the 2007-2010 Perspective" (Council of Ministers, 2002*b*.)

One of the key strategic programmes is the "National Development Plan 2004-2006" (Council of Ministers, 2002), which sets the objective of the creation of a competitive economy based on knowledge and initiative, assuring long-term, sustainable development; a lower rate of unemployment; and the attainment of economic and social standards equal to those currently existing in the European Union (EU), both at regional and governmental level. The following targets, which are considered of primary importance in the programme, can contribute to RES development: a high level of environmental protection; an increased share of high value-added products (*e.g.* biomass); and support for all regions and social groups participating in the development and modernisation process. Structural change in agriculture and fisheries constitutes one of the National Development Plan's social and economic development objectives. Financial resources to support achievement of the objectives will be provided by the EU (in the form of structural funds and coherence funds), as well as by national institutions (the central budget, the local government budget and targeted funds). The programme estimates that funds for research and development (R&D) will increase in 2006 from the current level of -0.65% GDP, to 1.5% GDP, while, for environmental protection, the figure will decrease from 1.8% GDP, to 1.2% GDP.

The Sectoral Operational Programme (SOP), "The Restructuring and Modernisation of the Food Sector and Rural Development", constitutes one of the elements of the social and economic development strategy defined in the National Development Plan. The following objectives have been defined in the SOP strategy:

1. Enhanced competitiveness of agriculture and the food economy; and
2. Sustainable development of rural areas.

They will be implemented under the programme's three priorities of:

1. Support for change and adjustment in agriculture;
2. Sustainable development of rural areas; and
3. Development and adjustment to EU norms regarding processed agricultural products.

SOP covers the years 2004-06 and its implementation will be financed by EU funds and with national funds, including the state budget and local government and support beneficiaries' own funds.

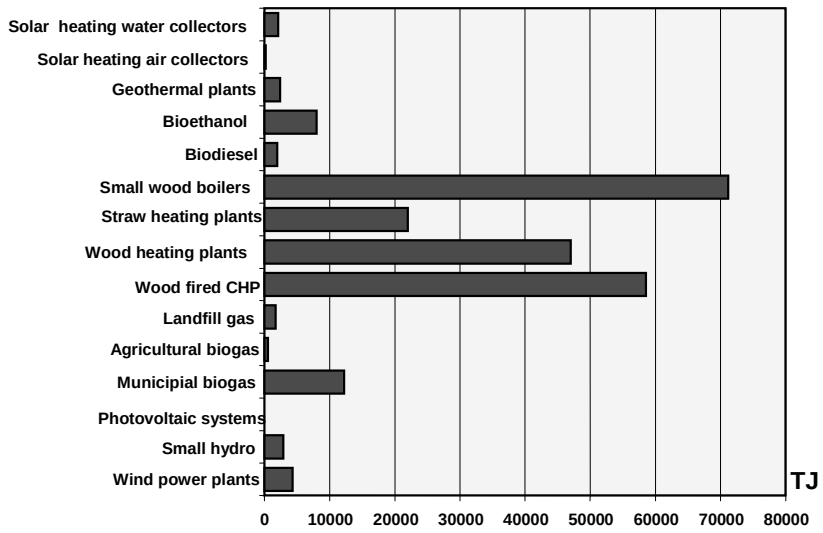
The present contribution of RES to the primary energy balance has been estimated at 2.5%, or approximately 104 PJ (petajoules) (EC BREC, 1999). Wood has the largest share of all the sources of renewable energy. The current structure of energy utilisation produced from renewable sources is as follows:

Biomass	98.05%
Hydro power	1.82%
Wind power	0.02%
Solar energy	0.01%.

Polish policy regarding renewable energy has developed in accordance with Poland's accession to the EU and adherence to the Kyoto Protocol. The end of the 1990s was a period of increased political commitment to create conditions for renewable energy development. The *Resolution on an Increase of Renewable Energy Sources Utilisation*, approved in 1999 by the Polish Parliament, was a milestone in the process. The Parliament called the Council of Ministers to prepare the *Development Strategy of the Renewable Energy Sector* to harmonise Poland's national energy and environmental policies. The Minister of Environment assumed the task of preparing the strategy on behalf of the Council of Ministers. In 2000, the Council of Ministers adopted the document *Development Strategy of the Renewable Energy Sector*, and it was endorsed by the Parliament the following year. It was the first policy document to address the subject of the renewable energy sector as a whole, highlighting the basic goals and conditions for its development up to 2020. It evolved in response to the EU's *White Paper* "Energy for the Future: Renewable Energy Sources". The "Strategy" is an innovative policy, but it also has the distinction of being the first policy programme of such importance to be implemented in Central and Eastern Europe. It sets the following development targets: a 7.5% contribution of renewable energy to the primary energy balance in 2010, and a 14% contribution in 2020. This would require the production of 340 PJ of "green energy" in 2010, *i.e.* an increase of 235 PJ compared with 1999, assuming the energy needs of Poland in 2010 to be 4 570 PJ (Figure 1). Such targets will oblige the Polish government to take positive action to support renewables. The targets are ambitious: in 1999, renewables made up approximately 2.5% of the total energy balance – a figure which will have to be tripled over the coming ten years in order to meet the government's targets.

For several years Poland has been active in the field of international co-operation, especially regarding the Kyoto Protocol mechanisms. Relevant Activities Implemented Jointly (AIJ) and Joint Implementation (JI) (*i.e.* Kyoto flexible mechanisms) projects resulted in a small number of energy investments, including renewable projects such as: landfill, gas utilisation and switching from coal to biomass use. Currently, the most active countries are the Netherlands, Denmark and Sweden. As a third option, an Emission Trading Mechanism, has been discussed and agreed at governmental level.

Figure 1. Renewable energy production in 2010, TJ as per the (Strategy)



Source: ESD and EC BREC, 2001

"Environmental Policy for the Period 2003-2006, with the 2007-2010 Long-term Perspective", an up-dated version of the Second Environmental Policy, gives much attention to RES use, including bioenergy. Implementation of the following activities is foreseen over 2003-06 as part of the policy objectives:

- Creation of the mid-term executive programme for the "Strategy of RES Industry Development", aiming at optimisation of biomass use, development of hydro, wind and solar energy, and an increase of geothermal energy use (time-limit: 2004).
- Preparation and endorsement of the RES Act (2003).
- Preparation of the Implementation Plan of the Directive 77/2001/EC (2006).
- Preparation of statistics for RES installations as well as measurement of their performance; annual database updates (2006).
- Evaluation of the degree of environmental policy implementation and issue of a report on the monitoring process on RES development strategy.
- Carrying out a complex evaluation of RES resources and infrastructure at regional level (setting out the preferred regions), incorporating RES issues into regional development plans. Identification of a priority project for EU funds (2004).
- Preparation and implementation of the new cost-effective mechanisms supporting RES development, including the Green Certificates System, mechanisms for tax exemption and amendment of the Energy Law (2006).
- Creation of a separate fund within the National Environment Fund to support pilot projects, and the development, commercialisation and promotion of RES installations. The fund would also provide a supplementary contribution to EU funds.
- Construction of RES installations in conformity with the Implementation Plans for the RES development strategy (private and public investors).

The process of accession to the EU and the transposition of Poland's legal system have led to the country's gradual adoption of EU regulations specifically concerning RES development under Polish conditions, and this also impacts significantly on the bioenergy sector. For example, "Directive 2001/80/EC on the Limitation of Emissions of Certain Pollutants into the Air from Large Combustion Plants" is a strong driving force for the development of large-scale plants for co-firing biomass with coal throughout Poland.

Biomass potential

Poland has the potential to produce most of the various types of bioenergy resources, but in the short term the most important will be:

- Wood from forests, tree cuttings, orchard waste and short rotation coppice (SRC);
- Straw and other by-products and/or wastes from agricultural production;
- Liquid/solid manure, used for methane fermentation;
- Oilseeds, processed into esters and used as biodiesel;
- Potatoes, cereals and other crops or waste processed into ethanol.

Estimates of the current use of bioenergy in Poland are uncertain, because of a lack of statistical data. The technical potential of biomass resources has been calculated at over 750 PJ, but Poland's geographical location, combined with its diversified natural resources and climate, constitute an additional potential source of biomass. The largest proportion of resources is made up of agricultural residues: basic cereals, straw and hay (approximately 12 million tonnes/year [producing 195 PJ]) (Table 1); forestry residues (6-7 million m^3 [45 PJ]) and firewood (2.5 million m^3 [17.5 PJ]) (Grzybek *et al.,* 2001). Most wood industry by-products, equal to approximately 7.2 million m^3 (50 PJ), are consumed by the wood-processing industry for production purposes (3.7 million m^3) and energy production (3.3 million m^3). The main consumers of the industry's by-products are the pulp and paper industry and the particle-board and sawmill industry. Diversification of regional economic development creates the possibility of finding relatively rich logging-residue and agricultural waste, which might be supplied to the district heating systems.

The use of straw for energy production was estimated at 40 000 tonnes in 2001, (approximately 0.5 PJ). There are about 40 small and medium-sized (0.5-7 MWt) straw-fired district heating plants currently operating in Poland, the first of which were implemented as demonstration projects in 1995. In addition to these, there are in the region of 100 straw-fired boilers in agricultural dwellings. It has been estimated that the production of every 1 MWt of straw-fired district heating requires the employment of 3-4 people (Grzybek *et al.*, 2001). Some results show straw-fired, small-scale district heating as having the lowest costs of any similar system using other sources of fuel, although investment outlay is higher than is the case with natural gas or fuel oil.

Utilisation of biogas in terms of digestion of liquid manure, sewage sludge and landfill gas production plays a less important role than solid biofuels. Energy crops will have a more important role to play in the mid and long-term. Currently, several pilot schemes are underway and SRC research plantations are in operation. The Polish government has not implemented a national support system for energy crops – further developments in this area are anticipated under the EU's Common Agricultural Policy regulations.

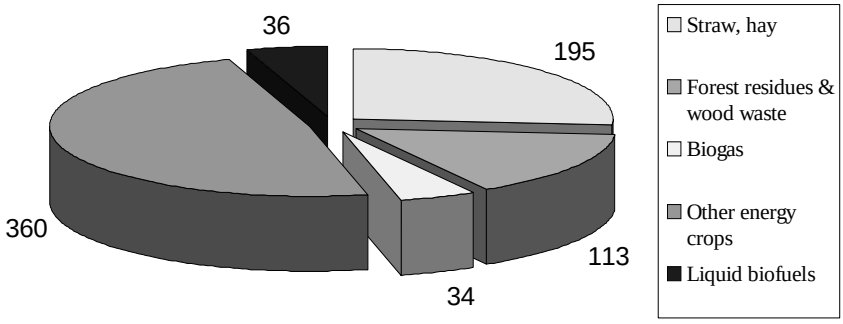
In Poland there are 1.6 million ha of unused land and as much as 3.5 million ha of contaminated agricultural land (which may be withdrawn from agricultural use) (GUS, 2001). Utilising 2 million ha of this combined area for SRC would result in the production of approximately 360 PJ. Thus, potential bioenergy use is several times greater in the near future than at the present time (Figure 2).

Table 1. Theoretical and technical energy potential of straw in Poland

Type	Total quantity	Utilisation factor	Quantity available for energy purposes	Technical potential
	(million tonnes)	(%)	(million tonnes)	(PJ)
Cereals straw	21.5	50	8.9	147
Rape straw	2.4	70	1.4	23
Hay	18.1	10	1.5	25
TOTAL	42.0	-	11.8	195

Source: Grzybek *et al.*, 2001.

Figure 2. Estimation of technical biomass potential in Poland (PJ)



Source: Authors.

Energy crops

Among the new crops being tested are: SRC willow (*e.g. Salix viminalis*) and perennial grasses such as *Miscanthus s. giganteu;, Miscanthus s. sacchariflorus;* artichoke; *Rosa multiflori* and *Sida hermaphrodita.*

At present *Salix viminalis* is the most common alternative crop. The total area currently under cultivation does not exceed 1 500 ha. Willow plantations are used as biological sewage-treatment plants, especially in rural regions. The high rate of annual growth indicates the usefulness of these plantations for biomass energy purposes. First trials showed that it is possible to produce 15-20 tonnes of dry matter per year from 1 hectare. Willow is also a good filter, trapping toxic compounds in the soil. More and more farms are building waste-water treatment plants, and utilising fast-growing willow. However, this species requires special conditions for growth (primarily water), which must be taken into account while planning future energy plantations. Shortage of equipment for harvesting willow on the Polish market is another barrier to its wider implementation.

The suitability of selected perennial grasses capable of producing large amounts of biomass was also tested in Poland as a potential raw material for energy production. These species are tolerant to concentrations of heavy metals, and therefore may be suitable for planting along roadsides. Prospective programmes for producing new forms of "alternative grasses" in Poland should cover soil and climatic requirements; multiplication, agricultural methodology and technological processing.

Liquid biofuel (rape methyl ester, ethanol)

Liquid biofuels – ethanol and biodiesel – have attracted huge interest in Poland and have been the cause of much discussion. Surplus production of ethanol gave rise to the first experiments, using ethanol as an additive to gasoline, in 1991. Raw materials include molasses and low-quality grain, potatoes, or other agricultural products. In 1997 ethanol additives to gasoline reached 100 000 tonnes per year, then dropped to approximately 50 000 tonnes and remained stable until 2003. Poland also runs a pilot scheme producing in the region of 100 000 tonnes per year of rape methyl ester (RME),

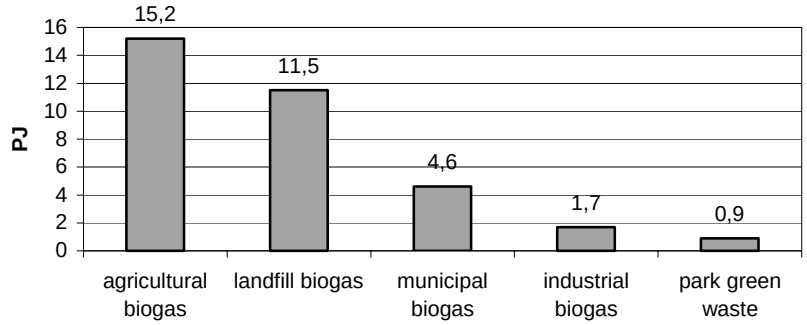
and there are other projects still in the development phase. A key driving force is the expectation that liquid biofuels can facilitate rural industrialisation and reduce the currently high unemployment rates in some rural regions. The Act on Biofuels and Biocomponents (Ministry of Agriculture and Rural Development, 2002*b*) was prepared in 2002 but, following a presidential veto, the entire legislative procedure had to be re-embarked upon and this resulted in a new proposal of the Act (in March 2003). Polish law now requires that every litre of petrol contain at least 3.5% ethyl alcohol In the future, the percentage of bio-components will be increased, reaching 5.75% in 2010. At present, the percentage of bio-components in fuel for diesel engines has yet to be determined (esters will be added as from 2005).

Biogas

In 1997 over 60% of the controlled rural water wells were classified as polluted by the National Sanitary Inspectorate. Anaerobic digestion of animal manure is one possibility for minimising the negative environmental impacts of livestock farms (livestock production and intensive fertiliser-use cause most of the water pollution in Poland's rural areas). Up until now, the agricultural sector has developed biogas plants with the main object of generating thermal energy (and, in certain cases, producing high-quality fertiliser as a by-product). Over the last 20 years, ten biogas installations have been developed on individual farms in Poland (Romaniuk and Rogulska, 1997) – however, the majority of them are not in operation today, for economic and technical reasons. Prospective investors have been discouraged by high investment costs and the lack of adequately proven technologies, although there is some interest in biogas production for energy on large, industrial pig or cattle-breeding farms, and several, centralised co-fermentation biogas plants are currently under development.

The total technical potential of biogas in Poland has been estimated at 34 PJ (Oniszk-Popławska *et al.*, 2003), but current utilisation is only around 1.5 PJ (Figure 3). Agricultural biogas is the source with the largest individual technical potential, but landfill biogas is also significant. There are about 30 biogas systems in waste water treatment plants with an installed capacity of about 38.9 MW (megawatts), producing approximately 250 TJ (terajoules) of heat and 72 GWh (gigawatt-hours) of electricity. Combined, this equals 1 PJ of primary energy from municipal biogas.

Figure 3. Biogas potential in Poland



Source: Oniszk-Popławska *et al.*, 2003.

Implementation of bioenergy technologies

The development of biomass technologies based on solid biofuels is the fastest-growing renewable energy branch in Poland (Table 2). Following the successful implementation of several demonstration biomass district heating (DHP) systems, beginning in 1990, the favourable reaction of the market led to increased interest in bioenergy on the part of the DHP operators. The wood-processing industry, together with the pulp and paper industry, are well adapted to bioenergy technologies, having been the major users of waste biomass since the early 1980s. Increases are anticipated in production intensity and imports of domestic systems based on fuel wood and straw. The greatest challenge for bioenergy will be to implement a full production chain of biofuels and to develop a larger market share for biofuels. Meeting renewable policy objectives, together with developing the market for solid biofuels, should create a basis for the production of biomass electricity on a more important scale, and for co-generation over the long term. Development of the liquid biofuels market currently awaits final political decisions.

Table 2. Biomass energy technologies implemented in Poland – state in 2001

Type of installation	Power installed	Energy production per year	
	(MWth el)*	Electricity (GWh)	Thermal (TJ)
CHP systems in pulp and paper and furniture industry	330	449.1	5 298.5
Automatic wood-fired heating plants >500 kW	600	-	9 633.6
Straw district heating plants >500 kW	50	-	802.8
Wood small and medium-scale boilers >500 kW	5 500	-	88 308
Straw small and medium scale-boilers >500 kW	45	-	722.5
Biogas plants (CHP and DH) – *data from 2000*	38.9	72.5	250
Landfill gas plants (CHP and DH) – *data from 2000*	15.9	59	102

* MW thermal electricity.
Source: ECBREC and GUS, 2002.

Detailed analysis of the potential market for biomass suggests exceptional prospects for the development of bioenergy in Poland. Solid biofuels may play a very important role in the development of energy systems in rural areas over the short and mid term. Elaboration of policy governing renewable energy in the immediate future should provide a major factor of support to the development of bioenergy. Current, short-term needs in the field of solid biofuel utilisation include (among others):

- Proven, small-scale technologies for domestic dwellings (<40 kW) – effective from both the ecological and economical point of view;
- The implementation of intensive district heating, based on straw-fired technologies (0.5-5 MW);
- The import or production of full-chain equipment (*i.e.* chippers, forwarders, transporters, container-handling and storage facilities) for forestry fuel production; elaboration and implementation of local forestry wood fuel production; and also
- Demonstration projects, and developing experience in planning, consulting and implementation of medium-sized projects.

In Poland the production of wood briquettes began the early 1990s, while production of wood pellets started only 2-3 years ago. Currently, pellet producers have just begun to penetrate the EU pellets market and initial experience indicates positive prospects, especially when dry sawdust is available at a low price or free of charge. However, analysis of wood-waste management reveals a limited surplus of dry by-products, as the majority of waste flows out for the production of wood boards and other purposes. Wood briquettes (roughly estimated production – over 100 000 tonnes per year) are produced for the Polish and the EU market, while pellets are exported to Germany, Denmark or Sweden. Data on production levels for pellets have not yet been confirmed, as the market is still in the initial phase, but current production can be estimated at 20 000 tonnes per year.

Bioenergy financing

Over recent years a strategy has evolved of strong financial support for bioenergy use for district heating and for industrial projects. On average, all investments in industrial and district heating applications have been supported with investment subsidies of 30-50%. A rough estimate is that over PLN 40 million and 20 million has been made available, respectively, in the form of investment grants and soft loans to subsidise bioenergy investments since 1990, mainly through national and bilateral financing.

Some of the industrial and district heating projects based on bioenergy were funded through bilateral co-operation programmes with Sweden, Denmark, Finland and the Netherlands. Looking forward (to at least 2010), rough projections indicate that the annual budget for bioenergy may fluctuate between PLN 10-20 million: however, larger bioenergy projects are currently envisaged (including industrial CHP systems) – therefore the budget may potentially be doubled or even tripled.

Following accession in 2004, it is anticipated that EU structural funds and coherence funds will be utilised to promote an increase in bioenergy applications, especially in the areas of rural district heating, biomass production and agriculture. Since 2002, the Special Accession Programme for Agriculture and Rural Development (SAPARD) has been preparing the way for the implementation of bioenergy technologies. It provides support for three types of activities: conversion and marketing of agricultural products; investment in farms; and the development of rural infrastructure (the latter may include bioenergy development in rural areas).

There are also expectations that JI-projects (such as the Kyoto Protocol flexible mechanisms) will provide a source of funding for bioenergy investments. Since 1995 several AIJ and JI pilot projects have been implemented in Poland, notably in conjunction with Norway, Canada, Finland and the Netherlands. Poland has signed Memoranda of Understanding with Canada, Finland, and the Netherlands, and others are currently under development. National guidelines for JI are being drafted, showing that 50-130 Mt CO_2 equivalent may be available for the first commitment period. National priorities for JI are renewable energy (especially small and medium-scale biomass district heating and wind), CHP, energy efficiency improvement and forestry activities.

Summary

Taking into account analysis made of both the utilisation and the technical potential of renewable energy sources in Poland, it can be seen that biomass use for heating purposes and co-combustion in large plants will be the first sector to expand, as these are very cost-effective options. In the medium term, bioenergy production will play a crucial role in the development of renewable energy in Poland and is foreseen to be the main contributor to the green electricity target (surpassing wind and water). The development of biofuels for the transport sector will depend on the eventual outcome of political decisions.

The proposed actions to be taken in the near future to enhance the development of the RES sector have already been set out in the Polish National RES Strategy. The most important tasks that are estimated to guarantee dynamic RES energy production in Poland can be described briefly as:

- Legal regulations in the RES sector, *e.g.* the RES Act.
- Introduction of the economic mechanisms supporting the RES industry *i.e.* development of innovative systems such as tradable Green Certificates.
- Educational and promotional activities, as well as international co-operation for the benefit of RES.

One of the most important actions concerning bioenergy utilisation in Poland was the elaboration of a long-term strategy for the development of the bioenergy sector. Its main objective is an assessment of the country's potential to contribute to the development of biomass energy technologies and production technologies for liquid, solid and gaseous fuels. It also gives an appraisal of support given to the process of integrating Polish agriculture with EU agriculture. The strategy should aid:

- the attainment of the targets for the share of RES in the energy balance;
- the implementation of the Kyoto Protocol;
- the improvement of energy security in the enlarged EU of 25 countries; and it should also
- help identify conditions for the sustainable development of rural areas (*i.e*. by giving an assessment of external costs and benefits).

These plans, which will shortly be put into action, will enhance the development of the bioenergy market in Poland but it is evident that close regional co-operation, especially with neighbouring countries, would produce a stronger synergic effect, through better transfer of experience/technology and the development of common standards and financial frameworks for joint projects.

In conclusion, it should be stated that despite major expectations (*e.g.* the National RES Strategy for Poland) and forecasting for technical opportunities relating to bioenergy deployment in Poland (ESD and EC BREC, 2001), the sector faces difficulties in entering the market due to various imperfections in the Polish legal/policy framework.

BIBLIOGRAPHY

EC BREC [EC Baltic Renewable Energy Centre] (1999), *Economic and Legal Aspects for the Utilization of RES in Poland. Expertise for the Ministry of Environment*. Warsaw: www.ecbrec.pl.

ESD and ECBREC (2001), *The use of SAFIRE model for the modelling of renewable energy development in Poland until 2020*, Expert Study for the Ministry of Environment.

Grzybek A., P. Gradziuk and K. Kowalczyk (2001), *Straw as a fuel*, Warsaw POLBIOM, *in Polish.*

GUS – Central Statistical Office (2003), *Statistical Yearbook of Poland*, Warsaw.

GUS – Central Statistical Office (2001), *Statistical Yearbook of Poland*, Warsaw.

GUS – Central Statistical Office (2000), *Statistical Yearbook of Poland*, Warsaw.

Hunder.M., Rogulska M., Wisniewski G. (2003), *Mapping of bioenergy RTD in Poland*, VIII Polish-Danish Workshop on Biomass for Energy, Starbienino, June 2003.

Ministry of Agriculture and Rural Development URL: www.minrol.gov.pl.

Ministry of Agriculture and Rural Development (2002*a*), *Rural Areas Development Plan for Poland for the Years 2004-2006*.

Ministry of Agriculture and Rural Development (2002*b*), *Project of the Act on biofuels and biocomponents.*

Oniszk-Popławska, A. (2002), "Renewable energy supporting strategies in Poland", ENER Forum 3. *Successfully Promoting Renewable Energy Sources in Europe*. Budapest, Hungary, 6-7 June.

Oniszk-Popławska, A., M. Zowsik and S. Nowakowski (2003), "State of the art and perspectives for development of different biogas technologies in Poland", VIII *Polish-Danish Workshop on Biomass for Energy*, Starbienino, June.

Romaniuk, W. and M. Rogulska (1997), "Methane fermentation of manure with compost production as one of factors for sustainable development of agriculture in Poland", in *Proceedings of International Conference on Sustainable Agriculture for Food, Energy and Industry*, Brunsweig, Germany, 23-27 June.

Council of Ministers (2003), *National Development Plan for the years 2004-2006.*

Council of Ministers (2002*a*), *Initiative, Development, Labour. Economy Strategy of the Coalition SLD-PSL*.

Council of Ministers (2002*b*), *National Environmental Policy for the period 2003-2006 with the 2007-2010 perspective*.

Council of Ministers (2000), *Development Strategy of the Renewable Energy Sector*.

CONDITIONS FOR THE INCREASED MARKET PENETRATION OF SHORT ROTATION COPPICE FOR ENERGY PURPOSES IN SWEDEN

Björn Telenius and Paul Westin[1]

Abstract

Willow short rotation coppice started as a research and development project in the late 1970s and Sweden is a world leader of research and development and commercial development of short rotation coppice. The research and development and end-use is driven by national energy policy, but the conditions for market introduction are strongly influenced by agricultural policy at European Union level. During the period 1989-96, energy and agricultural policies supported the successful market introduction of short rotation coppice, but between 1997-98 the establishment grants were drastically reduced and plantation activities came to a halt. The grant levels were again raised between 1998-2003 and there is now an emerging optimism among entrepreneurs. During 2003 the Swedish government requested an analysis from the Energy Agency regarding conditions for the profitable large-scale introduction of short rotation coppice. The following is, by large, an account and summary of the findings in the Energy Agency's report to the Swedish government.

SRC competitiveness

Today's acreage and technology entail a production cost of about EUR 15/MWh (Mega watt-hours). The wood fuel market price is about EUR 13/MWh. Thus, some level of subsidies or market intervention is still needed in order for short rotation coppice (SRC) to be competitive. The national SRC-specific plantation subsidy of EUR 548 per hectare corresponds to about EUR 1.6/MWh. In addition, the European Union (EU) subsidises grain, SRC and other crops with between EUR 168-327/ha/year. Therefore SRC is a viable alternative both for landowners and the district heating industry.

Analyses and estimates in the report show that a total acreage of 100 000 hectares would reduce costs by 20-25%, due to increased production efficiency. This is considerably more than the estimated short-term profit potential from genetic and technological development. It has been estimated that considerable cost reductions will start to become evident at about 30 000 ha. As the cost reductions will come from scale effects, they are permanent and hence constitute a strong argument for temporary subsidies in the phase of market introduction. Another argument for subsidies is that SRC should receive at least the same level of subsidies as grains in order to achieve neutrality of competition. Considering EU agricultural policies and the necessity of restructuring the agricultural sector, arguments for higher levels of subsidies to SRC can also be made. SRC is more energy-efficient than other energy crops and it remains part of the open landscape, since it is harvested regularly.

Computed calculations (based on expert judgments) also showed that in many regions in Sweden the profitability of SRC was higher than for grain production (wheat and barley).

1. Swedish Energy Agency, Eskilstuna, Sweden.

SRC production and market development

Research and development (R&D) has played a very important role in the establishment of SRC. It is especially noticeable that new willow clones are much more productive than traditional ones. Research has also shown that it is vital to manage SRC stands efficiently and that SRC is not suited to unproductive soils. Well-managed stands planted today with modern plant material are expected to produce 8-9 tonnes of dry matter/ha annually (*i.e.* 35-40 MWh/ha/year). Earlier plantations produced considerably less due to poor management and lower-quality plants. New clones are about 50% more productive than the first commercial ones. Continued rapid genetic improvement is expected.

There is a very large market for wood fuels in Sweden today. Well-developed district heating systems, CO_2 tax and other incentives have created a strong market for wood fuels. In the year 2002 almost 100 TWh (Terawatt-hours) of a total energy supply of 600 TWh (of which 150 TWh are nuclear) were comprised of wood fuels, forest residues, waste and peat. The dominant commercial market, apart from the paper and pulp industry's internal use of wood fuels, is the district heating industry. Approximately 45 TWh of district heating is used in Sweden annually, and district heating accounts for more than 40% of the country's total heating demand. About 60% of the district heating companies' fuel mix is covered by wood fuels. SRC combustion properties are similar to fresh wood residues. In a heating plant where willow is used, its share of the wood fuel mix is normally 10-15%.

There is also an interest for SRC and Swedish knowledge transfer in Europe, primarily in Poland and the United Kingdom.

Barriers to SRC expansion

Despite favourable computed assessments of its profitability, SRC expansion is slow, largely due to non-technical barriers. These barriers include the:

- Uncertainty of future agricultural policy changes;
- Low profitability from the first generation of plantations; and
- Tradition and lack of information.

Stable conditions regarding government support schemes and agricultural policy are vital for SRC in comparison with other crops, since the investment in an SRC plantation is more long-term than grain production, which has a one-year cycle (SRC yields full productivity after a period of approximately 5-7 years).

Some of the earlier experiences of SRC developments in Sweden are not relevant today. When plantation grants were raised to a very high level during the early 1990s through until 1996, this attracted plantation activities that were doomed to failure – plantations took place on bad soils and management practices were neglected. It is important that these plantations are not used as examples or points of reference when discussing the possibilities and profitability of SRC.

The cultivation of SRC differs essentially from most other farming activities, and consequently attracts clients different from the farmer's usual customers – therefore good SRC management also requires the development of new knowledge and skills. In addition, information about how to manage and organise production is needed in order to generate greater interest among farmers, as well as in the district heating industry.

A final example of a barrier to the larger-scale development of SRC is that farmers tend to see it as a high-risk project. In addition, many have limited experience of the production system and are wary of the long-term commitment of part of their arable land.

Multifunctional plantations

As in many other new technological systems and new products, successful introduction may start in niche applications. The so-called multifunctional plantations of SRC are some of these niches. SRC has excellent possibilities to produce values outside the energy system. A key characteristic of multifunctional plantations is that they provide benefits – monetary or qualitative – to more than the farmer and the district heating company. Multifunctional plantations that yield monetary value to a third party include:

- Acting as a recipient of municipal sludge and biomass ash; and
- Cleaning of municipal wastewater.

These two examples provide benefits to municipal wastewater treatment and waste handling companies. Municipal sludge should no longer be deposited at dumpsites or landfills. However, sections of the farming community strongly object to fertilising fields used for crop or cattle production with sludge. As it is necessary to fertilise SRC plantations in order to yield good returns, and as the farming community accepts the use of municipal sludge for this purpose, this is a very good niche application and a multipurpose activity. The municipal wastewater company will have lower costs for sludge treatment and the farmer will yield higher returns on the plantation. It is a win-win situation.

Biomass ash should be returned to the soil in order to reach a sustainable biomass production system. Minerals should not be depleted in the soil. Biomass ash recycling in the forestry industry is difficult, but for SRC it is quite easily done.

SRC is also an excellent alternative to other more costly alternatives for lowering dissipation of nitrogen into the environment, especially into lakes, rivers and eventually the Baltic Sea.

A multifunctional plantation measure that is attractive to some farmers is to arrange plantations with passages that allow birds, deer and other game to enter the plantations. Farmers who arrange hunting parties in these types of plantations can expect higher hunting revenues due to an increased value for the hunters.

Other multifunctional benefits that may be of value to society (and thus should be measured as national revenues), but which are difficult to internalise, include:

- Reduction of soil cadmium concentration;
- Increased carbon storage in the soil; and
- Higher levels of biodiversity.

Some SRC clones are effective in accumulating cadmium and, according to estimates, as much as 8% of Swedish soils have cadmium concentrations that could be hazardous to human health when used for food production. SRC could be used for cadmium concentration reduction, and the cadmium could be recovered in the district heating plant emission cleaning system. In countries with less developed markets for solid biofuels, the value of multifunctional plantations may be even higher than in Sweden.

Conclusions

- SRC production costs are similar to wood fuel prices. In many regions SRC is competitive with grain production. High risks and non-technical barriers limit its expansion.

- SRC is one of the most competitive new renewable energy sources and conditions are good for substantial market growth. However, with respect to energy supply, it should be regarded in the long-term perspective.

- Increased acreage has top priority and will generate substantial permanent cost reductions, *i.e.* subsidies are well motivated and can subsequently be phased out.

- Stable agricultural policy conditions are vital.

- Multifunctional SRC plantations have an important role in the market introduction phase.

BIOMASS USE AND POTENTIAL IN TURKEY

F. Taner, I. Ardic, B. Halisdemir and E. Pehlivan[1]

Abstract

Worldwide interest in finding new energy sources continues to increase and researchers are attempting to discover economic and renewable energy sources. One such source is biomass, which can be used both as an energy source and as basic material for chemical feedstock. In this study, the potential importance is assessed, and the use of certain types of biomass determined, by assimilating statistical data on: agricultural products (vegetables, fruits and livestock); the annual amount, per capita, of non-recyclable components contained in municipal solid waste; the results obtained from experimental studies and the existing literature on the properties of biomass. Estimates based on available statistical data and the results of the experimental studies suggest that the annual dry biomass potential (excluding waste) is about 360 Tg, which is equivalent to 260 Tg of crude-like fuels. The available agricultural and animal residues can provide the 467-623 petajoules/year and 50.172 petajoules/year, equal to 22-27% of energy consumption in Turkey. This will be doubled on completion of the GAP (South-east Anatolian Project). The GAP is a programme designed to collect all types of biomass and develop their use. It can be concluded that the efficient conversion of a biomass source into an energy source offers a partial solution to the energy problem in Turkey. In order to achieve a sustainable solution to the energy problem, systems for converting biomass into energy must be improved, and research must be concentrated on the conversion of biomass into conventional fuel – solid, liquid, or gas – thus reducing the use of fossil fuels.

Introduction

Many countries are trying to use their national energy sources efficiently. The scarcity of energy has created the need to discover new energy sources and ways of converting them into conventional fuels. One of these sources is, of course, biomass that is produced naturally and/or produced as a result of industrial processes (such as occurs in the production of fruit, vegetables, or livestock); the treatment of wastewater to remove water-soluble organic compounds; and the processing of wood and municipal solid waste.

With the recent negotiations surrounding the Kyoto Protocol and growing awareness of the limits of traditional approaches to energy use, the urgent need to develop more climate-friendly energy technologies is becoming recognised worldwide. Renewable energy technologies are receiving heightened attention, and modern biomass-based energy (the use of wood, crop residues and dung as fuel) is increasingly seen as an important component of the transition to a low-carbon energy future (Barnes and Floor, 1999).

1. University of Mersin, Mersin, Turkey.

As a renewable energy source, biomass has several compelling features. Biomass can provide electricity on demand rather than intermittently, as is the case with solar and wind power. It can be turned into liquid fuel, such as alcohol, or transformed into gaseous fuels through gasification. In addition, the production of biomass can be integrated with wasteland restoration through programmes for rural economic development. These benefits could be realised over the coming decades if sufficient research is devoted to promoting the development of the related technology, such as direct combustion generation of electricity and gasification. It would also be necessary to lower the current costs of these technologies to encourage the expansion of markets for biomass energy (US Congress of Technology Assessment, 1992).

In order to evaluate biomass, it is necessary to consider the properties of all known kinds of biomass species. Ultimate analysis of biomass is very important in order to determine the theoretical air-fuel ratio in thermoconversion systems, to calculate the energy that will be produced from it, and also to predict potential pollution. It was reported (Suarez *et al.*, 2000) that the major elemental constituents of biomass are carbon, oxygen and hydrogen. The mass fraction of carbon ranged from 38.2% (rice husk) to 48.8% (soplillo); hydrogen from 5.6% (rice husk) to 7.0% (bagasse); and oxygen from 33.7% (rice husk) to 43.7% (coffee husk).

Very low nitrogen content (0.3-0.83%) compared to coal (1.0-1.5%), very low sulfur content (0.01-0.15%) compared to coal (0.5-10%), and a low chlorine content (0.01-0.1%) have been reported (Ebeling and Jenkins, 1985; Walter and Overend, 1998; Mansaray and Ghaly, 1997; Gulijurtly and Cabrita, 1998). The low presence of these elements in biomass from vegetable sources offers more environmentally friendly properties (Mansaray and Ghaly, 1997).

A study (Singh *et al.*, 2000) considers the prospects and perspective of bioenergy in India and concludes that biomass has immense potential in the Indian context and all efforts should be made to make optimum use of it.

In Lithuania, renewable energy projects within the framework of the National Energy Efficiency Programme aim at reducing imports of energy resources, improving environmental conditions and lessening the impact of climate change. It has also been noted that the use of biomass (woodchips, processing wastes, sawdust, straw, etc.), biogas and also small-scale hydro energy sources is increasing in Lithuania (Katinas and Skema, 2001).

Biogas production from biomass appears to have potential as an alternative energy for countries that are potentially rich in biomass resources, such as Sudan (Omer and Fadalla, 2003), Denmark (Meang *et al*., 1999) and Guadeloupe (Tarkowski and Uliasz-Misiak). In Denmark, centralised biogas plants have been able to increase gas production as a result of combining industrial organic wastes with manure, and in Guadeloupe waste from stock-farms, solid communal waste and waste biomass from forests is being used for biogas production.

Liquefaction is one of the energy conversion processes. Solid biomass is converted into liquid fuels by thermochemical treatment. The generation of tars, oil and chars from plant material and its various components has been a subject of study for over a century. Research is aimed at improving the conversion of biomass into fuel (oil and biogas). Much research has been undertaken, worldwide; development of technologies from the experimental results is underway and, in addition to the instigation of a pilot system, large-scale systems have been established. Appell *et al*. (1975) have extensively studied the conversion of cellulosic wastes into liquid fuel in aqueous alkaline media. Some liquefaction experiments have been applied to various lignocellulosic waste materials in aqueous solutions of acetic acid and sodium hydroxide in the laboratory (Taner 1986*a*; 1986*b;* 1988; Taner *et al.*, 1989).

Liquid hydrocarbon oil and water have been produced from the liquefaction of cellulosic matter present in municipal solid wastes. The resulting pyrolytic oil and water fraction seemed to be contaminated with considerable amounts of oxygen compounds as compared with fuels derived from a petroleum origin (Gharieb *et al.*, 1998). Celeghini *et al.* (1998) studied the experimental variables' effects on direct liquefaction. This study provides information on how a sugarcane bagasse lignin was submitted to a liquefaction process to obtain light oil. In another study (Jongwon, 1999) the effect of the addition of lignin to coal during liquefaction, by utilising the black liquor waste stream from the pulping process, is investigated. Liquid products obtained from pyrolysis of synthetic blends of Turkish oil shales and lignites in experimental studies are discussed in Sensoz *et al.*, 2000.

Other research in Turkey discusses the process of liquefaction of Verbascum stalk. In this study, the Verbascum stalk was converted into liquid products by using organic solvents, such as methanol, ethanol and acetone, with and without a catalyst, in an autoclave at temperatures of 533 K, 553 K and 573 K (Cemek *et al.*, 2001).

Sources of biomass in Turkey

There are very many sources of biomass in Turkey. Agriculture is the main activity and represents a large share of gross national income. Agricultural activities are concentrated on the production of industrial plants used for the production of industrial products – e.g. edible oil from sources such as olives, cotton seeds, sunflower, peanut and corn (Table 1). Two sources of biomass result from this type of agricultural production, the first being the residue left on the fields after harvesting, and the second, the waste produced during processing of the agricultural products into industrial products. For instance, after harvesting soyabeans, the plant material left on the field is a source of biomass; in addition to which, following the production of soyabean oil, the residue remaining after the oil has been extracted from the soyabean grain is a second source of solid waste biomass produced by the oil industry. In the same way, all agricultural production leads to the production of two sources of biomass, one from the field and one from industry.

Crop wastes

These are mainly residues from the production of industrial agricultural products, such as cotton stalk, corn stalk, sunflower stalk, tobacco stalk, sugarbeet leaves, potato leaves, soyabean stems, straw, rice stalk, etc. (Table 1). As part of the preparation of the soil for the next plantation, all the remaining biomass is burned on the field. Only a small fraction of the biomass which is freely available for collection by local inhabitants is used for heating purposes. At present, there is insufficient knowledge of the production rate of the diverse types of biomass produced by various methods.

Vegetable waste

After harvesting the crop, the stems and other remaining parts of the plant are left in the fields. Some of this residue is suitable for use as animal feed, some is stacked and allowed to decompose naturally, to produce organic fertiliser, and - in the absence of a collection system - the rest is burned on the field, and is thus lost. It has been reported (Acaroglu, 1999; Kaygusuz *et al.*, 2002, Taşdemiroğlu, 1986) that the annual amount of agricultural residue and animal waste is 50-65 Mt/year (dry) and 11.05 Mt/year (dry) respectively, of which 60% is available for energy production. Potentially, agricultural and animal residues represent the equivalent of 22-27% of energy consumption in Turkey.

Table 1. Production potentials of main agricultural products in Turkey

FRUITS	2002 Production (Mt)*	VEGETABLES	2002 Production (Gt)**	LIVESTOCK	2002 Production (Head)
Primary Fruit	10 995 550	Wheat	21 000	Sheep	26 972 000
Grapes	3 600 000	Sugarbeet	13 000	Cattle	10 548 000
Apples	2 500 000	Alfalfa for forage & silage	9 645	Goats	7 022 000
Oranges	1 200 000	Tomatoes	9 000	Beehives	4 115 353
Apricots	580	Barley	7 500	Chickens	217 575
Pears	375	Potatoes	5 000	Turkeys	3 254
Avocados	350	Leguminous nes, forage & silage	4 200	Geese	1 398
Cherries	250	Watermelons	3 900	Camels	930
Strawberries	120	Grapes	3 600	Ducks	914
Bananas	70	Maize	2 500	Asses	462
		Seed cotton	2 400	Horses	271
		Onions, dry	2 270	Buffaloes	138
		Cantaloupes and melons	1 900		
		Cucumbers and gherkins	1 750		
		Olives	1 500		
		Chillies and peppers, green	1 500		
		Spices nes	3 221		

Notes: nes – not easily separated

* Mt: Mega tonnes; ** Gt: Giga tonnes.

Source: FAO Statistics, 2002.

Animal manure

Animals are produced for meat, milk, eggs, butter and cheese (these being the basic foods consumed in Turkey). The animals are also used for leather and wool production**.** Animal manure is one of the most important sources of biomass: some is suitable for use as solid fuel for heating in urban areas; some can be used as organic fertiliser on the fields, after decomposing naturally; and recently it has been used experimentally in family-sized biogas digesters, to produce biogas.

Non-recyclable components of municipal solid waste

This is another main biomass source in Turkey and about 0.5 kg/d capita (dry biomass) is produced daily (Taner, *et al.*, 2000). The composition of the non-recyclable municipal waste consists of plant material produced during the processing of agricultural products for food for domestic purposes. The waste is collected by the municipality and is discharged in a dumping area.

Activated sludge

Activated sludge, produced by the biological treatment of wastewater rich in water-soluble organic compounds, is one industrial biomass source. The rate of mass production is not known, but some data are available. It was reported (DİE, 1996) that about 3 200 tonnes/dry sludge are produced annually. Of this, 8.2% is used as fertiliser and the rest is removed to dumping sites.

Agro-food waste

The industrial processing of agricultural products generates a considerable amount of solid waste, consisting of plant material. This is not normally recycled, and is disposed of on dumping sites.

Seaweed

One biomass source that is not well documented is seaweed. It was reported (Taner *et al.*, 2001) that the organic fraction of seaweed can be used for biogas production.

Properties and potential of biomass in Turkey

The main source of biomass in Turkey is plant material, produced at various stages of agricultural production. Very many kinds of biomass species are produced. Some of their properties and potential are shown in Table 2. The annual biomass production rate from livestock and some of its properties are shown in Table 3. As can be seen from these tables, the annual production rate of biomass is high and needs to be used efficiently.

The energy potential expressed in tonnes of oil can be estimated by the amount of biomass generated over a given period and the respective higher heating values. Table 4 shows this result, taking into account the annual production of these crops in 2002 (FAO, 2002).

Estimates have indicated that the annual energy potential of agricultural residues (47 656.78 Gg/year of biomass) (Table 4) is equivalent to the energy of approximately 3.10 Gg of fuel-oil, which equals 22-27% of Turkey's annual crude oil production. A development programme must be conducted in Turkey to ensure the efficient exploitation of renewable energy resources. Great interest has been shown in biomass, due to the large amount produced each year, especially cotton stalk, corn and sunflower stems. Combustion is the most common way to employ these energy resources.

The higher heating value of the various forms of biomass studied ranged from 16.5 to 22.6 Mega joules (MJ)/kg (dry mass basis), the highest value being for firewood.

The major biomass elemental constituents are carbon, oxygen and hydrogen. The mass fraction of carbon ranged from 38.2% to 48.8%, with the highest value for firewood. The hydrogen weight fraction ranged from 5.6% to 7.0%, and the oxygen weight fraction from 33.7% to 43.7%, showing that biomass is a highly oxygenated material.

Table 2. Elemental composition and some properties of some agricultural residues

	Elemental Composition (%) on a dry basis					Proximate Composition (%) on a dry basis			
Biomass type	Carbon	Hydrogen	Oxygen	Nitrogen	Sulphur	Ash	VM	FC	HHV (MJ/kg)
Wheat straw	46.7	6.3	41.2	0.4	0.1	5.3	79.63	16.75	18.4
Barley straw	46.3	6.4	43.4	0.3	0.1	3.5	73.84	18.84	17.1
Oat straw	47.8	6	41.2	0.4	0.1	4.5	83.02	15.01	17.7
Rye straw	46.3	6.02	43.47	0.13	0.11	3.97	78.88	17.04	17.7
Rice straw	41.78	4.63	36.57	0.7	0.08	16.24	69.33	17.25	15.3
Maize straw	45.6	5.4	43.36	0.3	0.04	5.3	--	--	16.8
Corn cobs	46.58	5.87	45.46	0.47	0.01	1.61	80.1	18.54	17.6
Maize stover	43.65	5.56	43.31	0.61	0.01	6.86	75.17	19.25	16.5
Cotton stover	47.05	5.35	40.77	0.65	0.21	5.97	73.29	21.2	17.2
Rice Husk	38.2	5.6	33.7			22.5			16.47

Notes:

Volatile Matter: VM; Fixed Carbon: FC; HHV: Higher Heating Value.

Source: Acaroglu, 1999.

Table 3. Number of livestock and the potential of livestock wastes in Turkey in 1995

Type of livestock	Daily Production of fresh manure (kg/d AU)	Solid matter (% by mass)	Daily production of dry manure per AU (kg/d AU)	Available dry matter (kg/d AU)	Number of livestock (1995)	Animal Units[1]	Production rate of dry biomass (t/d)
Milk cows	33.33	12.70	4.23	2.75	6 008 000	6 008 000	16 534.02
Meat cattle	34.68	11.60	4.02	1.01	5 781 000	5 781 000	5 815.69
Hens and roosters[2]	25.29	25.00	6.32	6.26	126 135 000	555 661	3 478.48
Sheep and goats[3]	16.44	25.00	4.11	0.53	42 902 000	4 724 890	2 523.10
Horses, donkeys, mules[4]	37.71	21.00	7.92	2.30	1 315 000	724 119	1 663.30
Turkey	26.62	25.00	6.65	4.53	3 291 000	57 992	262.41

Notes:

1. One Animal Unit (AU) = 454 kg
2. Mass of hens and roosters = 2 kg/head
3. Mass of sheep and goats = 50 kg/head
4. Mass of horses, donkeys, mules = 250 kg/head

Source: Acaroglu, 1999.

The experimental results of proximate analysis; the higher heating value of several kinds of biomass; and the mass percentage of waste plant material (namely non-recyclable domestic waste produced by the residents of Mersin) were used to calculate the energy equivalent and potential of the biomass. Based on these results, an estimate was made of the energy potential from waste produced by processing agricultural products used for domestic consumption and residues left on the field after harvesting. It was determined that biomass has great energy potential, due to the particular properties of the biomass produced in Turkey (Halisdemir, 2001) (Table 4).

Use of biomass in Turkey

In Turkey, insufficient attention is being given to the potential for biomass use and the benefits it can offer. However, a small number of combusting technologies for the treatment of hospital waste are in operation, and an attempt has been made to solve the environmental problems arising from solid waste disposal, by establishing solid waste treatment plants. The various methods of utilising biomass depend on the type of solid waste involved. The energy equivalents of various biomass species are given in Table 4 (Halisdemir, 2001).

Direct combusting

Woody biomass is used for domestic heating purposes in the countryside. Firewood is also introduced directly into bakery furnaces and wood stoves to increase the temperature and improve the aerodynamic properties in the combustion chamber. The gases generated by the process do not combust and are evacuated in the form of smoke: the presence of some particulates can also be noted near these installations, both airborne and at ground level. In addition to wood, other forms of agricultural waste, such as coconut shell or olive stones, are recuperated by residents living in the neighbourhood of the processing plants and burned as domestic fuel.

Composting

Composting is another biomass conversion process. Composting and the use of compost are very common solid waste disposal methods in Europe and the United States. Composting in Turkey is concentrated in regions such as Istanbul, Gebze and İzmir. There is a wide variation in efficiency, however, with the composting and recycling plants in the city of Istanbul operating at a capacity of 1 000 tones per day (Bastürk *et al.*, 2001), and in Kemer-Antalya, at only 150 tonnes per day (Erdem *et al.*, 2001).

In Istanbul, composting is achieved through a process of introducing pressurized air into the waste material. Compost formation is completed in 8 weeks using this method, with 1 000 tonnes of solid waste a day processed by the Compost and Recycling Establishment, 500 tonnes of which enters the fermentation unit for composting (ISTAC, 2003). The compost produced in Istanbul is used to improve the quality of the city's public parks, open spaces and sports fields.

New conversion technologies have been developed for biomass energy exploitation, such as pyrolysis, gasification, liquefaction, and direct combustion (Bridgwater, 1994). Unfortunately, most countries have failed to develop these systems adequately for various reasons, one being the unidentified physical and chemical properties of the specific forms of biomass produced in each country.

Table 4. Annual production rate, properties and energy equivalents of biomass in Turkey, 2001

Types of Waste	Annual biomass production	Annual biomass production	Moisture	Ash	HHV*	Annual biomass energy pro-duction	Energy equivalency	
	(Gg/yr)	(Gg/yr) (dry)	(%)	(%)	(MJ/kg) (dry)	(Pj/yr)	Fuel oil (Gg)	Electricity (Gwh)
Kitchen Wastes	7 959.39	4 133.88	48.0	13.0	11.15	46.148	1.0680	12.819
Cattle	119 542.29	26 299.30	78.0	16.7	19.20	504.95	11.6900	140.260
Sheep/goats	17 021.15	5 957.40	65.0	25.0	31.20	185.87	4.3000	51.630
Poultry	17 575.08	4 921.02	72.0	26.0	30.20	148.61	3.4400	41.280
Cucumbers	1 470.00	16.42	94.9	3.3	17.45	0.287	0.0070	0.079
Eggplant	915.00	34.13	84.9	5.2	15.92	0.543	0.0130	0.151
Tomatoes	8 290.00	8.73	88.3	3.1	14.67	0.128	0.0030	0.035
Stuff peppers	390.00	9.37	87.8	5.1	14.54	0.136	0.0030	0.038
Green peppers	1 010.00	13.06	85.3	4.2	12.96	0.169	0.0039	0.047
Potatoes	5 250.00	111.72	82.7	5.7	16.28	1.819	0.0421	0.505
Carrots	232.00	5.82	88.5	4.6	16.79	0.098	0.0023	0.027
Lettuces	300.00	6.98	88.7	3.3	13.52	0.094	0.0022	0.026
Maize	2 300.00	347.06	71.9	4.5	18.77	6.514	0.1508	1.810
Dry Onions	2 270.00	22.09	70.5	5.9	14.96	0.330	0.0076	0.092
Fresh beans	455.00	2.96	75.9	4.9	15.68	0.046	0.0011	0.013
Lemons	390.00	27.06	73.0	5.3	19.54	0.528	0.0122	0.147
Oranges	970.00	95.67	73.2	4.9	20.95	2.004	0.0464	0.056
Mandarins	480.00	34.34	75.5	4.0	19.68	0.676	0.0156	0.188
Grapes	3 600.00	49.90	78.0	5.3	20.05	1.005	0.0232	0.278
Apples	2 450.00	75.87	82.1	2.6	20.96	1.590	0.0368	0.442
Watermelons	3 930.00	126.39	92.0	8.5	16.25	2.054	0.0475	0.571
Melons	1 885.00	75.46	85.6	6.4	16.43	1.240	0.0287	0.344
Bananas	32.00	1.59	87.3	8.9	15.48	0.025	0.0006	0.007
Apricots	490.00	6.90	75.3	1.0	19.37	0.134	0.0031	0.037
Kiwis	700.00	20.42	84.4	6.0	20.01	0.409	0.0095	0.114
Grapefruit	100.00	8.33	74.2	5.3	20.66	0.172	0.0040	0.048
Walnuts	120.00	68.77	12.9	1.2	21.20	1.458	0.0337	0.405
Hazelnuts	580.00	57.12	33.0	3.3	20.14	1.150	0.0266	0.320
Almonds	36.00	9.22	10.5	2.1	20.34	0.188	0.0043	0.052
Rice	179.00	unknown	11.8	4.0	14.80	-	-	-
Chickpeas	625.00	unknown	9.9	6.3	13.04	-	-	-
Lentils	100.00	unknown	12.7	5.4	13.21	-	-	-
TOTAL	**47 656.78**		**-**	**-**	**-**	**17.1**	**3.10**	**16.6**

Note: * Higher Heating Values. Source: Halisdemir, 2001; and SIS, 2001.

Biogasification

Biogas is produced in land-fill areas. There are a few, medium-sized biogas plants in operation, but the use of animal wastes for biogasification must be evaluated.

Animal food and fermentation

Sugarbeet leaves are a source of animal food. Molasses are used in the production of yeast, necessary for bread-making. Some forms of biomass are used in the production of various materials for medical purposes**.**

Result and discussion

The higher heating values are important thermal properties for the design and evaluation of thermochemical conversion systems. The HHV of plant material ranges from 15-22 MJ/kg (dry), depending on the plant species. Rice husk showed the lowest heating value – only 16.47 MJ/kg, confirming the fact that an increase in ash content results in a fuel's lower energy (Mansaray and Ghaly, 1997).

Biomass has an energy content of about half that of coal and is, therefore, an important energy source for countries like Turkey, which rely heavily on imported fuel (Tables 5 and 6). However, fossil fuels continue to be important to energy production in Turkey, as in the rest of the world, and studies and projections show that this is unlikely to change over the next twenty years. According to the estimates of total cereal and oilseed production, approximately 50-65 Mt of biomass are produced annually in Turkey, of which 60% can be used to produce energy. If currently unexploited sources of biomass were to be added to the biomass already available, all the energy needs of the country could be met. It has been calculated that up to 27% of Turkey's energy needs can be covered by biomass that is currently available.

The main energy problem affecting the impoverished populations of the Third World, especially in Sub-Saharan Africa, is their heavy reliance on biomass resources to meet household and agro-industrial needs. In most rural areas of Asia, biomass is the principal fuel used for cooking and heating, and there is little likelihood that this trend will change in the near future. Rural populations, in particular, rely on biomass fuels to meet well over 90% of their energy requirements. Even with dramatic increases in fossil fuel use, biomass will continue to be a critical part of the energy-mix in developing countries, where wood and dung can be as important as oil and natural gas.

Biomass energy problems are now better understood, and appropriate solutions are available for different sets of circumstances. The move to petroleum-based fuels has given rise to the existence of a wider range of options today. These include using biomass in more efficient ways, whether by means of improved stoves, or by using biomass for generating electricity for local, regional or national grids. In this regard, large international energy firms have begun to exploit sources of renewable energy, including biomass, for their financial potential. The availability of data on the production rates and the properties of biomass will lead to an improved understanding of how to maximise the development of biomass in Turkey.

These technologies should therefore be actively developed and diversified in order to raise the energy efficiency of the installations, or to obtain different products such as fuel gas, fuel oil, or higher-value products for the chemical industry, whilst at the same time reducing environmental pollution (Bridgwater, 1994; Deibold, 1997).

Table 5. Conventional energy production in Turkey (July 2003)

Years	Coal (Mt)	Lignite (Mt)	Asphaltine (kt)	Natural Gas (Mm^3)	Petroleum (Mt)	Hydro-electric (TWh)*	Geothermal		Wood (Mt)	Animal-Plant Waste (Mt)	Solar (ktep)	Wind (GWh)	Total (Mtep)
							Electricity (Gwh)	Heat (ktep**)					
1990	2.7	44.41	276	212	3.72	23.19	80	364	17.87	8.03	28	0	25.48
1994	2.8	51.55	0	200	3.69	30.59	79	415	18.27	7.07	129	0	26.51
1996	2.4	53.89	34	206	3.50	40.48	84	471	18.37	6.67	159	0	27.39
1998	2.2	65.20	23	565	3.22	42.23	91	582	18.37	6.40	210	6	29.32
1999	2.0	65.02	29	731	2.94	34.68	102	618	17.64	6.18	236	21	27.66
2000	2.3	60.85	22	639	2.75	30.88	109	618	13.94	5.98	262	-	26.83
2001	2.4	63.45	31	312	2.55	24.01	152	618	16.26	5.79	287	-	26.27

Notes: * TWh: terawatt-hours; ** tep: tonnes equivalent to petroleum.
Source: Republic of Turkey, Ministry of Energy and Natural Sources, 2003.

Table 6. Conventional energy consumption of Turkey (July 2003)

Years	Coal (Mt)	Lignite (Mt)	Asphaltine (kt)	Natural Gas (Mm^3)	Petroleum (Mt)	Hydro-electric (TWh)	Geothermal		Wood (Mt)	Animal-Plant Waste (Mt)	Solar (ktep)	Wind (GWh)	Total (Mtep)
							Electricity (Gwh)	Heat (ktep)					
1990	8.19	45.89	287	3.42	22.70	23.15	80	364	17.87	8.03	28	0	52.99
1994	8.19	51.18	0	5.41	25.86	30.57	79	415	18.27	7.07	129	0	59.13
1996	10.89	54.96	34	8.11	29.60	40.48	84	471	18.37	6.67	159	0	69.86
1998	13.15	64.50	23	10.65	29.02	42.23	91	582	18.37	6.40	210	6	74.71
1999	11.36	64.05	29	12.90	28.86	34.68	102	618	17.64	6.18	236	21	74.28
2000	15.39	64.39	22	15.09	31.07	30.88	109	618	16.94	5.98	262	-	81.22
2001	11.04	64.88	31	16.34	29.66	24.01	152	618	16.26	5.79	287	-	77.04

Source: Republic of Turkey, Ministry of Energy and Natural Sources, 2003.

Conclusions

- Turkey lacks fossil fuel energy resources (coal, petroleum, electricity).
- It possesses significant biomass potential [from agricultural, domestic, industrial, natural (seaweed/plant) sources].
- The potential benefits of biomass are not being fully realised.
- Large amounts of biomass are not well documented.
- The amount, production rate and properties of biomass are not properly recorded.
- Some biomass is lost, through waste.
- Research needs to be extended to determine all the parameters for biomass.
- Research and infrastructure must be supported to develop the biomass conversion technology for conventional fuel production.
- RDF (refuse-derived fuel) technologies must be explored and developed to evaluate waste biomass efficiently.
- There is an urgent need to extend the domestic-scale anaerobic digestion systems in the countryside, in order to increase the amount of biogas produced from animal manure, which will consequently reduce Turkey's reliance on imported fuel.

It is becoming increasingly important that biomass be recognised as a potential source of energy, chemical feedstock and organic fertiliser that can supply a sustainable solution to today's environmental and energy problems. Substantial effort must be devoted to the development of biomass use both for the sake of the future and for the conservation of natural resources and the environment.

Acknowledgements

The authors would like to thank Enver Aksoy, of the Ministry of Agriculture and Rural Affairs, Ankara, for his presentation of this paper at the OECD Workshop on Biomass and Agriculture, held on 10-13 June 2003, Vienna, Austria.

BIBLIOGRAPHY

Acaroglu, M. (1999), "The potential of biomass and animal waste of Turkey and the possibilities of these as fuel in thermal generating stations", *Energy Sources*, 21, 4, pp. 339-346.

Appell, H.R., Y.C. Fu, E.G. Illig, F.W. Stafgan and R.D. Miller (1975), *Conversion of Cellulosic Wastes to Oil*, U.S. Bureau of Mines Report of Investigation, No. 8 013.

Barnes, Douglas F. and Willen Floor (1999), "Biomass Energy and the Poor in the Developing World", *Journal of International Affairs*, Vol. 53, Issue 1, p. 237.

Basturk, A. (2001), *Katı Atıkların Kompostlastırılması ve Istanbul Örneği*, UKAK 2001, 11, Ulusal Katı Atık Kongresi, 1. Oturum, ss: 17-23, İzmir.

Bridgwater, A.V. (1994), "Catalysis in the thermal biomass conversion", *Appl. Catalysis a Gen.*, 116, pp. 5-47.

Celeghini, R.M.S. and F.M. Lancas (1998), "Experimental Variables Effects on The Direct Liquefaction", *Energy Sources*, Vol. 20, Issue 7, pp. 673-680.

Cemek, M. and Kucuk, M. M. (2001), "Liquid Products from Verbascum Stalk by Supercritical fluid extraction", *Energy Conversion & Management*, 42, pp. 125-130.

Deibold, J.P. (1997), "Overview of fast pyrolysis of biomass for the production of liquid fuels", in A.V. Bridgwater and D.G.B. Boocock (eds), *Developments in thermochemical biomass conversion*, pp. 5-19. Blackie Academic and Professional Chapman & Hall, London, United Kingdom.

Ebeling, J.M. and B.M. Jenkins (1985), "Physical and chemical properties of biomass fuels", *Transactions of the American Society of Agricultural Engineers*, 28, 3, pp. 898-902.

Erdem, A. (2001), *Katı Atık Bertarafında Kompostun Yeri*, UKAK 2001, 1, Ulusal Katı Atık Kongresi, 11. Oturum, ss: 1-11, İzmir.

Food and Agriculture Organization of the United Nations [FAO] *Agricultural Statistics (2002)*, Rome: http://apps1.fao.org.

Gharieb, H. *et al*. (1998), "Liquefaction of Cellulosic Wastes VI. Oxygen Compounds", *Energy Sources*, Vol. 20, Issue 6, p. 513.

Guliyurtly, L. and L. Cabrita (1998), "Combustion of cork and pine in fluidized bed combustor", in H. Hopetz (ed.), *Biomass for energy and industry*, Proceedings of the International Conference, Wurzburg, Germany, p. 1 398.

Halisdemir, B. (2001), "Determination of Heating Values of Organic Materials in Municipal Solid Waste Components", M.Sc. thesis, University of Mersin, Institute of Basic and Applied Science, Mersin, Turkey.

ISTAC; Istanbul Greater Metropolitan City Municipality Environment Protection and Waste Material Recycling Industry and Trade J.S.CO (2003), Istanbul: www.istac.com.tr.

Jongwon, K. (1999), "Coliquefaction of Coal and Black Liquor to Environmentally Acceptable Liquid Fuels", *Energy Sources*, Vol. 21, Issue 9, pp. 839-847.

Katinas, V. and R. Skema (2001), "Renewable energy policy in Lithuania", *Energy Policy*, 29, pp. 811-816.

Kaygusuz, K. and A. Kaygusuz (2002), "Renewable energy and sustainable development in Turkey", *Renewable Energy*, 25, pp. 431-453.

Mansaray, K.G. and A.E. Ghaly (1997), "Physical and thermochemical properties of rice husk", *Energy Sources*, 19, pp. 989-1 004.

Meang, H., H. Lund and F. Hvelplund (1999), "Biogas plants in Denmark: technological and economic developments", *Applied Energy*, 64.

Omer, M. and Y. Fadalla (2003), "Biogas energy technology in Sudan", *Renewable Energy*, 28, pp. 499-507.

Republic of Turkey, Ministry of Energy and Natural Sources (2003): www. enerji.gov.tr/enerji.

Sensoz, S., E. Putun and O.M. Kockar (2000), "Liquid Products from Pyrolysis of Synthetic Blends of Turkish Oil Shales and Lignites", *Energy Sources*, Vol. 22, Issue 8, pp. 751-763.

Singh, Bimal P., M.R. Panigrahi and H.S. Ray (2000), "Review of Biomass as a Source of Energy for India", *Energy Sources*, Vol. 22, Issue 7, p. 649.

State Institute of Statistics [SIS] (1996), *Environmental Statistics*, Ankara, Turkey.

SIS (2001), *Energy Statistics*, Ankara, Turkey.

Suarez, Jose Antonio, Carlos Alberto Luengo, Felix Fonseca Felfli and Guilherme Bezzon (2000), "Thermochemical Properties of Cuban Biomass", *Energy Sources*, Vol. 22, Issue 10, p. 851.

Taner, F. (1988), *Liquefaction of Cotton Stalk with Acetic Acid and Sodium Hydroxide at 5 Mpa*, VTT Symposium on Non-Waste Technology, Espoo, Finland, 22-23 June.

Taner, F. (1986*a*), *Thermochemical Treatment of Solid Waste Obtained From Wastewater Treatment Plant of Pulp and Paper Factory with Acetic Acid*, Proceedings of the 3rd International Symposium MER3, 18-20 March, Antwerp, Belgium, pp. 7.67-7.73.

Taner, F. (1986*b*), *Thermochemical Treatment of Cotton Stalk*, International Conference on Renewable Energy Sources, 18-23 May, Madrid, Spain.

Taner, F., M. Eryılmaz, F. Yücesoy Eryılmaz and E. Erkurt (2001), "Biomass potential in the Black Sea, Marmara Sea, Aegean Sea as a Biogas Source," 18th World Energy Congress, Buenos Aires, Argentina, 21-25 October.

Taner, F., B. Halisdemir and E. Odabaşı (2000), "Separation, Collection and Transportation of MSW - a Case Study in Turkey", in B. Nath *et al.*, *Sustainable Solid waste Management in the South. Black Sea Region*, Kluwer Academic Publishers, Sofia.

Taner, F., U. Kimyonsen and G. Ersoz (1989), *Thermochemical Treatment of Cotton Stalk with 5% Acetic Acid and NaOH at 10 Mpa Initial Pressure*, Proceedings of the 5th Environmental Science and Technology Conference, Adana, Turkey, p. 341.

Tarkowski, R. and B. Uliasz-Misiak, "Renewable energy sources in Guadeloupe" *Applied Energy* (in press).

Taşdemiroğlu, E. (1986), "Biomass Energy Potential in Turkey", Proceedings of the 1986 International Congress on Renewable Energy Sources, pp. 148-165.

U.S. Congress Office of Technology Assessment (1992), *Fueling Development: Energy Technologies for Developing Countries*, Report OTA-E-516, U.S. Government Printing Office, Washington, D.C., United States, pp. 214-227.

Walter, A. C. and R.P. Overend (1998), "Analysis of BIG-GT cycles in the sugar cane industry" in H. Kopetz (ed.), *Biomass for energy and industry*, Proceedings of the International Conference, Wurzburg, Germany, pp. 1 158-1 161.

UNITED KINGDOM GOVERNMENT ENERGY POLICY – AIMS AND SUPPORT FOR SUSTAINABLE ENERGY PRODUCTION

Melvyn F. Askew[1]

Abstract

The UK Government recognises that the UK faces a number of challenges in relation to its current use of energy and there are a number of drivers that are currently increasing UK Government interest in renewable sources of energy generation.

The contribution of energy consumption to greenhouse gas emissions, international commitments to reduce these and concerns over the long-term stability of supplies of energy has encouraged the Government to assess critically the future energy policy for the UK. Much of this is reflected in the recently published UK Government *White Paper* (2003), which focuses on plans to create a low carbon economy.

The UK Government is convinced of the impacts of global warming and recognises that it is responsible for 2% of the world's CO_2 emissions (one of the major contributors to global warming). The UK is committed to work to reduce this. The UK Government has set itself a target to work towards a 60% reduction in CO_2 emissions by 2050 (the equivalent of 65 million tonnes of carbon), following recommendations by a Royal Commission on Environmental Pollution. To add focus, a short-term target of a 20% reduction in CO_2 by 2010 has been set (compared with 1990 emission levels). Currently the UK has reduced CO_2 emission levels by 5.2%, but levels are stabilising, so further encouragement is required.

The UK is a net exporter of energy, but this situation is likely to change within the next decade. With the gradual depletion of North Sea oil and gas reserves, the UK will become a net importer of gas by 2006 and of oil by 2010. This increases risks associated with reliability and volatility of supplies. The UK intends to diversify its sources of energy supply and minimise its dependency on external supplies, which is good news for renewable sources of energy – generated from wind, water, biomass or waste.

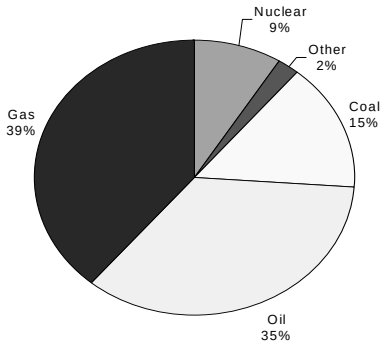
UK energy industry

The UK has an open and competitive energy market and the Government wishes to maintain this to ensure energy remains affordable. The UK electricity supply is heavily reliant upon fossil fuels, with only 3% generated from "renewables" and more than half of this is accounted for by major hydro-electricity projects (Figure 1). This compares unfavourably with Nordic examples like Denmark where almost 17% of energy is derived from renewable resources.

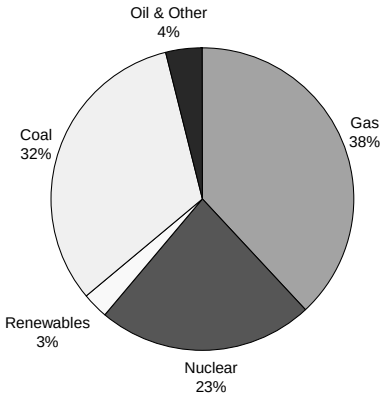
1. Central Science Laboratory (CSL), Sand Hutton, York, United Kingdom.

Figure 1. Primary energy demand and electricity generation, 2002, United Kingdom

Primary Energy Demand in 2002, UK



Electricity Generation in 2002, UK



Source: Author.

The Government recognises that there is a need to update the current generation capacity to comply with European Air Quality measures (REF). There has been little new investment in recent years in anything other than generation from renewables.

The UK electricity supply network is designed for centralised energy generation and supply to consumers and it is recognised that this needs to change to deal with the relatively localised small-scale supply associated with renewable sources.

The Government is keen to increase generation from renewables, stimulate small-scale distributed supplies and encourage the uptake of combined heat and power (CHP) projects – an area where Sweden has recognised expertise. Most CHP in the UK is industrial and the Government would like to double the amount of CHP installed in the UK by 2010.

Stimulation of renewables

As an open free market, the Government does not, and does not wish, to control energy generation and does not have targets for energy generated from different renewable resources. The UK Government policy is to create a framework to encourage adoption of technologies and to stimulate developments. This has resulted in a number of policies and financial incentives to stimulate development of renewable energy generation in the UK which are reported later in this paper. The vision for the energy system in 2020 in the UK is much more diverse than today. At its heart will be a much greater mix of energy, especially electricity sources and technologies, affecting both means of supply and the control and management of demand. For example:

- Much of our energy will be imported, either from or through a single European market embracing more than 25 countries.

- The backbone of the electricity system will still be a market-based grid, balancing the supply of large power stations. But some of those large power stations will be offshore marine plants, including wave, tidal and wind farms. Generally smaller onshore wind farms will also be generating. The market will need to be able to handle intermittent generation by using backup capacity when weather conditions reduce or cut off these sources.

- There will be much more local generation, in part from medium to small local/community power plant, fuelled by locally grown biomass, from local wind sources, or possibly from local wave and tidal generators. These will feed local distributed networks, which can sell excess capacity into the grid. Plant will also increasingly generate heat for local use.

- There will be much more micro-generation, for example from CHP plant, fuel cells in buildings, or photovoltaics. This will also generate excess capacity from time to time, which will be sold back into the local distributed network.

- Energy efficiency improvements will reduce demand overall, despite new demand for electricity, for example as homes move to digital television and as computers further penetrate the domestic market. Air conditioning may become more widespread.

- New homes will be designed to need very little energy and will perhaps even achieve zero carbon emissions. The existing building stock will increasingly adopt energy efficiency measures. Many buildings will have the capacity at least to reduce their demand on the grid, for example by using solar heating systems to provide some of their water heating needs, if not to generate electricity to sell back into the local network.

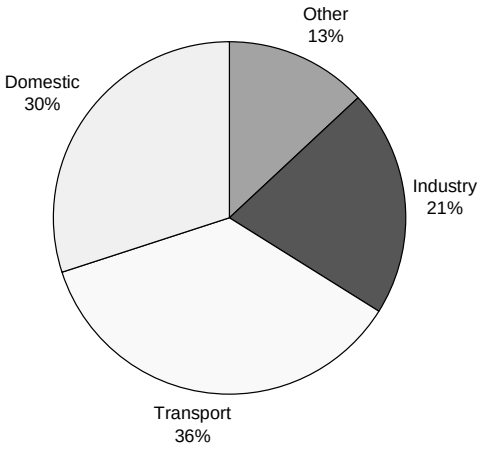
- Gas will form a large part of the energy mix as the savings from more efficient boiler technologies are offset by demand for gas for CHP (which in turn displaces electricity demand).

Coal-fired generation will either play a smaller part than today in the energy mix or be linked in part to CO_2 capture and storage (if that proves technically, environmentally and economically feasible).

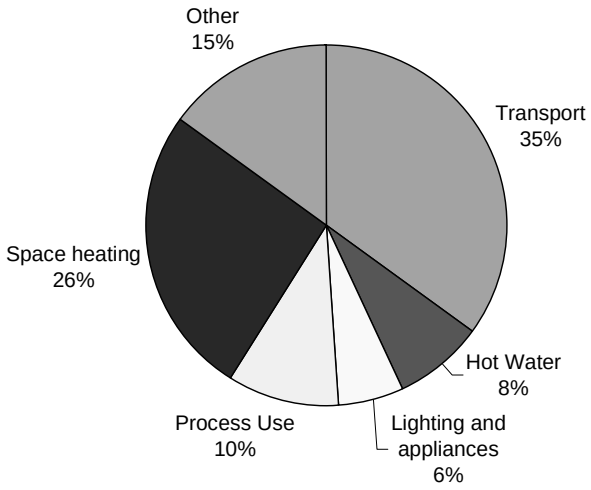
Energy consumption in UK is shown in the following charts.

Figure 2. Final energy consumption in 2002, United Kingdom

BY SECTOR



BY END USE



Source: Author.

Further, the longer-term vision set out in the energy *White Paper* is:

- The existing fleet of nuclear power stations will almost all have reached the end of their working lives. If new nuclear power plant is needed to help meet the UK's carbon aims, this will be subject to later decision.

- Fuel cells will be playing a greater part in the economy, initially in static form in industry or as a means of storing energy, for example to back up intermittent renewables, but increasingly in transport. The hydrogen will be generated primarily by non-carbon electricity.

- In transport, hybrid (internal combustion/electric) vehicles will be commonplace in the car and light goods sectors, delivering significant efficiency savings. There will be substantial and increasing use of low carbon biofuels. Hydrogen will be increasingly fuelling the public service vehicle fleet (for example buses) and utility vehicles. It could also be breaking into the car market.

- Nuclear fusion will be at an advanced stage of research and development.

- People generally will be much more aware of the challenge of climate change and of the part they can play in reducing carbon emissions. Carbon content will increasingly become a commercial differentiator as the cost of carbon is reflected in prices and people choose lower carbon options.

Specific actions

The Government has set a target of generating 10% of the UK electricity demand from renewable resources by 2010, with the aim of doubling this by 2020. This will require generation of 10 000 megawatts by 2010 – currently only 12% of this target has been realised.

The Renewables Obligation is a key policy mechanism to encourage growth to meet these targets. Under the terms of their operating licence, all electricity suppliers are contracted to supply a specific proportion of their electricity from renewable sources, with targets increasing year on year to 2010. This is managed through a system of registered Renewables Obligation Certificates (ROCs) – these have a financial value, which can be traded with those unable to meet their obligations (and who would otherwise have to buy out their obligation at the rate of GBP 30 per MWh). It is estimated that this will provide approximately GBP 1 billion a year in investment for renewable electricity generation.

In addition to this stimulus, the UK Government has a support programme worth GBP 250 million for the support of electricity generation from renewables, which includes provision for capital grants, incentive schemes and research and development.

Bioenergy support

There are a number of existing and planned schemes to support development of biomass for energy production.

Capital Grants Scheme

The bio-energy Capital Grants Scheme is a competitive scheme designed to encourage biomass and crop production for energy by stimulating development of biomass-fuelled heat and electricity generation projects and technology demonstration projects, reducing the risks and costs involved in such developments.

It provides grants of up to 40% towards costs of equipment in complete working installations. It is aimed at large generation and CHP projects fuelled by energy crops and other biomass feedstocks including forestry wood fuel and agricultural by-products.

GBP 66 million was made available under this Scheme. However, the Scheme is currently closed to new applications, as the funding available is likely to be fully allocated to projects already submitted. The case for further funding in this area is currently being reviewed by the Department of Trade and Industry who co-fund the initiative.

The Department for Trade and Industry recently announced that GBP 18 million had been allocated to fund development of 5 biomass-powered electricity plants in England.

Clear Skies Scheme

This Scheme (formerly known as the Community and Household Capital Grant Scheme) aims to give homeowners and communities an opportunity to develop renewable energy projects by providing grants and advice. Grants in this case are relatively small, up to GBP 5 000 for homeowners and up to GBP 100 000 for community organisations.

Energy Crop Scheme

The have also been steps under the England Rural Development Plan to stimulate the development of biofuel crops and the infrastructure to deal with a changing agricultural industry. The Energy Crop Scheme was introduced at the end of 2000. It provides payments to cover the cost of establishing a limited range of energy crops including poplar (*Populus spp*) and willow (*Salix spp*) coppice (*i.e.* cut every 2-3 years) and miscanthus, a perennial grass species commercially grown for energy production in the UK. It provides between GBP 1 000 and GBP 1 600/ha (depending upon land type and receipt of other subsidy payments) for establishing willow or poplar and GBP 920/ha for establishing miscanthus; this covers about half the cost of establishing the crops.

Grants of up to 50% are available towards the cost of establishing producer groups for poplar and willow coppice production. Eligible costs include administration and office costs, equipment purchases and costs of harvesting machinery etc.

Applicants must have a contract with an end user within reasonable transport distance. GBP 29 million has been made available, but uptake has been disappointing so far.

Bioenergy Infrastructure Scheme

Building on the Energy Crops Scheme, a new Bioenergy Infrastructure Scheme will be launched in summer 2003, supported by all UK regions.

It is designed to help develop the supply chain required to harvest, store and supply energy crops and forestry woodfuel to energy end users. It builds on the Energy Crop Scheme by widening the range of eligible energy crops.

Details have yet to be finalised, but it is likely to provide provision for the establishment of producer groups similar to the Energy Crop Scheme and new businesses developing to supply biomass to end users. GBP 3.5 million has been allocated to the Scheme over the next 3 years.

Woodland Grant Schemes

There is a close linkage between energy crops and the use of forest material. Co-firing of energy crops with forestry material would help deliver the Government's objectives set out in the England Forestry Strategy. Development of the woodfuel market would support and improve woodland management while delivering biodiversity, landscape and economic benefits to the rural areas.

There are a number of existing schemes to stimulate the regeneration of existing woodlands or planting of new woodlands. The Woodland Grant Scheme provides grants to create new woodlands and to encourage regeneration of old woodlands by providing planting grants. This scheme also covers planting of short rotation coppice (SRC) in Wales and Scotland in place of the Energy Crops Scheme.

The Farm Woodland Premium Scheme works in addition to the Woodland Grant Scheme and is aimed at the creation of new woodlands on farms and offers annual payments for up to 15 years to compensate for lost income. SRC is not eligible under this scheme.

Government objectives

All of the above Schemes are designed to help stimulate different sectors of the biomass supply and energy generation chain.

In addition, there is a link with strategies to tackle waste problems. Gas derived from landfill waste (*i.e.* buried municipal and industrial waste) is already being used to generate electricity. However, increasing the amount of biomass waste being used for energy production would ease pressure on landfill capacity.

The UK Government has established goals and strategies, which it hopes will support the long-term investment required in the industry.

In addition to the direct grant and incentive schemes, the UK Government is also working with the Electricity Generation Industry and Industry Regulators to overcome some of the other barriers preventing wider uptake of renewables. It is clear that further support is required by the UK power generation and supply network and that small-scale generation is likely to deliver some of the desired outcomes.

Barriers

A number of barriers have been encountered by lead developers in the development of renewable energy sources, and simply gaining access to the supply network is difficult and slow. Discussions with the Industry regulator OFGEM are in progress to try and devise incentives for the Distribution Network Operators to accelerate this process.

OFGEM is also working to reduce the administrative burden on small suppliers. Small generators have been subject to disproportionately large costs resulting from charges associated with balancing the supply/demand on the network. New Electricity Trading Arrangements (NETA) are evolving to deal with such problems.

Obtaining planning consents has been a problem, especially with wind generation. The Office of the Deputy Prime Minister plans to publish new planning advice on "renewables for England" to provide guidance for local planning authorities and developers on the best ways of promoting renewables and to encourage a strategic overarching approach to deployment of projects.

By providing underpinning support for energy crop establishment and for collection and organisation of supply, some of the previous problems associated with securing sufficient supplies of appropriate biomass should be overcome.

Through such supporting measures, the Government hopes that large and small sectors of industry, as well as individual initiatives, take advantage of the initiatives on offer. It is recognised that Sweden has considerable experience in energy generation from biomass and significant experience in small combined heat and power projects. Inward investment and import of technology and experiences from Sweden and the other Nordic countries could provide significant help to the UK in meeting its energy objectives.

BIBLIOGRAPHY

UK Government *White Paper* (2003), "Our energy future-creating carbon economy", 25 February (available in electronic copy at: www.dti.gov.uk/publications/whitepapers.html).

2. North America

Page

The Canadian Situation – Biomass and Agriculture
Dave Tupper, Agriculture and Agri-Food Canada, Canada *465*

United States Support for the Agricultural Production of Biomass: the Challenge of Integrating Energy, Agricultural, Environmental and Economic Policies
Terry Nipp, AESOP Enterprises, Ltd., United States *477*

A Vision and Roadmap for the Bioeconomy in Iowa (United States)
Jill Euken, Iowa State University, United States *511*

Genencor and the Biobased Economy of the Future: an International Biotechnology Company's Perspective on Biomass and Agriculture
Jack Huttner, Genencor International, United States *531*

THE CANADIAN SITUATION – BIOMASS AND AGRICULTURE

Dave Tupper[1]

Abstract

The emergence of bio-products in a marketplace is a complex function of resource supply of that product and its raw materials and by-products, as well as the supply of substitute and competitive products and by-products. This situation is easily analysed. The more difficult calculus is the valuation of benefits and costs which are more difficult to monetise, such as the effects on climate change and clean air. These are transboundary issues which no one individual can monetise. Governments are becoming increasingly sensitive to these effects. The current state of ethanol development in Canada explores some of these issues.

Mankind has been harvesting and utilising biomass from agriculture since Eve gave Adam the apple. The intensity and productivity of agriculture has increased markedly, particularly in the past century with the advent of widespread mechanisation, improvement in plant genetics and more intensive use and management of inputs. For society this has been, by most accounts, a huge success. The growth in food supply has outpaced Malthusian predictions, although there are some profound distributional issues to be resolved. For agricultural producers, the story is different. As productivity has gone up, prices, in real terms, have declined, as have margins. In most developed countries, the farm community is being challenged by the need to manage an ever-increasing span of resources to maintain an acceptable standard of living. The sustainability of farm and rural communities is inextricably linked to the sustainability of the biomass extraction/processing technologies and intensity.

The supply of agricultural biomass

Some commentators begin their discussion of biomass in agriculture with the observation that some countries have a surplus of agricultural biomass – a large supply – which is untapped. The argument is that supply is a necessary, but obviously not a sufficient, condition to exploit the biomass opportunity. In the context of Canada, these assertions resemble the following:

> *Canada is endowed with abundant natural resources and has among the world's most productive agriculture and forest sectors that export grain, meat, lumber, paper and other products to almost every corner of the globe. After all, Canada is steward to 7% of the world's landmass, 10% of the world's forests, 25% of the world's fresh water and is known as the breadbasket of the world.*

1. Agriculture and Agri-Food Canada, Ottawa, Canada.

While Canada does occupy the world's third-largest landmass, it ranks seventh in terms of amount of arable acres (Table 1). More than 50% of Canada's landmass is permanently frozen, and virtually all of the remainder is frozen for some part of the year. In terms of productivity, Canada's wheat yields, for example, are among the lowest in the developed world (Table 2). A significant portion of Canada's arable landmass is challenged by both a short growing season and moisture deficits. This said, Canada does have an appreciable agriculture biomass capacity. However, capitalising on it requires more than an abundance of supply.

Table 1. Arable land – selected countries

Country	Land Area ($000 km^2$)	Rank	Arable Land as a % of Land Area	Arable Land ($000 km^2$)	Rank
Australia	7 682	6	6.2	476	6
Brazil	8 457	5	6.3	532	5
Canada	9 221	3	4.9	451	7
China	9 327	2	13.3	1 240	4
India	2 973		54.4	1 617	2
Mexico	1 909		13.0	248	
Russian	16 889	1	7.4	1 249	3
Ukraine	579		56.4	326	
United States	9 159	4	19.3	1 767	1
World	130 100		10.5	13 660	

Source: World Bank, 2002.

Table 2. Wheat production and yields, 1994-97 average

Country	Production (000 tons)	Yield (tons/ha)
World	563 509	2.52
Australia	16 998	1.71
Canada	25 565	2.24
Central and Eastern Europe	32 523	3.38
EU-15	91 112	5.54
Mexico	3 699	4.08
Ukraine	15 520	2.77
United States	63 380	2.51

Source: USDA, 1998.

The calculus of biomass economics

One of the significant challenges with the use of bio-products and bio-processes is that they are often not cost-competitive with products providing the same services – in strict economic terms. There are however, a number of benefits associated with the use of biomass that are difficult to value in a conventional manner. How for example, can we value cleaner air or community economic health? These are issues that are difficult for individuals to value, but for which there is recognised, albeit intangible, societal benefit. For example, the cost of producing grain-based ethanol is higher than the cost of providing regular gasoline to consumers. Wherever ethanol production and use have prospered around the globe, it has been significantly aided by conditions or benefits provided by governments. Individuals are not inclined to pay more for ethanol-blended gasoline than they would for regular gasoline. However, in those countries where ethanol use is growing, those governments have intervened in the marketplace and have placed some societal value on the non-economic impacts of utilising ethanol. This societal calculus is difficult to quantify, and may indeed be as much driven by political passion as it is by attempts to monetise these non-market impacts. An interesting corollary to this situation is that there are bio-products which are economically competitive and which also possess or engender some of these societal benefits. In these cases, society is capturing a free benefit.

Fuel ethanol as an example of Canadian bio-products

Ethanol production in Canada is modest, about 200 million litres a year. Imports represent another 100 million litres of volume. Total use represents about 0.6% of gasoline volume. However, as part of its climate change programme, the government of Canada has set a target of substituting 10% ethanol (E-10) to 35% of Canada's gasoline supply by 2010. This target translates into 1.4 billion litres, thereby requiring the expansion of the production side of the industry by a factor of seven in the next seven years. When put in these terms, the goal might seem unattainable, but in reality it only requires the building of five to seven world-scale plants. The United States currently has more than 70 plants of this scale and is commissioning new facilities at a rate of more than one per month.

There has been a long-standing interest in the development of a Canadian ethanol industry, with its original champions being found in the agricultural lobby, primarily the corn industry. Canadian corn producers have been seeking, and continue to seek, new markets for corn. The list of benefits cited by proponents of the development of a Canadian ethanol industry are much the same as for any bio-product: environmental benefits, including greenhouse gas (GHG) reductions and cleaner air, increased agricultural incomes, rural employment, an engine of innovation, energy security and the potential for reduced government expenditures in support of agriculture. We will look at these issues in turn after a brief description of ethanol and its production system. The challenges and opportunities facing the development or expansion of Canada's ethanol industry are emblematic of those facing the development of other bio-industries.

Fuel ethanol production and use

Ethanol is made by fermenting almost any material that contains starch or sugar. Grains such as corn and wheat are good sources, but potatoes, sugarcane, and other sugar or starch products are also suitable. Ethanol is a product of fermentation. Starches must be broken down into simple sugars before fermentation can occur. Enzymes, heat and chemical intervention accelerate these processes, which vary somewhat by feedstock. Ethanol has three possible uses in transportation fuel: as an oxygenate, an octane enhancer or as a fuel extender.

The current catalyst for the development of a domestic fuel ethanol industry in Canada is as a component of the climate change plan. There was an early climate change programme, Action Plan 2000, which in part established a goal of 25% of Canada's gasoline being substituted with E-10. This 25% goal was posited to reduce GHG emissions by 0.8 Mt (million tonnes) of carbon dioxide (CO_2) equivalents. The additional 10%, in moving to the 35% target, is posited to reduce GHG emissions by a further 0.9 Mt. This combined effect contributes less than 1% to Canada's Kyoto goal of reducing GHG emissions by 240 Mt by 2010.

CO_2 is the most significant anthropogenic greenhouse gas, and a significant source of GHG emissions is the combustion of coal and petroleum fuels. Substituting biomass, and products derived from biomass, for coal and petroleum products reduces overall GHG emissions because coal and petroleum are not utilised to the same degree. Plant growth (crop production) removes CO_2 from the atmosphere, and some lesser amount is released back into the atmosphere when the biofuel is used as an energy source. The use of biofuels in transportation fuels essentially lowers the carbon content of the fuel. There is however, a reduction of less than 1% in GHG emissions when measured at the tailpipe between gasoline and ethanol.

It has been calculated that the use of ethanol in an E-10 blend, produced from grain (corn or wheat) will reduce GHG emissions, on a life-cycle basis, by about 4%. E-10 produced from cellulose (grain straw, corn stover or wood waste) is calculated to reduce GHG emissions at twice this rate (6-8%), although the technology has yet to be demonstrated commercially. While Canada has an exportable surplus of grain for human consumption, the country is essentially feedgrain-deficient. Canada's livestock herd consumes more feedgrains than it produces. As ethanol is most cheaply produced from feedgrains, any additional demand would likely have to be imported, probably from the United States. While there would be GHG reductions, they would likely be derived from biomass (corn) produced in the United States.

The amount of GHG reduction achieved is a function of the GHG-absorbing capacity of the feedstock, the type of energy used in manufacturing ethanol, and the yield of ethanol, among other variables. For example, if it assumed that hydro-electricity or nuclear power is the primary energy source in the ethanol manufacturing process, the model predicts greater GHG reductions compared to using natural gas or coal as the energy requirement.

One of the critical issues for GHG reductions as part of the Kyoto Protocol is country accounting – how does any one country validate its GHG reduction claims? That remains an issue to be resolved among Kyoto signatories. Validation and ownership of the GHG benefit are critical issues in societal valuation of biofuels. It can be expected that several participants in the ethanol value chain, including farmers, ethanol producers, fuel blenders/retailers, consumers and governments, may all attempt to claim some or all of the GHG benefit. Key to this discourse, and to the issue of the societal value of using biofuels, is the price at which it is valued. While there are nascent CO_2 markets, the price of GHG reductions remains to be determined.

The source of the GHG reductions raises several interesting issues. One is the extent to which the growing of the CO_2-absorbing feedstock is incremental to the Business As Usual (BAU) situation. If, for example, no more corn is grown (domestically or in other countries) to satisfy ethanol demand, it might be difficult to assert that ethanol demand has created GHG reductions. This situation might arise if the demand for corn were to lead to an increase in its price, and corn consumers found substitute products providing much the same characteristics. In fact, in a later section this paper will cite experts predicting this very effect – the production response is much less than the increased demand.

Another ethanol issue within the context of the Kyoto Protocol is where the feedstock is produced. For example, Canada is already a net importer of corn and other feedgrains such that Canada's feedgrains are priced on an import basis. Creating additional domestic corn demands through ethanol production will not increase corn production because there is no commensurate price signal to promote corn production. It might be difficult to claim GHG reductions that flow from the use of imported feedstocks.

Clean air

One of significant drivers in the ethanol programme in the United States has been the oxygenate properties of ethanol in gasoline, which leads to a more complete combustion of the fuel and changes tailpipe emissions. Depending on a number of factors, the use of E-10 blends can have varying effects on air quality. Some "pollutants" are increased, while others decline. Under the 1990 US Clean Air Act, the Oxyfuel Program requires the use of gasoline with 2.7% oxygen (by weight) in areas with high levels of carbon monoxide during autumn and winter. The Reformulated Fuel Program requires 2% oxygen (by weight) throughout the year in the most polluted metropolitan areas. Although other oxygenates can be substituted to some degree, ethanol has become the product of choice, thereby establishing a *de facto* mandate.

One of the chemical properties of ethanol, when added to gasoline, is its effect on raising the rate of evaporation of the fuel – its Reid Vapour Pressure (RVP). Gasoline is formulated to balance these evaporative losses (which in themselves contribute to air pollution) with the need to be reasonably combustible. Ethanol, in blends of less than about 25% raise the RVP and lead to greater fuel evaporation. Blends with a greater than 25% concentration, lower RVP. The technical challenge is to optimise the RVP of the blended fuel. In many areas, however, governments have granted RVP waivers which allow blenders to utilise normal RVP gasoline in ethanol blends, which creates a high RVP fuel. There is a body of thought that suggests that the use of this high RVP fuel leads to an overall deterioration of air quality.

An additional factor to consider in the clean air discussion is its value. Cleaner air has a stronger policy underpinning and value to society if air quality is poor. The extent to which adverse human health outcomes are caused by poor air quality is under the scrutiny of a growing body of investigation. Again, valuation of these outcomes is problematic. The air quality in a number of US cities was the underpinning of the oxygenate mandate in the Clean Air Act, as noted above. In Canada, however, air quality, while not pristine, is not polluted to the same extent as in the larger US metropolitan areas. Some pundits have characterised the use of ethanol in gasoline in this context as a rural solution to an urban problem.

Increased agricultural incomes

In Canada, and in the United States, the agricultural lobby has been one of the main proponents of fostering a domestic ethanol industry. Corn associations have been at the forefront, as corn is the predominant feedstock in the North American ethanol industry. The motivation for agriculture associations is the prospect that increased demand for corn will lead to increased prices and, all things being equal, higher net incomes.

The ethanol industry in the US is currently utilising over 1 billion bushels of corn per year, or about 10% of US corn production. US ethanol production is anticipated to grow from current levels of slightly less than 3 billion US gallons per year, to five billion gallons by 2012. Such growth suggests that almost 20% of the US corn crop would be utilised in ethanol production.

The US Department of Agriculture (USDA) conducted an analysis of this scenario last summer which was transmitted to Senator Tom Harkin 1 August 2002 (USDA, 2002). Increasing the demand for corn has a complex effect within the agricultural sector, as both producers and users substitute commodities in the face of changing price relationships (Table 3). For example, while an increased demand for corn will lead to increased prices, there will be a substitution of corn with other feedgrains (barley, oats, sorghum, etc.) and feed components (soymeal). As prices for these commodities change, users, such as livestock feeders, face rising costs of production and tend to alter their use with resultant livestock production changes. The effect on prices and output varies according to the extent to which substitute inputs can be obtained.

The important observations to be made from these relationships, which are reproduced in other studies, is that from a biomass/agriculture perspective, increased demand for any one commodity will not enjoy a full price response due to product substitution, and may lead to adverse price outcomes within the sector.

These substitution effects can be aggregated and monetised. This USDA study estimated that the net impact on gross farm income in 2011 would be positive USD 700 million, an increase of 0.2%. The effect on net farm income is USD 1.4 billion, an increase of 2.2%.

Interestingly, while the demand for corn is estimated to grow by almost 10% (1 billion bushels), the production response is only 130 million bushels, indicating that the equivalent of about 870 million bushels would be substituted. The revenue effect on the corn sector is easily calculated as the price difference on existing demand volumes plus the new price on the new production response. The net effect is probably confined to the price difference (USD 0.13/bu) applied on all production, as it can be expected that the resources required for the new production had previously been providing corn equivalent returns prior to the new demand. It is also important to note that, as in Canada, less than half of the US corn grown is fed to livestock and never leaves the farm. The value of this part of the corn crop is often cited as a cost of production for livestock rather than a crop revenue.

Table 3. Estimated average market price effects from a Renewable Fuel Standard in the United States

Commodity	Price impact in 2011	%
Corn	USD 0.13/bu	4.7
Barley	USD 0.07/bu	4.7
Soybeans	USD 0.05/bu	0.8
Soymeal	- USD 19.30/ton	- 10.4
Soy oil	4.33 cents/lb	14.7
Steers	USD 0.17/cwt	0.2
Hogs	-USD 0.1/cwt	- 0.3
Broilers	- 1.33 cents/lb	-3.1

Note: bu: bushels; lb: pounds; cwt: hundredweight.

Source: USDA, 2002.

Urbanchuk (2001) provides an analysis of a more aggressive Renewable Fuel Standard (RFS) proposal (8.8 billion gallons by 2016) than was considered by the USDA (5 billion gallons by 2011) and came to more optimistic results. The same commodity substitution relationships are evident, however (Table 4). There is a considerable spillover effect on other commodities. While the USDA study suggested that some commodity prices might actually decline, the Urbanchuk analysis contains the same scale of price relationships albeit where all agriculture commodity prices increase, some more than others. Some of the difference between the two studies may be due to their assessment of the price and use of the distillers dried grains (DDG). An optimistic, protein-related price estimation for DDG would tend to drive up livestock feed costs, and the substitution effect, more than a price estimation that discounts DDG as a feed ingredient difficult to market.

The Canadian situation is highly linked to that of the US. Canadian corn prices are more or less a direct function of US futures prices, plus costs of transportation because Canada is a net corn importer. This relationship implies that as US corn (and other commodity) prices change, so, too, do Canadian commodity prices. Canadian corn producers have already enjoyed a price bump due to the corn ethanol demand in the US. Canadian corn users, such as livestock producers, have also experienced this price/cost increase.

The Canadian climate change target of 1.4 billion litres of ethanol (35% E-10 use) would, if corn were the sole feedstock, require the use of 3.5 million tonnes, about one-third of national production. This would add another 130 million bushels to continental demand, which might cause continental prices to increase by a penny or two per bushel. It could be expected that this demand-price impact would reverberate throughout the agricultural sector as outlined above. The income effect of a corn price increase of about one-half of 1% does not apply to all of Canada's 9 million tonnes of production as less than half of the production leaves the farm. The accounting of the on-farm use is picked up in higher feed costs and probably has a neutral income effect for the mixed farmer growing corn for his/her livestock feed.

From an agriculture biomass perspective, the ethanol example illustrates that the system is very flexible. Where new or greater uses for bio-products create additional demands, there is a substitution effect within the system to achieve a new equilibrium. The production response to a new or increasing demand may often be less than the gross amount of the demand itself, as markets self-adjust and substitute commodities to find least cost solutions.

Table 4. Comparison of analytical impacts on agricultural commodities from the introduction of Renewable Fuel Standards in the United States

(% change in prices)

Commodity	USDA to 2011	Urbanchuk to 2016
Corn	4.7	11.1
Soybeans	4.7	11.8
Steers	0.2	5.9
Hogs	- 0.3	8.3
Broilers	- 3.1	5.1

Source: Urbanchuk, 2001; USDA, 2002.

Rural employment

Another driver for biomass and ethanol is the prospect of rural employment opportunities and rural economic growth. There are a number of studies in this area which come to markedly different conclusions.

In terms of production efficiency, a grain-based ethanol facility is well sized at about 150 million litres of annual production. Such a facility requires about 40 direct employees – or, expressed another way, each employee can produce about 4 million litres per year. A national target of 1.4 billion litres would therefore require about ten efficiently sized plants, or 400 employees.

Economists can estimate the effect on the economy using multipliers, which do vary somewhat by the type of activity. The magnitude of these multipliers is a function of their underlying assumptions. At one end of the spectrum there are other studies, such as Evans (1997) which assert that the 1997 demand for ethanol in the US of 1.52 billion gallons (5.75 billion litres) led to a total increase in employment of 195 200, or about one job for every 30 000 litres. This analysis assumes that all of the economic activity is new to the economy. It is thought that the effect on the economy, due to the substitution of already deployed resources, is much more modest than Evans' estimate.

There is only one world scale-sized plant currently in Canada although there are business plans in progress for a number of other facilities. It seems that many of these proposed ethanol plants will be located at the urban-rural interface in the Great Lakes Basin. Location in the Great Lakes Basin is preferred to obtain access to water, rail or road access to corn imports and is the location where the ethanol demand will be greatest due to the population density. Situating near cities provides access to a ready labour supply and municipal services, while also permitting access to local corn production. Some smaller plants are being proposed near rural communities in western Canada, which will use local feedwheat. It is not known which, if any, of the proposed facilities will come to fruition. The observation is however, that location of the facilities in Canada, and the resulting jobs, are unlikely to be located in remote rural areas; feedstock access, employment opportunity and final demand are factors which suggest that their location will be proximate to existing industrial and urban locations.

Again, the observation that extends to new or alternate uses of agricultural biomass is that location adjacent to local feedstock supplies may not be a critical factor. Firms require a labour pool from which to draw a variety of skilled employees, and access to key municipal services and to alternative feedstock transportation vectors – and situating near final product demand may determine that bio-products will be transformed in or near urban areas.

Engine of innovation

Biofuels is a commodity group which lends itself to innovation. Biofuels are, by most accounts, not cost-competitive with the transportation fuel they substitute. However, as noted earlier, fuel extension is only one potential use. Ethanol's value as an oxygenate, as an octane enhancer and as a differentiated product, are uses with perhaps higher values.

Given their relatively higher costs of production, biofuels are candidates for innovation which would lower costs of production. The focus of research in biofuels seems to take two approaches – improvements in technical efficiencies using existing technologies, and the development of different technologies that utilise lower-cost feedstocks. In this latter category, two Canadian firms are making significant progress; the Iogen company has patented technologies pursuing ethanol production from cellulosic feedstocks and the BIOX company has also patented technologies to manufacture biodiesel from waste grease and fats. These are small firms for which the challenge of commercialising their

technologies is beyond their means. In bringing their technology to its present state, both firms have benefited from government assistance related to research. It may be necessary to provide additional assistance to nurture the commercialisation process. In the US, large firms under contract with the federal government, such as Novozymes and Genencor, are actively investigating ethanol production from cellulosic feedstocks.

The pursuit of increasing plant efficiencies, on the other hand, is being pursued by large international companies, such as Katzen International, Praj Industries and ED & F Man. These firms provide engineering and construction expertise to the ethanol industry and therefore have an incentive to provide the most efficient and cost-effective plant plans to prospective ethanol producers. While these firms build on a body of science and knowledge that is in part supported by governments, this kind of technical maturity is typically found only in the private sector.

In addition to the production of ethanol, the ethanol production process generates additional products, primarily DDG and CO_2. It is conceivable, however, that pre-treatment of the feedstock, to isolate high value fractions, would leave the ethanol yield relatively unimpaired. The creation of additional by-products would increase the returns to ethanol plant owners. This is an area where government-assisted research may bear fruit.

Analysis of DDG markets and development of more effective marketing strategies is a pressing research issue. Current estimates of both US and Canadian DDG markets indicate that up to one-quarter of DDG production is exported, being unable to find a competitive home in North America. The US Grain Council is undertaking such a study.

It is important to continue to work with existing technologies and feedstocks as a bridge to potentially lower costing technologies and feedstocks of the future. It is critical that consumers enjoy ever-increasing supplies of ethanol to improve their familiarity with the product. While current usage levels are low (less than 7% of Canadian gasoline contains ethanol), consumer acceptance is something that must be nurtured. In this same vein, to achieve early GHG reductions and other benefits, it is necessary to increase supply sooner, rather than later.

Energy security

Biofuel, as a fuel substitute or extender, is an oft-cited policy rationale for governmental support of biofuel programmes. The strength of this rationale varies by country, depending on the ability to manage exposure to international oil markets and, of course, whether the country is a net oil importer or exporter. The Brazilian experience is at one extreme of the ethanol spectrum (Licht, 2001). Originally, the alcohol industry was an off-shoot of the sugar industry but, after oil prices increased dramatically in 1974, Brazil introduced the world's first major programme for the production of renewable fuels. In the mid-1970s its economy was the world's third-most-dependent on oil imports and by 1975, 32% of export earnings were required to finance energy imports, a figure that rose to 46% by 1979. The high oil import burden on Brazil's balance of trade was exacerbated by its bearing the largest foreign debt burden in the Third World. Energy insecurity, currency savings, and feedstock (sugar) supply were ingredients in the development of the *Proálcool* programme. By 1988, ethanol had a larger market share than gasoline, and over 80% of new cars were designed to operate on pure ethanol. Since that time a number of factors, including the discovery of new oil reserves, have affected the ethanol policy structure in Brazil such that market penetration is currently about 20% of the gasoline market.

In the US, the energy security argument is often cited in support of that country's ethanol programme. The US currently imports 56% of its petroleum needs. Ethanol reduces the need to import 128 000 barrels a day of oil and reduces the US trade deficit by USD 2 billion annually. That said, ethanol comprises less than one-half of 1% of gasoline use. The use of the entire US corn crop for ethanol would displace less than 5% of the country's gasoline needs.

The energy security situation in Canada is different. Canada is a net energy and oil exporter, although it imports significant volumes of both crude and refined product into east-coast ports, while exporting Alberta crude to the US. It is difficult to make an energy security argument in a Canadian context. However, as noted earlier, the policy rationale for ethanol may have strength in that, as a renewable fuel, it is displacing, and extending, the supply of non-renewable fuels. As technology develops, alternative fuels, energy sources and population and freight movement patterns may evolve to utilise greater amounts of renewable energy. Any amount of non-renewable energy displaced now may represent a net saving of non-renewable fuel use overall – with commensurate societal benefits.

Reduced government payments to agricultural producers

Governments in developed countries provide significant payments to agricultural producers. It is sometimes argued that increasing the demand for an agricultural commodity will lead to reduced costs to government treasuries as farmers extract more value from markets. The USDA study previously referenced looked at this issue and estimated that farm payments would be lower by about USD 55 million in 2012 for an RFS requiring the use of 5 billion gallons of ethanol. The Urbanchuk study, with a more aggressive RFS, estimated lower direct government payments to farmers of USD 7.8 billion between 2002 and 2016 – about half a billion dollars in annual savings. The modest savings in the USDA study are attributable to the price response being smaller than that predicted by Urbanchuk. It is a feature of the US Farm Bill that lower loan deficiency payments would flow from increasing prices.

The structure of Canadian agricultural programming does not have this price sensitivity feature. The federal and provincial governments have recently agreed to an Agricultural Policy Framework with firm financial commitments for the next five years. While the flow of funds to farmers may vary annually, the commitment to the sector is to invest a fixed amount of money – about CAD 1.8 billion annually. Until such time as the structure of government intervention in the sector changes, it is not possible to achieve government savings resulting from increased commodity demand and prices.

It should be noted that, in general, greater levels of employment and economic activity have positive effects on treasury balances. Greater tax revenues from income and consumption taxes, combined with lower social welfare expenditures, contribute to this situation. Highly skilled employment is likely to have more positive effects than economic activity from lower-skilled work.

Conclusion

This paper began with the observation that although Canada possessed appreciable amounts of agricultural biomass production capacity, it is probably less than would be anticipated and, in any event, the supply of biomass in and of itself may not be a good predictor of bio-product and bio-processing activity. Increasingly, technology and the institutional and cultural setting of a country are having predominant effects.

Although in some sense the ethanol industry is a mature industry – Man has been manufacturing ethanol in large quantities since time immemorial – it is an evolving industry. There are two broad forces at play. One is the continuing development of more cost-effective production that lowers, and promises to lower even further in the future, the cost of producing fuel ethanol. The other is an increasing societal awareness of the value of utilising renewable and sustainable products. The value of these renewable products has two components; one which can be monetised and traded, and another which is more ephemeral, but no less valuable – the softer environmental benefits that are difficult to monetise, but for which governments are increasingly capturing on our behalf.

There are a number of challenges associated with the valuation of both types of benefits. The case of ethanol in Canada, contrasted with its development in other jurisdictions, has highlighted some of these challenges. The physical resource base of the bio-product being commoditised is but one of the enabling factors, with the resource capacity of substitute commodities, the trade and resource relationship with neighbouring countries, the state of development of one's own economy, and the existing institutional framework and priorities of all levels of government within a country all having strong influences on the rate of development of new bio-products from agricultural biomass.

BIBLIOGRAPHY

Evans, Michael K. (1997), *The Economic Impact of the Demand for Ethanol:* www.ethanolrfa.org/docs/evans.html.

Licht, F.O. (2001), *World Ethanol Markets Analysis and Outlook*, Licht Commodity Analysis.

Urbanchuk, John M. (2001), *An Economic Analysis of Legislation for a Renewable Fuels Requirement for Highway Motor Fuels*, AUS Consultants, 7 November: www.ncga.com/ethanol/pdfs/Urbanchuk_Final_Report.pdf.

United States Department of Agriculture [USDA] (2002) – the USDA conducted an analysis of this scenario last summer which was transmitted in a letter to Senator Tom Harkin on 1 August.

USDA (1998), *International Agricultural Baseline Projections to 2007*, Economic Research Service, Washington, D.C., United States of America.

World Bank (2002), World Development Indicators 2002: www.worldbank.org/data/wdi2002/tables/table3-1.pdf.

UNITED STATES SUPPORT FOR THE AGRICULTURAL PRODUCTION OF BIOMASS: THE CHALLENGE OF INTEGRATING ENERGY, AGRICULTURAL, ENVIRONMENTAL AND ECONOMIC POLICIES

Terry Nipp[1]

Abstract

The US Administration estimates that over the next 20 years, US oil consumption will increase by 33%, natural gas consumption by over 50%, and demand for electricity will rise by 45% (NEP). Given these estimates, the US will significantly increase its dependency on foreign energy sources in the coming decades. At the same time that US energy needs are steadily increasing, US farmers struggle with their capacity to overproduce agricultural products, some of which could be more effectively utilised in the production of bioenergy fuels for transportation and electricity generation. Increased use of agriculturally produced bioenergy sources could reduce US dependence on foreign energy sources while creating new markets for agricultural producers. As well, the increased use of biomass as an energy source could help benefit the environment through reductions in the net production of greenhouse gases.

While there are clear benefits to better utilisation of US agricultural production to address energy needs, there are significant technical, organisational, and public policy challenges. Of the three, the public policy issues may prove the most vexing. Energy, agriculture and environmental policies tend to be developed independently. The three arenas have unique constituencies, each with its own policy goals, economic objectives, and political alliances. However, these are also "interlocking policy circles." The policy choices made in one arena may determine the success or failure for policy goals in the other two arenas. Choices made in agricultural policy may determine whether or not energy-oriented policy goals for biomass production are even possible. Decisions made about the use of bioenergy may predetermine the possibility of meeting specific air quality objectives.

To begin exploring the interdependence of these policy processes, this paper will provide an overview of US energy production and consumption trends, followed by a compilation of US legislation and federal agency programmes that impact the production of biomass for the production of bioenergy. These programmes and laws will be categorised as examples of specific policy tools in order to examine current legislation and agency programmes as a mix of policy choices. Last, an initial conceptual framework will be proposed for developing integrated agricultural, energy, and environmental policies.

1. AESOP Enterprises, Ltd., Washington, D.C., United States.

Overall energy trends

Currently, world energy supplies remain heavily dependent on fossil fuels: coal has a 22% share; oil, 40%; natural gas, 23%; nuclear power and hydroelectricity each make up about 7% of world energy supplies. Depending on the calculations used, the global use of non-hydro-renewables as an energy source for electricity or transportation runs about 1%, but it can be more than 25% in developing countries that use non-market fuel wood and farm residues for heating and cooking. The major components of global energy demand are for electricity generation (40%) and transportation (25%).

In the United States, total energy consumption is expected to increase more rapidly than domestic energy production through 2025 (Figure 1). As a result, net imports of energy are projected to meet a growing share of energy demand. Looking at recent US Department of Energy (USDOE) estimates for total energy production by fuel type through 2025 in Figure 2:

- Total domestic petroleum production (crude oil plus natural gas plant liquids) increases from 7.7 million barrels per day in 2001 to 8.0 million by 2025. Net petroleum imports, including both crude oil and refined products on the basis of barrels per day, are expected to account for 68% of demand, up from 55% in 2001. Projected US crude oil production declines to 5.3 million barrels per day by 2025, an average annual rate of 0.4% between 2001 and 2025.

- US coal production is projected to increase from 1 138 million short tons in 2001 to 1 359 million short tons by 2020, an average rate of 0.9% per year.

- Domestic natural gas production is projected to increase from 19.5 to 25.1 trillion cubic feet between 2001 and 2020, an average rate of 1.3% per year.

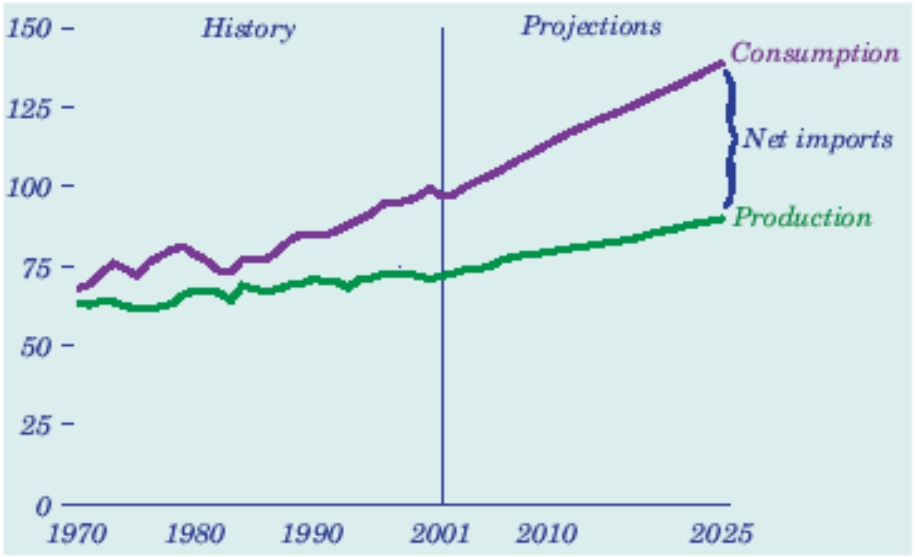
- Renewable energy production, including hydroelectric generation, is projected to increase from 5.5 to 8.7 quadrillion British thermal units (Btu) between 2001 and 2020, with growth in industrial biomass, ethanol, and all sources of renewable electricity generation. By 2025, renewable energy production reaches 9.2 quadrillion Btu.

Of course, these projections are based on assumptions that may or may not play out. The US could change its policies to stimulate the increased use of nuclear or hydrological power sources. World events may change the price and the demand for oil. For this discussion, the precise estimates are not as important as the overall position of non-hydro-renewables in Figure 2. The first obvious point is that non-hydro-renewables currently rank at the bottom of fuel sources for energy production. However, the second important point that can be drawn from these trends is that the use of non-hydro-renewables is projected to increase steadily, even to the point of approaching the current level of nuclear energy sources.

Renewable energy trends

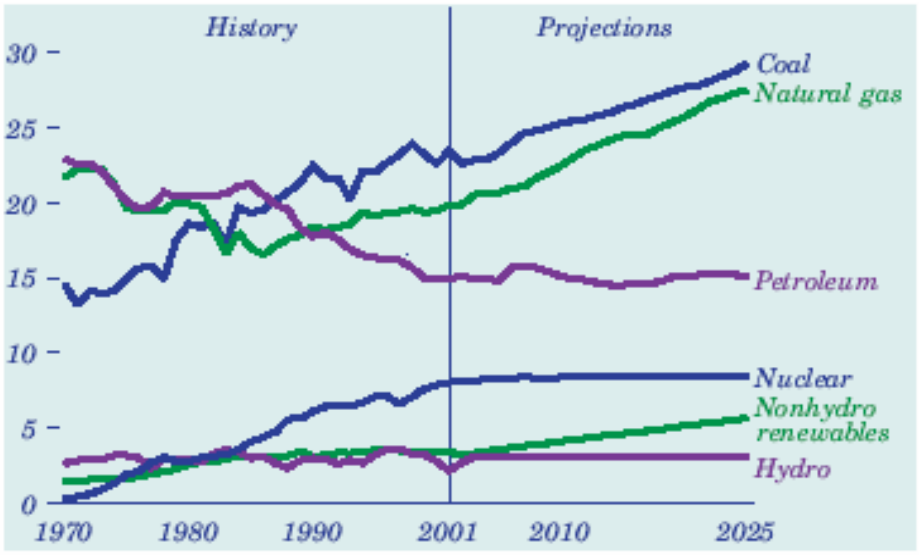
At this time, total renewable energy accounts for about 6.6% of energy demand in the United States (DOE/EIA, 2003). Of this, most is provided by large hydropower production systems. Industrial use of biofuels accounts for most of the rest of renewable energy's contribution. Most of the increase in the use of non-hydro-renewables (62%) is expected to come from combined production of heat and electricity from renewable energy sources.

Figure 1. Total energy production and consumption, 1970-2025
(quadrillion Btu)



Source: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384, 2001.

Figure 2. Energy production by fuel, 1970-2025
(quadrillion Btu)



Source: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384, 2001.

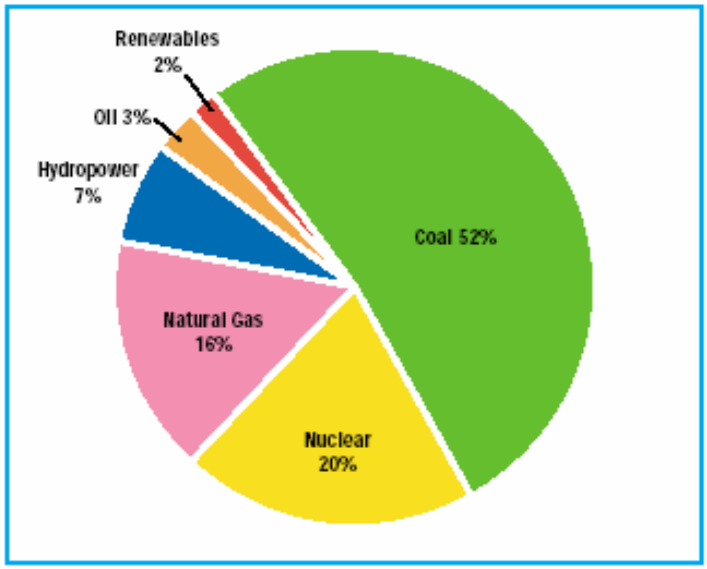
- Total renewable fuels are projected to increase from 298 billion kilowatt-hours of generation in 2001 (8.0% of total generation and 8.7% of retail sales) to 495 billion kilowatt-hours in 2025 (8.5% of generation and 9.4% of sales).
- Non-hydro-electric renewables account for 4% of projected additions to generating capacity from 2001 to 2025. Generation from non-hydro-power renewable energy sources is projected to increase from 80 billion kilowatt-hours in 2001 (2.1% of generation and 2.3% of sales) to 189 billion in 2025 (3.3% of generation and 3.6% of sales).

Currently, non-hydro-renewables provide approximately 2% of the fuel sources for electricity generation (Figure 3). A strong projected increase in the use of non-hydro-renewables specifically for electricity generation is clearly shown in Figure 4. USDOE projects that the largest source of non-hydro-electric renewable generation in the forecast is biomass, including combined heat and power and co-firing in coal-fired power plants. Electricity generation from biomass is projected to increase from 38 billion kilowatt-hours in 2001 to 78 billion kilowatt-hours (1.3% of generation and 1.5% of sales) in 2025. Again, the use of biomass as an energy source shows dramatic potential, but it is starting from a very low base line. Both the potential increase in production and the low initial baseline have important organisational implications for programme managers and policy makers.

Environmental impacts

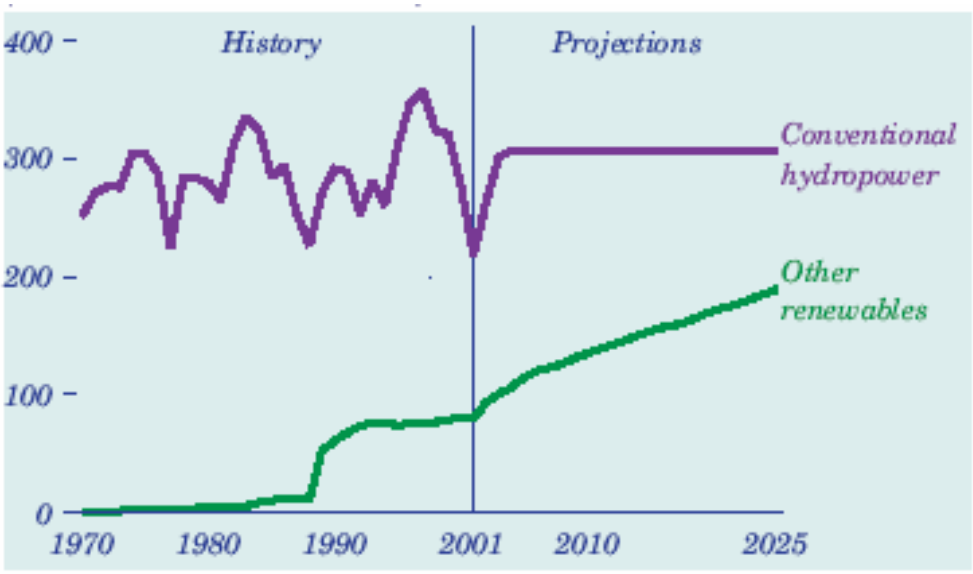
Assuming no policy changes that might impact carbon dioxide emissions, USDOE projects that carbon dioxide emissions from energy use will increase from 1 559 to 2 082 million metric tons carbon equivalent between 2001 and 2020, an average annual increase of 1.5%. By 2025, total carbon dioxide emissions are projected to reach 2 237 million metric tons carbon equivalent. Figure 5 demonstrates these projected increases, with a breakout by sector use and fuel source. Figure 6 shows the relative amount of several pollutants that result from types of energy generation and use. The obvious point here is that unless something changes, it will be very difficult to maintain current air quality goals, much less improve on current standards.

Figure 3. Fuel sources for electricity generation in 2000



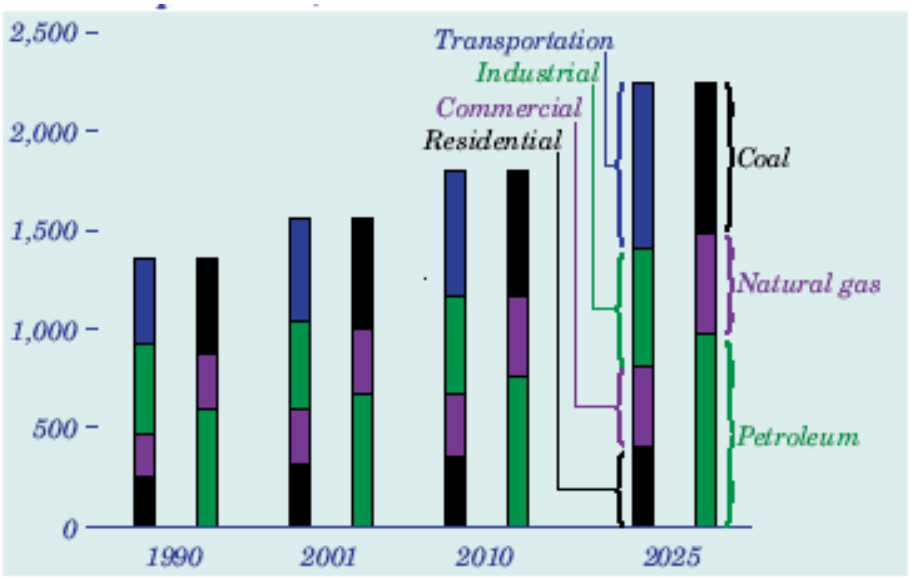
Source: *US National Energy Policy Report 2000*, from the US Department of Energy, Energy Information Administration.

Figure 4. Grid-connected electricity generation from renewable energy sources, 1970-2025
(billion kilowatt-hours)



Source: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384, 2001.

Figure 5. Projected US carbon dioxide emissions by sector and fuel, 1990-2025
(million metric tons carbon equivalent)



Source: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384, 2001.

What are we doing now?

During the past several years, there has been a number of interesting legislative and programmatic developments in support of increased use of bioproducts and bioenergy.

Administrative Order

In August 1999, President Clinton issued Executive Order 13134, which established the National Biobased Products and Bioenergy Coordination Office. The President stated:

> *I am setting a goal of tripling America's use of bioenergy and biobased products by 2010. That would generate as much as USD 20 billion a year in new income for farmers and rural communities while reducing greenhouse gas emissions by as much as 100 million tons a year – the equivalent of taking more than 70 million cars off the road.*

The Executive Order stimulated a new round of activities and discussions within and between USDOE and the US Department of Agriculture (USDA).

US legislation

Legislative history

The Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989 set the stage for today's renewable energy deliberations. The Energy Policy Act of 1992 (EPA, 1992) continued some of the 1989 authorities. It expanded research and development (R&D) on renewable energy sources and it established new incentives for the use of biomass and other alternatives for power and fuels. Title XII of EPA 1992 provided funding for demonstrations and commercial application projects in biobased fuels and power systems, including conversion of cellulosic biomass to fuels, ethanol production, and direct combustion or gasification of biomass. Title XII also creates an "Alcohol from Biomass" R&D programme to promote advanced alcohol production technologies (ethanol and methanol). Titles III, IV, and V encourage the use of alternative fuels in transportation.

Biomass Research and Development Act of 2000

The Federal Crop Insurance Act of 2000 included a mix of provisions designed to strengthen the economic "safety-net" for agricultural producers by providing greater access to more affordable risk management tools and to support alternative income-generating activities, including Title III, The Biomass Research and Development Act of 2000. The language for this Act was initiated by Senator Lugar of Indiana and was being developed at the same time that the Administration was developing Executive Order 13134. Consequently, the Executive Order anticipates some of the provisions of the Biomass R&D Act and the Act, in turn, amplifies and expands the language of the Executive Order. The Biomass R&D Act directs the Secretary of USDA and the Secretary of USDOE to co-operate and co-ordinate R&D activities with respect to production of biobased industrial products. The Act includes the following provisions of particular interest.

(Sec. 305) Establishes (1) the Biomass Research and Development Board to coordinate Federal programmes for the promotion and use of biobased industrial products; and (2) the Biomass Research and Development Technical Advisory Committee.

(Sec. 307) Directs the Secretaries to establish and carry out a Biomass Research and Development Initiative to award grants, financial assistance, and contracts for biobased industrial product research. Sets forth as eligible participants (1) a college or university, (2) a national laboratory, (3) a Federal or State research agency, (4) a private sector entity, (5) a non-profit entity, or (6) a consortium of two or more entities.

The Act directs the Administrator of the USDA/Cooperative State Research, Education, and Extension Service (CSREES) and the Chief of the USDA/Natural Resources Conservation Service (NRCS) to ensure that research results and technology are adopted, made available, and disseminated through their respective services to agricultural users.

Farm Security and Rural Development Act of 2002: Title IX

The Farm Security and Rural Development Act of 2002 (Farm Bill 2002) includes a number of provisions that support the production of biomass, bioproducts and biofuels. Most notable was the inclusion of a title dedicated to energy issues for the first time – Title IX, which includes a number of provisions that deal directly with the support of biomass and bioenergy production. This Title addresses the need to create a market demand for biobased products to stimulate the initial development of production and processing infrastructures, the need for research to improve the cost-competitiveness of biobased technologies, and the need for education and training for producers and processors to adopt and implement new technologies. The Act supports assessing the impact of biomass production and biobased technologies on the environment.

(Sec. 9002) Requires US federal agencies to favour biobased products when they procure supplies. The Act requires (1) the Secretary of USDA to prepare guidelines defining biobased products and procurement policies, (2) the Office of Federal Procurement Policy to implement such policies, and (3) each federal agency to develop a biobased procurement policy. Obligates funds for biobased product testing, with discretionary preference for products for which private firms share testing costs.

(Sec. 9003) Directs the Secretary of Agriculture to make cost-share grants to develop and construct biorefineries for projects that demonstrate the commercial viability of biomass conversion to fuels or chemicals.

(Sec. 9004) Directs the Secretary of Agriculture to make grants for a biodiesel fuel education programme.

(Sec. 9005) Directs the Secretary of Agriculture to make cost-share grants to assist farmers, ranchers, and rural small businesses to become more energy efficient, and in using renewable energy technology and resources.

(Sec. 9006) Directs the Secretary of Agriculture to make additional loans, loan guarantees, and cost-share grants to farmers, ranchers, and rural small businesses to purchase renewable energy systems and make energy efficiency improvements.

(Sec. 9007) Directs the Secretary and the Secretary of Energy to enter into a memorandum of co-operation in the application of hydrogen and fuel cell technology programmes for rural communities and agricultural producers.

(Sec. 9008) Amends the Biomass Research and Development Act of 2000 to revise funding provisions to continue funding.

(Sec. 9009) Amends the Agricultural Risk Protection Act of 2000 to authorise the Secretary of Agriculture, in co-operation with departments and agencies participating in the US Global Change Research Program and with eligible entities, to carry out research to promote understanding of (1) the flux of carbon in soils and plants (including trees), and (2) the exchange of other greenhouse gases from agriculture.

This section authorises the Secretary of Agriculture to implement extension projects (including on-farm projects with direct involvement of agricultural producers) to monitor the carbon sequestering benefits of conservation practices and the exchange of greenhouse gas emissions from agriculture, which demonstrate methods of measuring and monitoring (1) changes in carbon content and other carbon pools in soils and plants (including trees), and (2) the exchange of other greenhouse gases. These projects are to be developed in collaboration with departments and agencies participating in the US Global Change Research Program, local extension agents, agricultural experts from institutions of higher education, and other local agricultural or conservation organisations.

(Sec. 9010) This section directs the Secretary to continue the bioenergy (biodiesel and fuel-grade ethanol) programme of payments to eligible producers to encourage increased purchases of eligible commodities for the purpose of expanding bioenergy production.

Current comprehensive energy legislation

The US Congress was unable to resolve partisan differences in 2002 and continued debates regarding the development of a comprehensive US energy policy in 2003. At this time, the US House of Representatives has completed work on its version of the Energy Policy Act of 2003 – H.R. 6. The Senate attempted to complete its version of a comprehensive energy bill – S. 6, but was unable to do so. In order to avoid running aground a second time, the Senate took the unusual action of setting aside the bill that had been developed this legislative year and agreed to pass instead the bill that it had previously passed in 2002. The House and Senate are expected to go into conference in September of 2003 with the hope of sending a comprehensive Energy bill to the President in the early fall. However, there are a number of controversial issues between the House and the Senate and there are significant differences between the House Bill, the bill the Senate passed last year, and the bills that were under consideration in the Senate this year. Many are sceptical as to whether a final bill can be reconciled between the House and Senate, but there is a great deal of political pressure to complete the Energy legislation.

House: H.R. 6

On 11 April 2003, the House passed its version of the Energy Policy Act of 2003. There are a number of important bioenergy provisions. The Bill:

- Establishes a renewable fuels standard of 2.7 billion gallons by 2005 and 5 billion gallons by 2015.

- Establishes a safe harbour for renewable fuels containing methyl tertiary butyl ether (MTBE) that is used, or intended for use, as a motor vehicle fuel.

- Instructs the Secretary of Energy to establish a loan guarantee programme for private sector construction of facilities to process and convert municipal solid waste into fuel ethanol and other commercial by-products.

- Directs the Secretary of Energy to conduct energy R&D programmes concerning: (1) energy efficiency; (2) distributed energy and electric energy systems; and (3) renewable, fossil, and nuclear energy.

- Targets the following areas for programme implementation: (1) bioenergy programmes; (2) renewable energy in public buildings; (3) nuclear energy research programmes; (4) advanced fuel recycling technology; (5) university nuclear science and engineering support; (6) fossil energy research, including coal mining technologies; and (7) technologies for ultra-deepwater and unconventional natural gas and other petroleum resources.

- Includes the Energy Tax Policy Act of 2003, which amends the Internal Revenue Code with respect to credits and deductions pertaining to energy conservation, distribution, and production. This includes about USD 18 billion in tax incentives.

- Authorises USD 30 billion for R&D at USDOE for the period of FY 2004 through FY 2007

Senate: S. 14

On 30 April 2003, the Senate Committee on Energy and Natural Resources completed markup and reported its comprehensive energy legislation, which the Senate began to debate the week of 5 May 2003. In order to move the bill through the Committee, Chairman Domenici withdrew a controversial section on climate change to be addressed later. The Senate bill does not include language comparable to House language that allows drilling in the Arctic National Wildlife Refuge (ANWR). Even though the Senate set S. 14 aside and again passed the comprehensive energy legislation that it had passed in 2002, S. 14 remains the best available indicator of the consensus position of the Senate that will be brought forward in its debates with the House during the upcoming conference process. Items of interest in S. 14 include the following provisions.

- Sets forth a programme to spur diverse energy R&D.

- Amends the Energy Policy Act of 1992 to prescribe incentive payments for renewable energy production facilities.

- Establishes a grant programme for biomass commercial utilisation.

- Energy Research, Development, Demonstration, and Commercial Application Act of 2003 – Directs the Secretary of Energy to conduct programmes of energy research, development, demonstration, and commercial application that target (1) efficiency; (2) diversity of energy supply; (3) decreasing dependence on foreign energy; (4) energy security; and (5) decreasing environmental impact of energy-related activities.

- Directs the Secretary of Energy to implement Initiatives that target research, development, and commercial application, in the following areas: (1) energy efficiency, (2) distributed energy and electric energy systems, (3) renewable energy, (4) nuclear energy, (5) fossil energy, (6) science, (7) energy and environment, (8) coal technology loans, (9) electricity reliability standards and transmission access, (10) regional markets, and (11) market transparency and manipulation.

On 2 April 2003, the Senate Committee on Finances reported S. 597, a separate bill that deals with ethanol provisions similar to those included in the House version of the bill. This bill was debated in the summer as an amendment to S. 14. This legislation includes about USD 18 billion in incentives (payments) over a ten-year period, of which USD 2.6 billion is targeted to producers of renewable energy, USD 2.4 billion is for alternative fuels and fuel cell vehicles, USD 4 billion is for utilities to implement electricity restructuring, and USD 5 billion is targeted to the oil and gas industry.

US Agency programmes

The provisions of Executive Order 13134, the Biomass Research and Development Act of 2000 and the Energy Title of the 2002 Farm Bill have stimulated the development of an array of new federal agency programmes, particularly in USDOE and USDA. Other US agencies have also been very much involved, including the US Environmental Protection Agency (USEPA) and the US National Science Foundation. The US National Academy of Sciences has been charged by Congress to develop reviews and studies on some of the more controversial aspects of energy policy.

US Department of Energy

In response to the Biomass Research and Development Act of 2000, USDOE formed the Biomass R&D Technical Advisory Committee, which stimulated the development that produced a Vision statement and a "Roadmap" identifying research needs and priorities. Given some of the questions raised by OECD member countries regarding US goals for bioenergy, the following excerpts from the Roadmap are germane.

Vision

"The United States is approaching a biobased revolution that will fundamentally change the way we produce and consume energy and industrial products. From biological resources, we can derive products as diverse as fuels and lubricants, heat and electricity, chemicals, food, feed, building materials, paper, clothing, and much more."

Mission

To foster R&D on advanced technologies to transform our abundant biomass resources into clean, affordable, and domestically produced biofuels, biopower, and high- value bioproducts for improving the economic development and enhancing the energy supply options of the US

Goals

- Direct replacement of fuels to reduce US dependence upon foreign sources of petroleum.
- Spur the creation of a US bioeconomy.

These Roadmap statements are also consistent with overall energy policy goals outlined in the Administration's National Energy Policy statement.

Research programmes

Current USDOE programmes are described on its website at www.eere.energy.gov. The USDOE Office of Energy Efficiency and Renewable Energy (EERE) was reorganised in July 2002. The Biomass Program is one of eleven programmes in EERE. An organisational chart of the current structure of USDOE programmes related to biomass and biofuels is shown in Figure 7. As described in a programme fact sheet, the Office of the Biomass Program, key R&D priorities include the following areas of activities.

Thermochemical Conversion – thermochemical conversion can be used to create syngas for heat, power, or products. The Office is removing barriers to the cost-effectiveness and environmental viability of these processes.

Bioconversion – bioconversion can transform biomass resources into useful fuels and chemicals. The Office is investigating biological processing that integrates pre-treatment, separations, and purification in a manner that is efficient and cost-effective.

Industrial Biorefinery – the industrial biorefinery is a promising strategy for processing renewable biomass, such as corn stover and other resources, into a range of biobased products, fuels, and power.

Biobased Products – biomass can be used in place of petrochemical feedstocks to produce value-added chemicals, such as biobased engine oils and solvents, biobased plastics, and improved enzymes.

Small Modular Biopower – research is being conducted to develop small modular biomass systems that will be commercially competitive in integrated heat and power applications in the 1 kW to 5 MW range.

US Department of Agriculture

Unlike USDOE, there is not a single office at USDA with unique responsibilities for biomass and bioenergy. Rather, USDA has an array of programmes and approaches in a number of offices, which is co-ordinated through its "Biobased Products Bioenergy Coordination Council" (BBCC). Information about the pertinent programmes of each of the involved offices can be found at the USDA website: www.ars.usda.gov/bbcc/. Excerpts from the site follow. The overall organisational structure of USDA is shown in Figure 8.

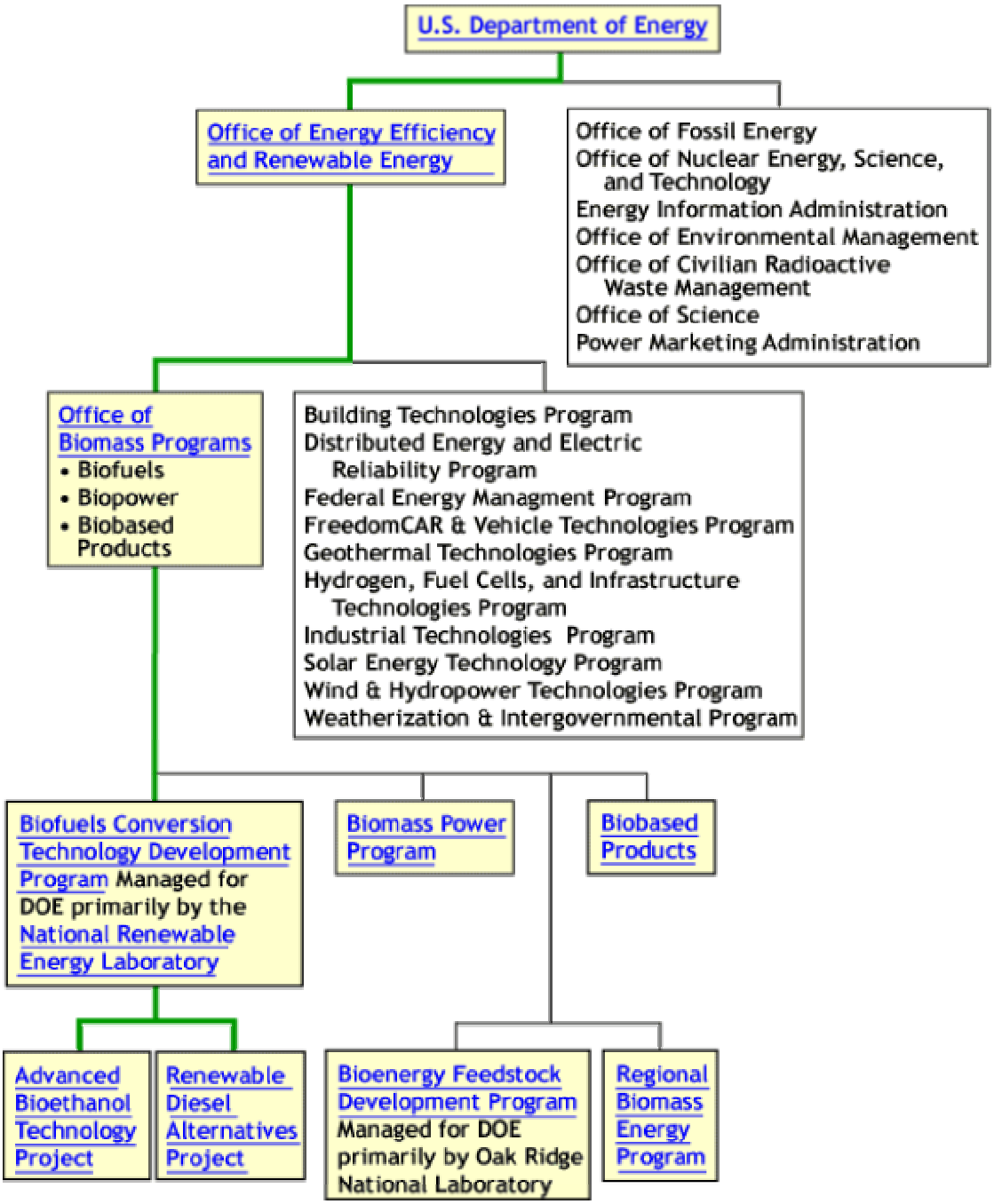
Office of Energy Policy and New Uses

Office of Energy Policy and New Uses (OPENU) provides leadership, oversight, co-ordination, and evaluation for all USDA energy and energy-related activities with the exception of those delegated to the USDA Assistant Secretary for Administration. The office analyses existing and proposed energy policies, strategies, and regulations concerning or potentially affecting agriculture. It also evaluates the feasibility of new uses for agricultural products. The director of the Office also serves as permanent vice-chair of the BBCC.

Undersecretary for Research, Education and Economics

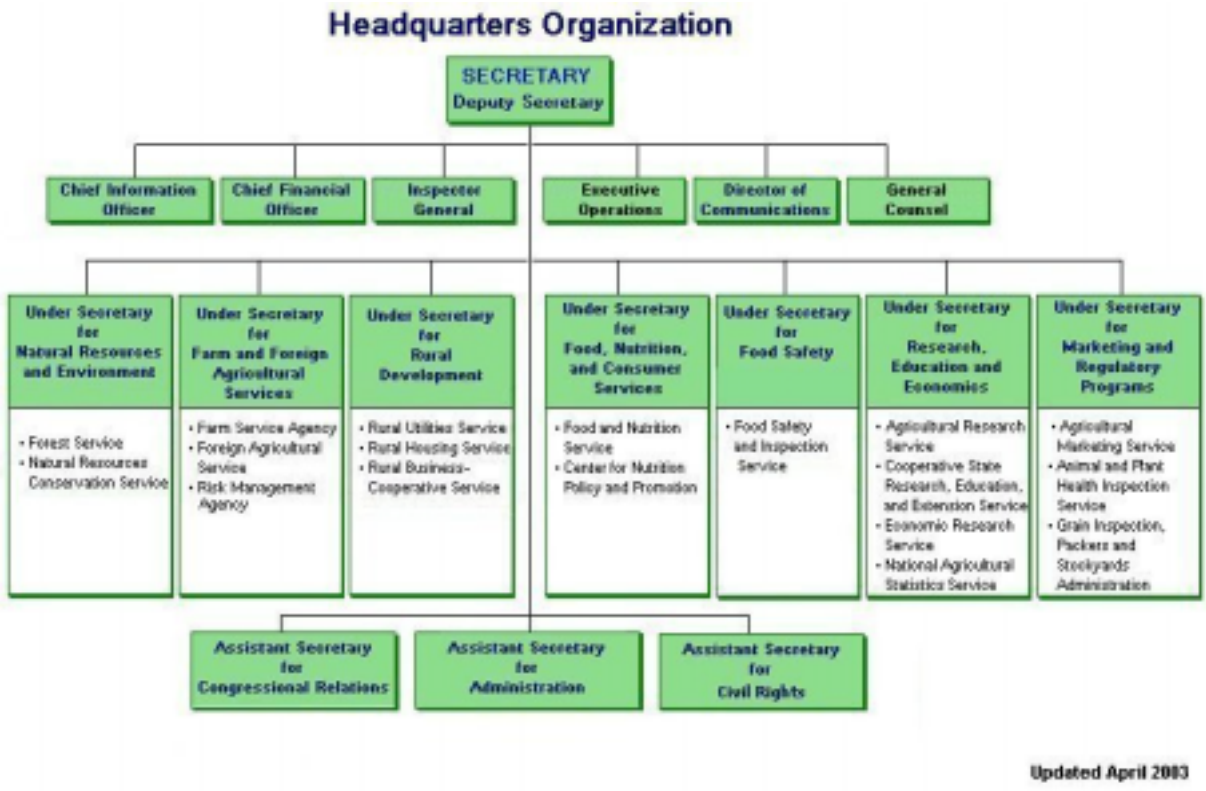
Office of the Under Secretary for Research, Education and Economics (REE). The Under Secretary for Research, Education, and Economics serves as the chair of the BBCC.

Figure 7. USDOE organisation chart – biomass and biofuels



Source: USDOE website.

Figure 8. USDA organisation chart



Agricultural Research Service (ARS) is the "in-house" research agency of the USDA. Research related to biobased products focuses on developing feedstocks and industrial products, including biofuels and bioenergy that expand markets for agricultural materials, replace imports and petroleum-based products, and offer opportunity to meet environmental needs. This includes developing, modifying and utilising new and advanced technologies to convert plant and animal commodities and by-products to new products and by developing energy crops as well as new crops to meet niche market opportunities.

Co-operative State Research, Education and Extension Service (CSREES) emphasises partnerships with the public and private sectors to conduct research, education and extension programmes. CSREES advances R&D in new uses for industrial crops and products through its Agricultural Materials Program, National Research Initiative, Small Business Innovation Research Program, and other activities. Areas of interest include paints and coatings from new crops, fuels and lubricants, new fibres, natural rubber, and biobased polymers from vegetable oils, proteins and starches.

Undersecretary for Natural Resources and Environment

Forest Service (FS) manages 192 million acres of National Forests and Grasslands, provides resource science and technology development, and assists states and private landowners in forestry activities. Specific research and technology development focus areas are small-diameter and low-value sources: developing and demonstrating economically and environmentally sound strategies, operations systems and technologies for management, harvest, and utilisation, and value-added processing, and

use for bioenergy; new woody cropping systems: developing short rotation woody crop systems, improving production efficiency, lowering costs, ensuring environmental quality, improving conservation and use of marginal lands, expanding new crop options through developing science, new technologies, and guidelines for these systems. Other research areas include improved transportation systems, fibre-reinforced cement products, uses for waste wood and plastics, housing components, and small-diameter trees from overcrowded woodlands.

Natural Resources Conservation Service (NRCS) provides national leadership in a partnership effort to help people conserve, enhance, and protect and sustain the nation's natural resources and environment. NRCS has stressed two priorities for the biobased products and bioenergy initiative: first, expanded production of feedstocks for biomass/bioenergy should occur with due consideration and protection of natural resources; second, local communities should be instrumental in organising biobased product and bioenergy enterprises, which are environmentally, economically and socially sustainable.

Undersecretary for Rural Development

Rural Business-Cooperative Service (RBS) – the Business Program (BP) works in partnership with the private sector and the community-based organisations to provide financial assistance and business planning. BP helps fund projects that create or preserve quality jobs and/or promote a clean rural environment. The financial resources of RBS BP are often leveraged with those of other public and private credit source lenders to meet business and credit needs in under-served areas. RD promotes economic development in rural communities by financing need facilities, assisting business development and rural co-operatives, and planning national strategies for economic development.

Rural Utilities Service (RUS) – The Rural Utilities Service (RUS) is the federal "point" agency for rural infrastructure assistance in electricity, water, and telecommunications. RUS makes low-cost loans and grants to help provide these services to rural communities.

Undersecretary for Farm and Foreign Agricultural Services

Farm Service Agency (FSA) – FSA has four missions: to stabilise farm income, to help farmers conserve land and water resources, to provide credit to new or disadvantaged farmers and ranchers, and to help farm operations recover from the effects of disaster. The agency consists of six programmes, including farm commodity programmes; farm ownership, operating and emergency loans; conservation and environmental programmes; emergency and disaster assistance; domestic and international food assistance; and international export credit programmes. The FSA administers two programmes related to bioenergy: the Bioenergy Program and the Conservation Reserve Research Pilots.

Foreign Agricultural Service (FAS) – FAS works through private industries to identify overseas market opportunities for new products such as vegetable oil lubricants, soy ink or biodegradable textile material made of corn, to name just a few. FAS activities also indirectly help reduce production cost of corn-based ethanol fuel in the US through promoting and expanding the exports of ethanol by-products (DDG and corn gluten meal) to overseas markets. FAS supports these activities through the Market Access Program (MAP), the Foreign Market Development (FMD) Program, and the scientific exchanges sponsored by the International Cooperation and Development (ICD) programmes.

Undersecretary for Marketing and Regulatory Programs

Agricultural Marketing Service (AMS) provides standardisation, grading and market news services for various commodity groups. The AMS commodity programmes also oversee marketing agreements and orders, administer research and promotion programmes, and purchase commodities for Federal food programmes. The AMS Science and Technology Program provides centralised scientific support to AMS programmes, including laboratory analyses, laboratory quality assurance, co-ordination of scientific research conducted by other agencies for AMS, and statistical and mathematical consulting services. The AMS Transportation and Marketing Program brings together a unique combination of traffic managers, engineers, rural policy analysts, international trade specialists and agricultural marketing specialists to help solve problems of US and world agricultural transportation. As such, AMS staff identifies, monitors, and analyses current and future energy markets due to its significant impact on agricultural transportation and marketing.

Office of the Chief Economist

Global Change Program Office (GCPO) operates within the Office of the Chief Economist and functions as the Department-wide co-ordinator of agriculture, rural and forestry-related global change programme and policy issues facing USDA. The Office ensures that USDA is a source of objective, analytical assessments of the effects of climate change and proposed mitigation strategies, including biomass energy and biobased products use.

Office of Budget and Program Analysis

Office of Budget and Program Analysis (OBPA) – Major activities consist of co-ordinating the preparation of the Department's budget estimates, legislative reports and regulations. OBPA provides direction and administration of the Department’s budgetary functions – including development, presentation, and administration of the budget – reviews programme and legislative proposals for programme and budget-related implications; and analyses programme and resource issues and alternatives.

Office of the Assistant Secretary for Administration

Office of the Assistant Secretary for Administration (ASA) provides leadership and oversight in acquisition, asset management, hazardous materials management, internal energy conservation, recycling, alternative fuels, and real property. The ASA serves as the Department’s Energy Executive and USDA’s Environmental Executives. The ASA has responsibility for co-ordinating environmentally preferable and energy-efficient initiatives and serves as an advocate for co-ordination of these initiatives in USDA facilities and programmes across the country. The Office of Procurement and Property Management is the ASA office most closely linked to biobased products and bioenergy.

USDA programme activities

Working through this array of offices, USDA has developed programmes and activities in the following priority areas, particularly in the areas of R&D.

Biomass conversion to energy

- Optimising cellulase fermentation via foam fractionation;
- Optimising corn wet milling process;

- Comparison of lignocellulosic pre-treatment technologies;
- Gasification/fermentation;
- Functional genomics of E. coli during model fermentations.

Manure conversion to energy/products

- Gasification of poultry litter;
- Biphasic fermentation of cotton gin waste and dairy manure;
- Nursery pots manufactured from composted dairy manure.

New industrial crops

- Castor, lesquerella, meadowfoam, guayule.

Forestry

- Wood and fibre quality of juvenile pine.

New uses

- Starches for packaging materials, plastics;
- Cheese whey for varnishes and packaging films.

Local value-added processing

- Conversion of soybeans to a variety of products;
- On farm conversion of soybean oil to industrial greases.

Marketing

- Corn/soybean based solvent tailored to specific uses.

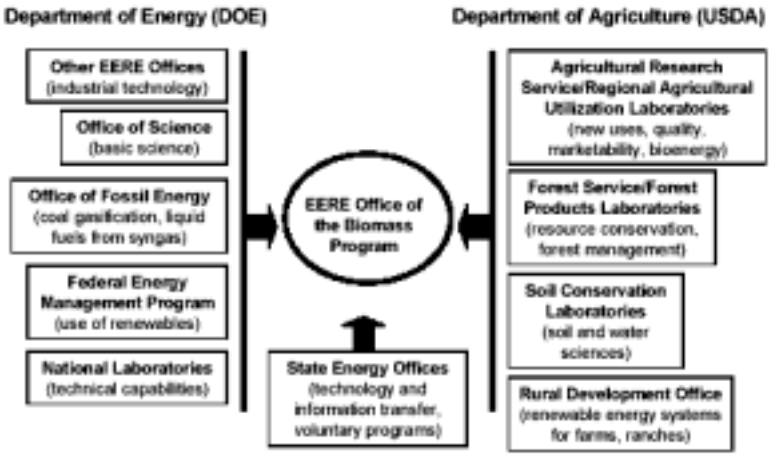
Success stories

- Castor-based, low voc, architectural paint used in Pentagon renovation;
- Soybean oil-based greases: Norfolk Southern Railroad, Crete Trucking;
- Corn/soybean-based solvent used in Walter Reed Hospital paint stripping.

Agency co-ordination

An obvious challenge for both USDOE and USDA is to internally co-ordinate their own programmes, as well as co-ordinate with each other and other federal agencies. Figure 9 diagrams the co-ordinating role of the USDOE/EERE Office of the Biomass Program. It is interesting to note that USDOE and USDA have fundamentally different approaches to organising their biomass and bioenergy programmes. USDOE reorganised its renewable energy programmes in the summer of 2002 to streamline its activities and group related programmes, with the result that 11 specific and related programmes are grouped within the office of Energy Efficiency and Renewable Energy, including the Office of Biomass Programs. USDA, on the other hand, takes a more decentralised approach, co-ordinating the diverse efforts of different offices and agencies, each of which has primary missions and goals unrelated to biomass and bioenergy *per se*, but which has important programme elements pertinent to biomass production and consumption.

Figure 9. Inter- and intra-agency co-ordination



Source: Multi-Year Plan.

Policy goals and policy tools

As evident from the preceding discussion, US legislation and US federal agencies have produced quite an array of programmes that impact biomass and bioenergy production. Out of a seeming hodge-podge of programmatic activities, four general policy goals can be distilled:

- energy sufficiency;
- economic development;
- environmental protection; and
- support for agricultural producers.

To reach these goals, four general types of policy tools tend to be utilised:

1. tax incentives;
2. regulations;
3. subsidies; and
4. support for R&D.

For this discussion, "subsidies" will be further categorised as consumption support or production support.

Figure 10 provides a "first-cut" at sorting out the mix of policy tools used in pursuit of each of the four policy goals. This first-cut is not likely to provide a perfect categorisation, but the matrix illustrates the key point, which is that each of the policy goals can be pursued with a unique mix of policy tools, and, conversely, each policy tool may be more or less adaptable to a specific policy goal.

Figure 10. Policy goals and current mix of policy tools

	Policy Goals			
Policy Tools	**Energy Security**	**Economic Development**	**Environment Protection**	**Agricultural Support**
Tax Incentives	♦	♦		
Regulations			♦	♦
Consumption Support				
Mandated purchases			◊	♦
Federal procurement		♦		♦
Production Support				
Subsidies				♦
Loan Guarantees				♦
Market development		♦		
Support for R&D	♦		♦	♦

Source: Author.

1. Tax incentives

There are a number of good examples of tax incentives in the comprehensive energy legislation currently being debated in the House and Senate. Existing renewable energy production tax credit provides a 1.8 cents/kwh (kilowatt-hour) credit for businesses that generate power from wind, closed loop biomass (energy crops), and poultry waste for sale to the local energy grid. The comprehensive energy bills in both the House and Senate would extend this credit and expand the eligible sources to include open loop biomass (forests, agricultural, and construction wastes). The Senate version of the bill would expand credit eligibility to swine and bovine waste, geothermal energy, solar energy, small irrigation power facilities, municipal biosolids and recycled sludge. In addition, the legislation would reauthorise the Renewable Energy Production Incentives Program (REPI) for state and local governments. REPI provides a 1.5 cents/kwh incentive to municipal utilities and rural co-operatives for building renewable energy generation capabilities.

2. Regulations

In general, many in the current Congress and the Administration appear wary of developing new regulations as a way of supporting the increased use of biomass and bioenergy production. However, the US Clean Air Act remains a powerful "driver" in the development of programmes and even though the US has not signed the Kyoto Agreement, there is a pervasive "awareness" of the need to reduce greenhouse gas emissions. The most interesting regulation that is emerging at the moment is the Renewable Fuel Standard, which will also function as a type of "consumption support."

3. Consumption support

Mandated purchases

Providing an interesting example of a somewhat circuitous subsidy, the US Congress is currently debating the establishment of a Renewable Fuel Standard (RFS) that would require increased use of ethanol as a gasoline additive. The House version of the bill would require blending 2.7 billion gallons of renewable fuel with gasoline in 2005, rising to 5 billion by 2015. Most of this would be met with ethanol, but other renewable fuels, including biodiesel, would qualify. The Senate debated adding a similar provision to its version of the bill. In general, the increased use of ethanol as a gasoline additive has been supported by an interesting mix of oil industry, ethanol producers and environmental groups. Critics of the bill have argued that it is thinly disguised assistance to US agricultural producers and that the requirement will boost prices to consumers and create shortages. Supporters have argued that the provision will reduce energy prices paid by consumers.

The House and Senate are also considering variations on eliminating the use of MTBE. There are variations on how strict and how immediate the elimination would be. The House bill, H.R. 6, would eliminate the current 2% oxygenate mandate for reformulated gasoline, but would not ban MTBE outright. The House has controversial provisions that would hold producers and processors "harmless" from any liability for damages resulting from the use of renewables or MTBE. Critics have argued that leaky storage tanks are the problem, not the requirement that ethanol or MTBE be used or not. There is not the same mix of support for these provisions as there is for the increased used of ethanol.

Federal procurements

Another innovative approach to providing subsidies is requiring the federal government, a fairly significant consumer in its own right, to favour purchases of products that have biomass-based components. The 2002 Farm Bill included Sec. 9002, the Federal Procurement of Biobased Products Act. USDA has developed draft regulations and guidelines for implementing the legislation. USDA currently appears to be interpreting the new law to require that Federal Agencies will (USDA):

- Give preference to products with highest biobased-content relative to availability, performance standards, and price.
- Ensure that biobased content is incorporated as a procurement specification.
- Develop a procurement preference programme that will ensure biobased products are purchased to the maximum extent practicable.
- Develop an agency promotion programme.
- Annually review and monitor the effectiveness of the preferred procurement programme.

In order to implement these provisions, USDA is developing a list of designated items that have acceptable biobased content for federal agency purchases. To develop this list, it is acquiring information about biobased components and products, including their relative availability, price, performance, environmental and public health benefits, life-cycle costs, and recommended biobased content. USDA is planning to develop criteria for a "USDA Certified Biobased Product" label. To be designated as having "biobased content" products must be manufactured with raw materials or wastes from domestic agricultural production, from farming, ranching, forestry, or aquaculture. USDA is also working to define the minimum content of biomass materials that will be necessary for a product to be classified as "biobased." It is also working on developing acceptable testing methodologies, including carbon dating. It will develop "Performance and Manufacturer Specifications" as well as Environmental Performance, working with the National Institute of Standards and Technology's "Building for Environmental and Economic Sustainability (BEES)" Program.

4. Production support

Subsidies

The 2002 Farm Bill includes numerous provisions that subsidise agricultural production of crop commodities, such as corn and soybeans. To limit the length of this discussion and to stay reasonably focused, a more detailed description of the various commodity support programmes will not be provided here. The clear and common goal of commodity subsidies is agricultural support.

An interesting variation on production subsidies relevant to bioenergy is provided in Section 9010 of the 2002 Farm Bill. This section continues a programme under which the Secretary of Agriculture makes payments to eligible producers to encourage increased purchases of eligible commodities for the purpose of expanding production of bioenergy and supporting new production capacity for bioenergy (USDA). USDA recently solicited public comment on the proposed rule for this programme. According to USDA, most of the respondents were opposed to any reduction in programme payments for biodiesel made from soybeans and they requested increased payments on biodiesel production from animal fats and oils.

Loan guarantees

Section 9006 of the 2002 Farm Bill directs the Secretary of Agriculture to make additional loans, loan guarantees, and cost-share grants to farmers, ranchers, and rural small businesses to purchase renewable energy systems and to make energy efficiency improvements. This programme supports the development of the physical infrastructure and equipment that is needed to develop biomass production and processing. This programme is managed though the Office of Rural Development's Rural Business Cooperative Service.

Market development

The USDA Office of Rural Development conducts a Program for Value-Added Agricultural Product Market Development, which provides competitive grants to help independent producers develop business plans and strategies to create marketing opportunities.

5. Support for research and development

Over a period of 20 years (1978-98) US spending on R&D for renewable energy totalled around USD 13 billion (in 1999 dollars). Most of the funding was targeted to electrify generation applications; the largest proportion of this research funding was allocated to solar photovoltaics (roughly USD 2.5 billion) and wind power (USD 1.5 billion). More recently, in response to the Biomass Research and Development Act of 2000 and Section 9008 of the 2002 Farm Bill, USDOE and USDA have developed a collaborative Biomass Research and Development Initiative. On 18 March 2003, the two departments issued a joint "request for proposals" (RFP) totalling up to USD 21 million for fiscal year 2003. Of the funds allocated for the RFP this year, USDA's commitment includes a USD 2 million fiscal year 2002 carryover balance and USD 14 million allocated by the Farm Bill for fiscal year 2003. DOE's commitment of up to USD 5 million came from non-Farm Bill sources. Excerpts from the joint RFP follow.

Biomass Research and Development Initiative

Purpose, priorities, and fund availability

The purposes of grants under this Initiative are to

1. encourage collaboration by a diverse range of experts in biomass production, handling, processing, and manufacturing for innovation-targeted research, technology development, and demonstration;
2. enhance creative and imaginative approaches toward biomass production, handling, processing, and manufacturing that will serve to develop and demonstrate the next generation of advanced technologies, making possible low-cost and sustainable biobased industrial products, biofuels, and biopower;
3. strengthen training, education, and practical experience of future scientists, engineers, managers, and business leaders in the field of biomass production, handling, processing, and manufacturing; and
4. promote integrated research partnerships among colleges, universities, national laboratories, Federal and State research agencies, and the private sector to address technical challenges that span multiple disciplines and of gaining better leverage from limited Federal research funds.

Higher priorities will be given to projects that:

- Demonstrate potential for significant advances in biomass production, handling, processing, and manufacturing;

- Demonstrate potentially viable distributed power generation opportunities using biomass suitable for moderate-sized operations, particularly addressing animal waste management issues;

- Improve understanding and ability to overcome technical and institutional barriers associated with connections to the commercial power grid and energy distribution and transmission system;

- Improve potential for developing rural-based processing and manufacturing of biobased products and power production from biomass;

- Demonstrate potential to substantially further national objectives such as sustainable resource supply, reduced greenhouse gas emissions, healthier rural economies, and improved strategic energy security and trade balances; and

- Demonstrate commercial relevance of the proposal; expected marketability and potential commercial viability of biomass production, handling, processing, or manufacturing procedure and the biobased products that would be developed.

This new collaborative initiative offers some critical opportunities for biomass and bioenergy R&D. The immediate challenge for this policy option will be to keep it funded over the next several years. The Congressional "authorisers" who created the Farm Bill funding component of this initiative used a funding source that typically is used for funding commodity support programmes. As there are Congressional and agency battles over limited funds, the Congressional "appropriators" are likely to try to take this funding back, not because they oppose R&D on bioenergy, but because they oppose an incursion into their areas of authority by the other Congressional Committees and they oppose the use of this funding source for anything other than commodity support payments.

There are a mix of provisions in the House and Senate versions of the Energy bill that would strengthen and support energy research. Supporters of increased funding for energy research have promoted the inclusion of language that would allow for significant increases in energy R&D, similar to what has been provided for health research through the National Institute of Health. It is important to note that increased "authorisations" are not the same as increased "appropriations" (when funding is actually allocated), but increased authorisations can set the stage for increased federal funding. Legislation has also been proposed that addresses the organisation and administration of science and technology programmes within USDOE. Relatively new legislation has been developed to support a "Sun Grant Initiative" (SGI) by a number of universities to strengthen the working relations between USDOE and the state agricultural colleges and State Agricultural Experiment Stations. The SGI is based on developing five regional "Centers of Excellence" for research and education programmes on biomass and bioenergy production. Each of these Centers would also administer a regional competitive grants programme developed to address local bioregional R&D needs in order to address national bioenergy goals and objectives.

Developing a framework for integrating policy choices

Because of the great biogeographical and climatic range and diversity within the US, it is not practical to have a single set of bioenergy goals and objectives that will be implemented rigidly for all parts of the country. For example, using biomass production to produce bioenergy will be very different in the grain producing Mid-west than it is in the South-east, where fast-growing pine forests may be a more important source of biofuels than some grain crops. To be implementable, national policies need to be developed with a clear recognition of regional variation and regional needs.

In the same manner, bioenergy production goals and programmes need to be integrated into a larger set of national renewable energy goals and programmes. In the South-west, solar energy may be the lead renewable energy source, providing more energy than biomass. In some portions of the North-west, hydroelectric power may be the priority programme. In each region, however, even when bioenergy is not the leading renewable energy source, biomass production can have an important role to play. Recognising that bioenergy will not be the only renewable energy source, or even the dominant source in some areas, the following discussion continues with a focus on the production of biomass for bioenergy as an important and necessary component of a comprehensive national policy to provide renewable energy.

Determine policy priority

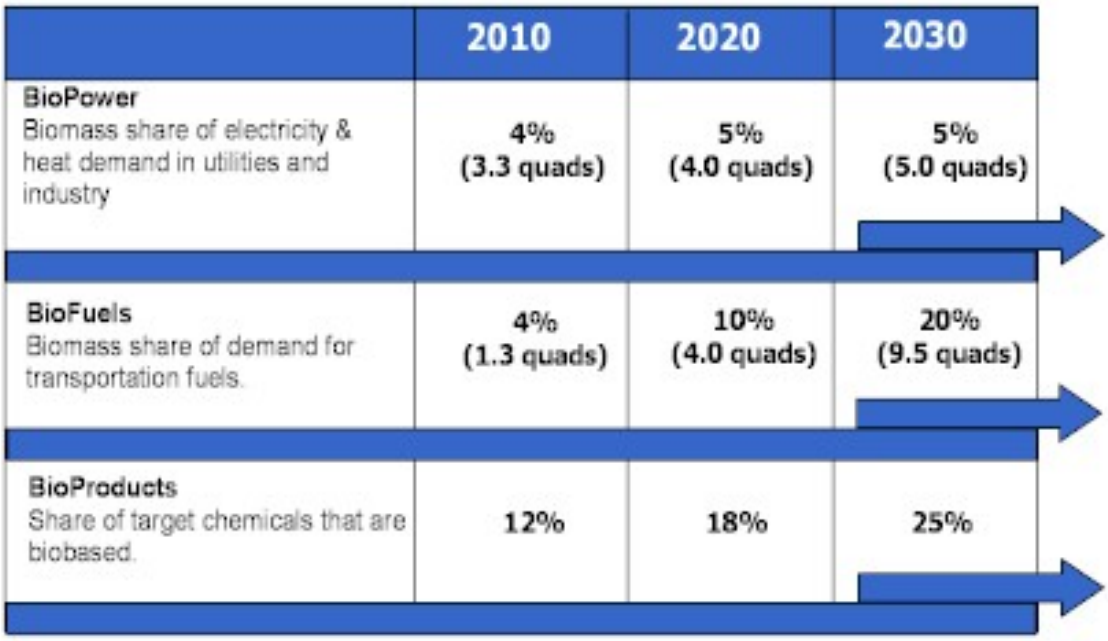
The primary purpose of the matrix in Figure 10 is to provide a visual aid to begin thinking about the mix of policy tools that might be best suited to a particular policy goal, and to begin thinking about effects that any given policy tool might have on each of the other policy goals. In an ideal world, one would define crisp and measurable objectives within each policy goal, and then seek a mix of policy tools that would provide an optimal combination of programmes and projects in order to reach all policy goals simultaneously. This idealised approach may be more appealing to scientists and mathematicians than it will be practical for policy makers, who must negotiate a balance among competing interest groups wanting immediate action on each day's most urgent problem. An iterative approach may have more of a chance in the "real world," where policy makers sort out the policy issue and policy goal that are most important for them today, directing agency managers and policy specialists to develop the most appropriate mix of policy tools to most effectively address that goal. After addressing today's issue and goal, then there may be a chance for policy makers to think about the implications for other goals and programmes and to adjust accordingly.

The choice of which goal is the most important will usually have implications for other policy goals. If the primary goal is to enhance farmer income for agricultural production, a different mix of policies may be chosen than if the primary goal is environmental protection or energy security. That said, it is possible that once the primary policy goal is identified and potential policies identified, then the potential impact on the other goals can at least be examined and possible policy modifications can be developed. This is in a sense, a statement of the obvious. We should always consider, after developing new legislation and new agency programmes, what the implications of our new programmes are on other national policy goals. But in fact we often do not consider the consequences of our "solutions" on other problems and along the way we miss opportunities to avoid policy contradictions and we overlook new and creative ways to develop synergistic policies. The matrix simply reminds us that the choices we make in one policy arena can have significant impacts on other policy goals.

Define targets

For the purpose of this discussion, I will assume that the lead policy goal is to enhance energy security through the increased use of biomass production for energy production. Once the lead goal is clarified, the next task is to define measurable objectives or targets (otherwise we'll never know if we're approaching our goal). Figure 11 shows targets for biofuel use developed by the USDOE. The targets identified by USDOE are consistent with the projected increase in the use of bioenergy in US energy consumption shown in Figure 2 and Figure 4, and they reflect worthy aspirations, but some note that the current use and production of biomass will have to increase dramatically and immediately in order to approach the USDOE targets. Returning to the matrix in Figure 10, it is likely that it will be necessary to redesign some portion of US farm production support programmes in order to meet the levels of biomass production envisioned in the USDOE targets. This will require a level of collaboration between energy-oriented and agriculture-oriented policy makers and programme managers that – to date – has simply not occurred.

Figure 11. DOE targets for biofuels



Source: National Biomass Coordination Office, Energy Efficiency and Renewable Energy, US Department of Energy.

Address obstacles

The next task is to take a good look at potential obstacles and anticipate problems that will need to be addressed. Biomass production for bioenergy generation has been around for a long time, what is keeping the relative use of biomass at such a low level? Are the problems technical, social, economic, or political?

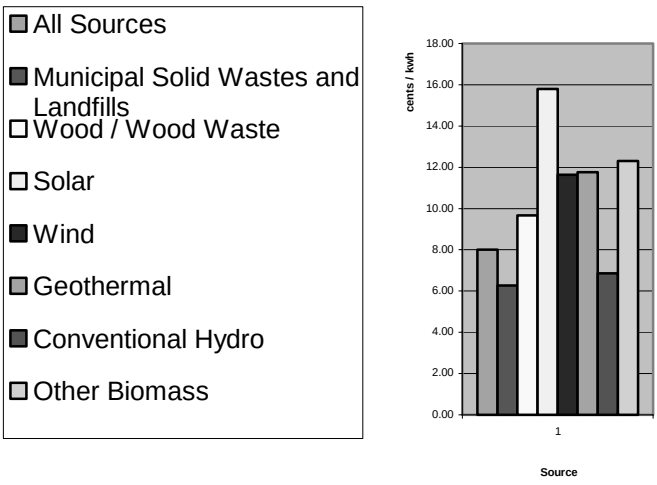
Reduce bioenergy production costs

Most studies on the barriers to increased use of biomass conclude that the relatively cheap cost of fossil fuels simply makes it impossible for other energy sources to compete (McVeigh *et al.*).

> *The failure of renewables to emerge more prominently in the nation's energy portfolio is intimately linked to the concurrent decline in the cost of conventional generation. Consider that in 1984, the Energy Information Administration projected nationwide electric generation costs to rise from 6.1 cents/kwh in 1983 to 6.4 cents/kwh in 1995; in fact, they declined to 3.6 cents/kwh. That 41% decline, though less percentage wise than what was achieved by wind power, nonetheless preserved a sufficiently large margin of advantage – 3.6 cents/kwh vs. 5.2 cents/kwh – for conventional over wind power as to foreclose more than a minute niche for the latter.*

Even though the cost of producing bioenergy and other renewable energy sources may have declined more rapidly than the costs of conventional energy sources, conventional sources are still so much cheaper the renewable sources simply haven't caught up. Among renewable energy sources, conventional hydroelectric power remains significantly cheaper than other renewable energy sources (Figure 12). The clear and immediate challenge for proponents of bioenergy is to greatly reduce the cost of producing bioenergy.

Figure 12. Electric utility average price of renewable electric power purchased from non-utility facilities, by energy source, 1995
(cents per kilowatt-hour)

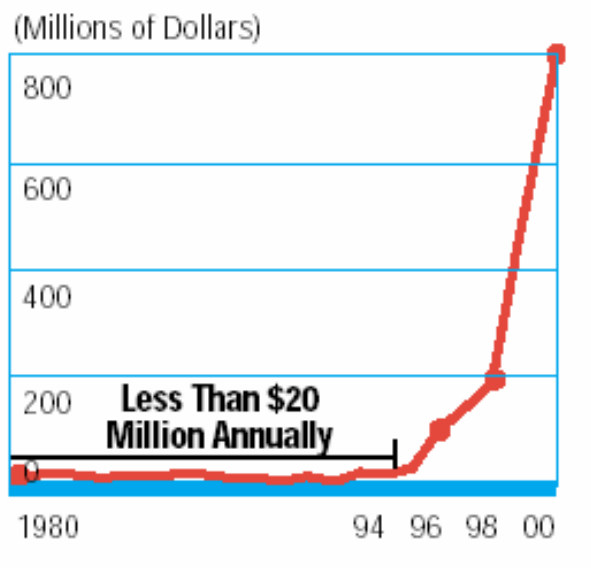


Source: Derived from USDOE, 1999, *Renewable Energy: Issues and Trends 1998,* Energy Information Administration, Washington, D.C., March.

Develop decentralised infrastructure

Some argue that the immense infrastructure that has been developed and is already in place to support the use of fossil fuels, nuclear power, and hydroelectric generation make it very difficult for new technologies to reach the scale or size of production that would allow them to become cost-competitive. This is particularly challenging for bioenergy production, as the "rate-limiting-step" is often the cost of shipping wet biomass "stock." While large-scale processing plants offer economies of scale, many argue that biomass production may be better served by developing a network of smaller processing plants, distributed across the countryside. The development of a distributed network of smaller-scale bioenergy producing centres offers a number of advantages. Transportation costs are reduced. Capital investments and returns are kept in "local" communities, improving the income of farmers and with greater economic benefits for local rural economies. In the past, investors have been reluctant to support smaller and more local energy systems, preferring instead to support large-scale infrastructure projects. The US Administration, however, now suggests that there is a greater willingness within the private sector to invest in distributed energy systems (Figure 13).

Figure 13. Investors are betting on distributed energy



Source: Data for 2000 are projected investments: source: Nth Power via *The Economist*, 5 August.

As witnessed by the recent catastrophic energy blackouts in the US North-east and Canada, our electric grid structure needs substantial reinvestments and updating, with the development of "self-sealing" networks than can buffer themselves from "shocks" and insulate each region's grids from collapse in nearby systems. As the US energy grid is modernised, there is an obvious opportunity to improve the ability for these large-scale systems to operate in a more decentralised fashion, interacting more effectively with diverse decentralised power sources, such as bioenergy-producing systems. The development of a more decentralised energy system with a greater use of diverse energy sources will also help address US homeland security concerns – a decentralised energy system made of many relatively small contributors is a more resilient system and one that is harder to attack.

Facilitate integrated projects

Some have suggested that the most expedient way to bring down the cost of bioenergy production is to "multi-task," doing several things at once. If bioenergy can be developed from agricultural wastes from other production activities, if bioenergy can be produced directly on the farm, and if the heat generated from bioenergy production can be used to co-generate electricity or heat farm buildings, then the total operation may be cost-effective, even if the individual components of the operation are not cost-competitive on their own. To compete with large-scale centralised energy production, bioenergy may require combinations of highly integrated components linked together in a vast decentralised system.

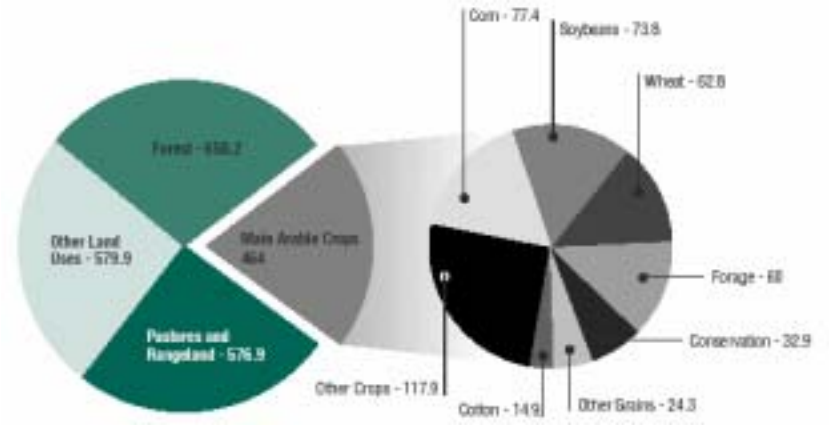
Develop synergetic solutions

At this point in the discussion, our policy goal priority is to enhance energy security by the increased use of biomass for energy production: our objectives and targets are defined in Figure 11, and our strategy is to develop a decentralised network of bioenergy production systems adapted to regional bioclimatic and agronomic requirements. To reach our target production level, what level of agricultural production will be necessary? Can enough biomass be produced in a cost-effective manner? What will the cumulative impact on the environment be?

Set agricultural production goals

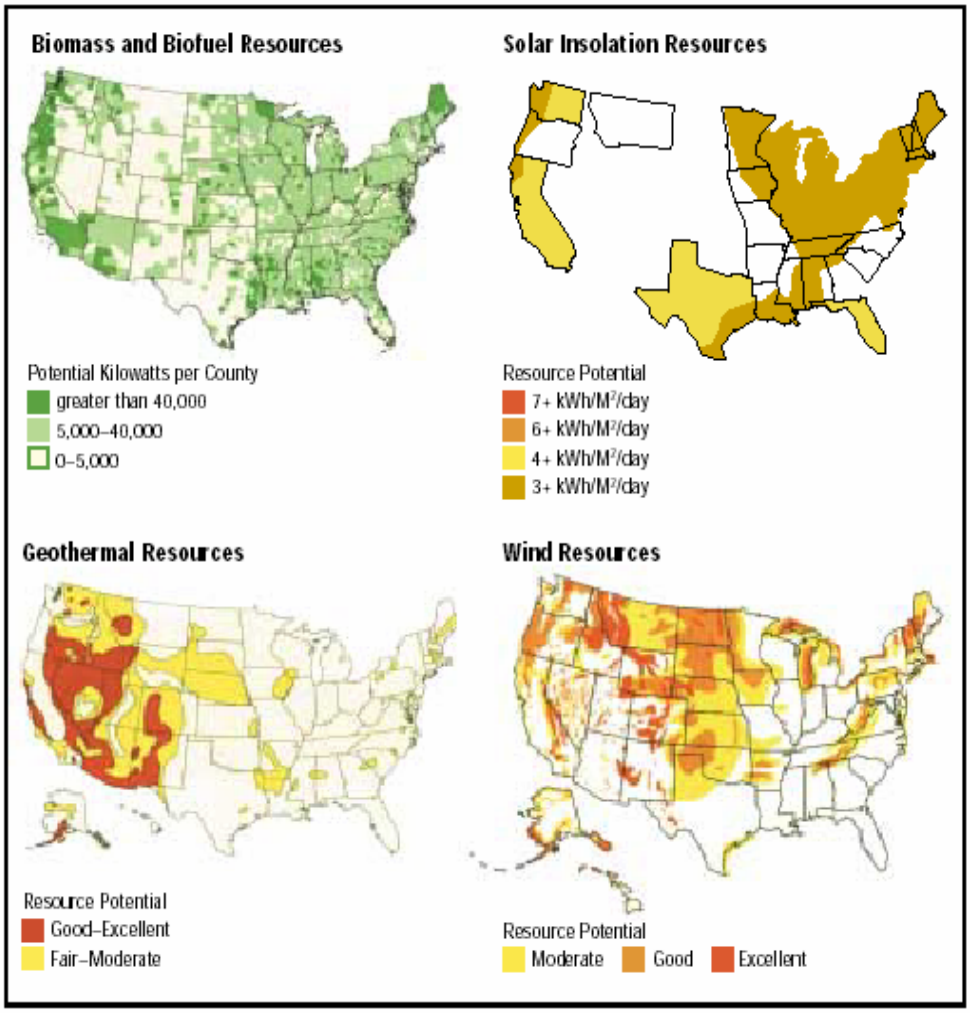
A review of Figures 14 and 15 suggests that US farmers can probably produce whatever level of biomass the market will pay for or government programmes can absorb. The productive capacity is there, but the market or government signals may not be there to drive the timely development of specialty biomass crops. Bioenergy and bioproducts entrepreneurs have complained that sometimes they cannot get reliable and affordable "feedstock" and producers complain that there is not a consistent enough demand for them to commit to increased production. There has been a persistent question of what comes first for bioenergy and bioproducts markets, the demand or the supply? In this context, and given that the government is already heavily involved in agricultural production support, it may be most expedient for the government to "kick-start" the supply side of this equation. Since the US is heavily involved in providing direct and indirect subsidies to farmers anyway, it may be time to look at those programmes to see how they could be adjusted to insure a steady supply of desired bioenergy feedstocks for bioenergy producers.

Figure 14. US land area of plant/crop-based resources for the biobased products industry
(millions of acres)



Source: Department of Commerce, Statistical Abstracts 1999, Agricultural Statistics Survey.

Figure 15. US resource potential for renewable energy



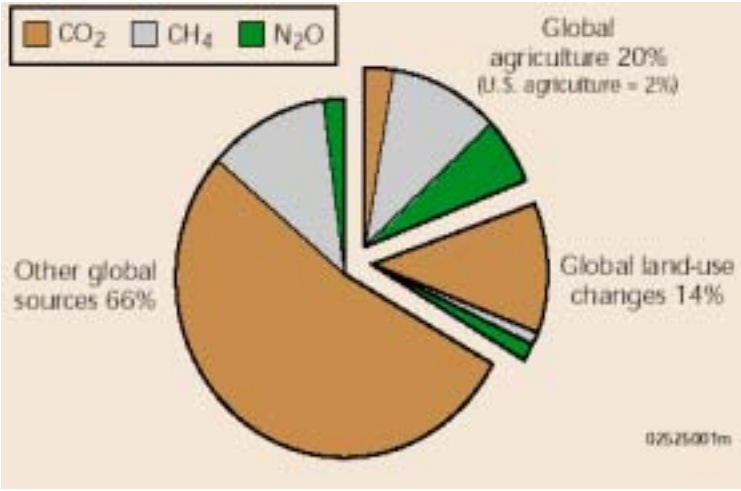
Source: USDOE, National Renewable Energy Laboratory.

Our "free-market" colleagues will point out that we'd all be better served by doing away with farm support subsidies altogether, letting the world market sort out prices, thereby improving international markets for developing countries, reducing the impact of over-production on the environment, and freeing up government funds for other more urgent needs. All of these may be true, but for good or bad, US support for farm support programmes is not likely to go away any time soon. Some might ask, since the US has plunged again into deficit spending, and since the internal battles over domestic spending will greatly intensify, won't there be strong public pressure to do away with or reduce farm payments? Yes, there probably will a move to reduce farm payments, likely supported by an unusual alliance of fiscal conservatives and urban liberals. However, farm and commodity groups will remain a powerful and resilient political force. Programmes may be reduced, as they ebb and flow over time, but they are not likely to go away. A more likely compromise is that there will be increased requirements for additional social benefits from these payments, such as environmental protection or increased rural economic development. Farmers are often wary of these requirements, with some

apprehension about the feasibility and costs of implementing new programme requirements. However, in lieu of reduced payments or new regulations, the most probable compromise will be less funding than is currently provided and with requirements, but the payments are not actually likely to be done away with. In the coming political environment, it makes eminent sense to begin talking now about adapting farm support programmes to provide desired levels of biomass feedstocks as one of the social benefits to be gained from farm support payments, an approach that will add relatively few new restrictions on producers.

While the cost of bioenergy production may not be cost-competitive by itself, *subsidised* production of biomass for bioenergy could be much more cost-competitive than it currently is. Integrating current conservation programmes with biomass production support could yield many benefits. A potentially interesting example of a programme that can be designed to meet multiple policy goals is the Conservation Reserve Program (CRP), which is defined in the Farm Bill. In general terms, the CRP pays farmers for taking land out of agricultural production. Farmers "conserve" the land by not tilling it. Theoretically, this can reduce agricultural supply and support higher prices for agricultural commodities. There has been a long-standing debate as to whether farmers should be allowed to harvest hay off land in the CRP if they do not till the soil. Although beneficial environmental impacts would be retained and grain production would still be reduced, some feel that allowing farmers to harvest a hay crop off the CRP amounts to "double dipping" by the participating farmers and it impacts other farmers and ranchers growing feed crops. However, farmers *could* be allowed to harvest biomass residue off CRP lands as long as they do not till the soil, which would indeed provide an additional income source but not one that would impact competing livestock feed markets. Allowing the harvesting of specified types of biomass residue off CRP land could have the ideal consequence of supporting farmer income, protecting agricultural soil and the environment, providing an energy source, while still reducing agricultural oversupply and supporting grain commodity prices – a hypothetical example of a well-designed programme meeting four policy goals simultaneously.

Figure 16. Percent contributions to the annual increase in the greenhouse gases carbon dioxide, methane and nitrous oxide

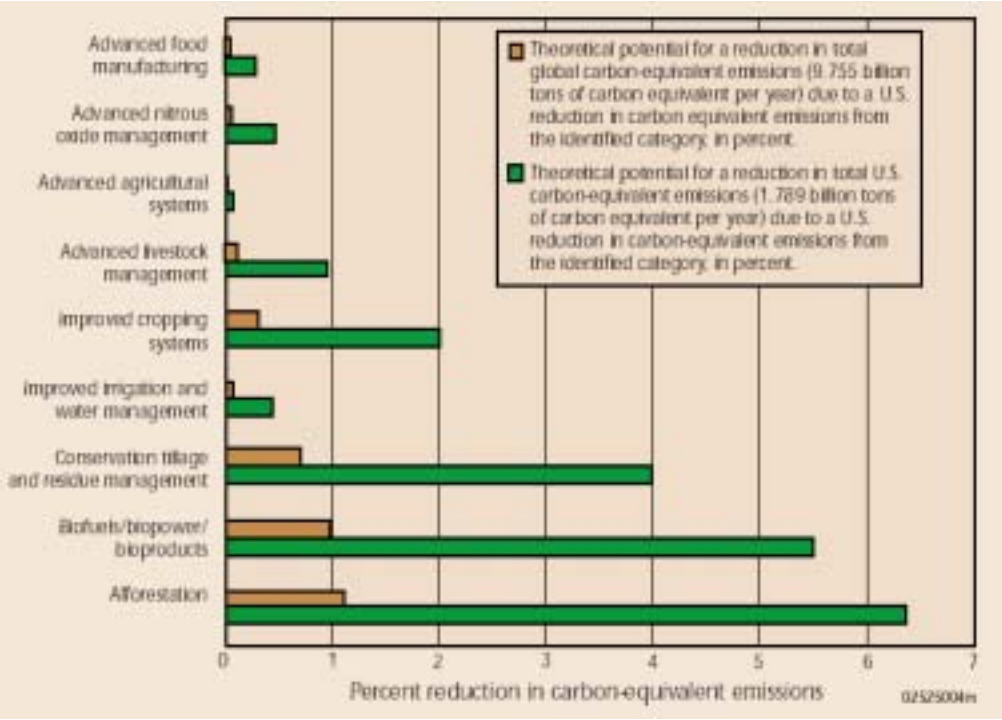


Note: Based on global warming potential.
Source: @OIT GG.

Capture environmental benefits

This paper has focused on the interplay between energy and agricultural production needs, with some consideration of the consequences for economic development. The missing piece of this discussion is the consideration of the impact on the environment. Figure 16 provides a summary of relative sources for increasing greenhouse gases and Figure 17 shows the potential role that agriculture could play in reducing greenhouse gases, including increased use of conservation tillage and increased use of biofuels. As the level of agricultural production needed to reach bioenergy targets is calculated, the net costs and benefits to the environment will also need to be considered.

Figure 17. Theoretical potential for annual reduction or sequestration of human-caused greenhouse gas emissions from agriculture and food manufacturing



Note: Expressed in % reduction in total carbon or carbon equivalent emitted to the atmosphere from three greenhouse gases (carbon dioxide, methane and nitrous oxide).
Source: @OIT GG.

Some conclusions

Some "take home" conclusions can be posited at this point.

- Although it will not likely be the most important energy source for the US in the coming decades, bioenergy can make up a very important component of a diversified renewable energy portfolio for the US.

- Increased use of a diversified and distributed bioenergy production network can have important benefits for US energy security, US farm income, economic development, and the environment.

- For bioenergy to increase to a level of production necessary to secure these benefits, US agricultural production will need some restructuring to ensure that there is sufficient biomass production targeted to meeting bioenergy needs.

  – New models for developing integrated bioenergy systems will need to be developed at the local level, requiring targeted research, education and training programmes.

  – New economic incentives and new economic development tools will need to be developed and implemented to support the development of a comprehensive but decentralised energy system.

  – US farm policies will need to be evaluated and adjusted to support greater production of biomass for bioenergy purposes. Current support mechanisms may need to be adjusted to meet multiple social goals.

- Energy, agriculture, and environmental policy makers, programme managers, and scientists will need to work together much more collaboratively to develop coherent and consistently beneficial bioenergy programmes and policies.

The choices that the US makes regarding the support of agricultural production of biomass for bioenergy production will have important ramifications for the farm income and global trade, world energy markets, and world trade.

Next steps

The challenge for agency officials and programme managers will be to develop a coherent and co-ordinated mix of programmes out of the current array of diverse and distinct policy mechanisms. The challenge for scientists will be to utilise current support for R&D to ensure that there are answers to the questions that policy makers will ask next. Has support for biomass production increased farmers' incomes? Has increased use of biomass and bioenergy provided measurable benefits to the environment? What are the spillover effects on global trade and world food production? The next challenge for policy makers will be to manage the competing and conflicting interests of agricultural producers, energy producers and the environmental community to craft the next round of policy options that allow everyone to win as we strive towards transition to a "biobased" economy.

BIBLIOGRAPHY

Bailey, Carmela A. (2003), Agricultural Materials Program, Cooperative State Research, Education, and Extension Service, Office of Research, Education and Economics, US Department of Agriculture, Washington, D.C., United States, 8 May.

Bamberger, Robert L. (2003), *Energy Policy: The Continuing Debate*, CRS Issue Brief for Congress: IB10116, Congressional Research Service: Resources, Science, and Industry Division, The Library of Congress, 9 May.

Cato Institute (2003), *Evaluating the Case for Renewable Energy: Is Government Support Warranted?* Cato Institute, 1-10-2002.

Darmstadter, J. (2000), "The Role of Renewable Resources in U.S. Electricity Generation – Experience and Prospects", Resources for the Future, *Climate Change Issues Brief* No. 24.

Darmstadter, J. (2002), "A Global Energy Perspective", Resources for the Future, *Issue Brief* 02-10.

Ferrell, John (2003), *The Science and Engineering for a Biobased Industry and Economy*, National Biomass Coordination Office of the Biomass Program Energy Efficiency and Renewable Energy, US Department of Energy, 8 May.

Fischer, C. and Michael Toman (1988), "Environmentally and Economically Damaging Subsidies: Concepts and Illustrations", Resources for the Future, *Climate Change Issue Brief* No. 14.

Hamilton, Bruce (2003), "Science and Engineering for a Biobased Industry and Economy", Division Director, Bioengineering and Environmental Systems, National Science Foundation, 8 May.

Lawrence Berkeley Laboratory and National Renewable Energy Laboratory (2001), *Forecasting the Growth of Green Power Markets in the United States*.

Lawrence Berkeley Laboratory (2002), *Case Studies of State Support for Renewable Energy*.

Loiter, J. M. and V. Norberg-Bohm (1999), *Technology Policy and Renewable Energy: Public Roles in the Development of New Energy Technologies*, pp. 85-97. V. 27.

Lyon, T.P. (2003), "Voluntary Versus Mandatory Approaches to Climate Change Mitigation", Resources for the Future, *Issue Brief* 03-01.

Macauley, M., Jhih-Shyang Shih *et al.* (2002), *Measuring the Contribution to the Economy of Investments in Renewable Energy: Estimates of Future Consumer Gains*, 1616 P St., N.W., Washington, D.C. 20036, Resources for the Future, *Discussion Paper* 02-05.

McVeigh, J., Dallas Burt, *et al.* (1999), "Winner, Loser, or Innocent Victim? Has Renewable Energy Performed as Expected?" *Discussion Paper* 99-28.

National Renewable Energy Laboratory (2001), *The Clean Air Act and Renewable Energy: Opportunities, Barriers, and Options*, NREL/CP-620-29654.

Sissine, Fred (2003), "Renewable Energy: Tax Credit, Budget, and Electricity Production Issues", CRS Issue Brief for Congress: IB10041, Congressional Research Service: Resources, Science, and Industry Division, The Library of Congress, 28 February.

Stempeck, Brian and Suzanne Struglinski (2003), "Energy markups get smooth start with hydrogen, hydropower passage" *Energy Policy*, E&E Daily, E&E Publishing, LLC, 9 April.

Truly, R. (2002), "Enhancing Homeland Security Through Renewable Energy" – Richard Truly's Remarks to the National Press Club.

US Department of Agriculture [USDA] and the US Department of Energy [USDOE] (2003), "Biomass Research and Development Initiative: 2003 Request for Proposals", 18 March.

USDOE (2003), *Energy Information Administration's Annual Energy Outlook 2003.*

USDOE (2003), *Multiyear Plan: 2003 to 2008,* Office of the Biomass Program, Office of Energy Efficiency and Renewable Energy.

USDOE (2002), *Roadmap for Biomass Technologies in the United States*, Biomass R&D Technical Advisory Committee, December.

US Executive Office of the President (1999), *Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation*, Government Printing Office, p. 260.

US Executive Office of the President (2001), *National Energy Policy Report*, Government Printing Office, p. 170.

A VISION AND ROADMAP FOR THE BIOECONOMY IN IOWA (UNITED STATES)

Jill Euken[1]

Abstract

The state of Iowa has been actively involved with a number of biomass-related activities to help reduce the country's reliance on imported petroleum, to reduce environmental impact, and to enhance rural economies. Individuals from many of these efforts came together as part of the Department of Energy's Industries of the Future process to develop a bioeconomy "Vision" and "Roadmap" for the state of Iowa. The goal was to develop a vision for converting agricultural crops and residues into biobased products and bioenergy, and also to chart a roadmap for achieving this vision. Over 600 Iowans contributed their ideas to the process, participating in focus groups and workshops throughout the state. Based on the input received, an Iowa Vision was developed:

Iowa leads the nation in developing the bioeconomy. Growth of the bioeconomy has led to an unprecedented period of sustained economic growth and has allowed Iowa to develop abundant amenities and a quality of life rated among the highest in the United States. Iowa biorefineries enjoy widespread support from Iowans because they consistently:

- Produce superior products;
- Capture significant value for all segments of bioproduct value chains;
- Provide high rates of return to investors;
- Attract local and outside capital;
- Provide exciting, challenging, and lucrative jobs; and
- Improve environmental conditions and ecological diversity.

An industry-led steering committee was formed to take the variety of input and develop directional targets for biobased products and bioenergy. The committee also highlighted issues that need to be addressed in order to increase the availability and use of biomass. The issues were aligned under the key themes of science and technology, capital investment, market development, policy, standards and incentives, and education and outreach. This process has led to the growth of a number of activities within the state.

1. Center for Industrial Research and Service (CIRAS), Iowa State University Extension, Lewis, Iowa, United States.

A new not-for-profit organisation, BIOWA™, has been formed to implement the Vision and Roadmap. BIOWA™ membership includes individuals from private industry, academia, farm organisations and others that are committed to the development of Iowa's bioeconomy. The goals of the organisation are to:

- Develop at least ten regional biorefineries in Iowa by 2020;
- Build at least five new bio-businesses per year, or expand existing bio-businesses; and
- Provide investment and employment opportunities for Iowans in biobased businesses.

At the national level, several Executive Orders and other legislative actions have required federal agencies to identify and procure biobased products. In addition, section 9002 of Title IX of the 2002 Farm Bill establishes a preferred procurement programme. The US Department of Agriculture (USDA) has partnered with Iowa State University to develop a system to aid this process. A parallel effort is underway within the state to assist Iowa manufacturers in selling biobased products to state and federal agencies.

Introduction

Objectives

In 1994, a publication on biomass energy distributed by the United States Department of Energy (USDOE) highlighted an agricultural community in Iowa that revitalised its markets for agricultural products by diversifying into energy crops. The response to this publication was immediate: the Department of Energy received numerous inquiries from people across the United States and from abroad who wished to visit this biomass success story in Iowa (Peters, 1994).

In fact, this community only existed on paper. It was created to illustrate what might be achieved if biomass products and energy were incorporated into the rural economy. However, because of Iowa's pre-eminence in agricultural production, there were and continue to be national and international expectations for innovations in agriculture to emerge from Iowa.

The Iowa Industries of the Future/Agriculture project is designed on the premise that an inspiring Vision, effectively communicated, can shape the future. This document represents the result of a disciplined effort in Iowa to envision a new bioeconomy; explore its implications; communicate its potential; and outline issues that need to be addressed in order to increase the availability and use of biomass to produce biobased products and bioenergy.

Modelled on the national process that created the National Vision and Roadmap documents, a diverse group of people contributed knowledge and expertise to this document. The group was lead by biomass growers as well as leaders in industry, research, academia, and government. Their objectives (USDOE, 2001) were to:

- Create an inspiring vision of a vibrant, integrated biobased products and bioenergy industry in Iowa;
- Pose challenging, yet achievable, "stretch" goals and milestones for reaching the vision;

- Outline the technology, policy, education and market support required for the growth of an integrated bioeconomy in Iowa; and

- Spur the innovative thinking, vigorous debate, investment and action necessary to realise this vision.

The Iowa Industries of the Future/Agriculture project was guided by the same set of objectives as it set out to develop a "Vision" and "Roadmap" for the bioeconomy of Iowa.

Biomass resources

Biomass resources are defined as source material that is available on a renewable or recurring basis, including agricultural crops and crop residues, trees and waste streams from the animal feeding, food, feed and fibre industries.

The hydrocarbon economy

In the past century, modern society has developed an enormous and sophisticated infrastructure for extracting, processing, storing, distributing and utilising products and energy from fossil fuel resources.

The infrastructure for this hydrocarbon economy includes physical assets and intellectual assets (cumulative knowledge gained through many billions of dollars invested in public and private research).

The hydrocarbon economy has served the world well – providing abundant products, fuels, energy and materials at reasonable cost for the developed countries of the world. However, many are questioning whether the hydrocarbon economy is sustainable. Potential problems for the petroleum economy may include:

- Supply of petroleum being interrupted;

- Price of petroleum sky-rocketing;

- Environmental impacts of continued increase in use of petroleum products and of extraction; and

- Increase in demand for industrial and consumer products, fuels, and materials from Third-World countries and developed countries.

The potential problems listed above could create significant negative impact on any or all of the following:

- National security;

- Standards of living; and

- Environmental quality.

The bioeconomy

Biomass resources are a strategic option to meet the growing need for industrial products and energy. Developing biobased industries can help the US maintain a leadership position in science and technology and maintain a high standard of living.

Expansion of biobased industrial production in Iowa will require an overall scale-up of manufacturing capabilities, diversification of processing technologies and reduction of processing costs. The development of efficient "biorefineries" – integrated processing plants that yield numerous products – could reduce costs and allow biobased products to compete more effectively with petroleum-based products.

The 21st century will see many petroleum-derived products replaced with less expensive, better-performing biobased products made from renewable materials grown in farm fields and forests. The opportunity for Iowa and the US is clear. However, it will require vision, integration of stakeholders, co-ordination of research and investment in new approaches.

Iowa and resources for the bioeconomy

When the infamous bank robber Willie Sutton was asked why he robbed banks, he is reported to have replied "Because that's where the money is." By the same token, the reason Iowa will lead the nation in developing the bioeconomy is because "that's where the biomass is!"

Iowa combines fertile soils, abundant rainfall, warm, sunny growing seasons, and a highly skilled agricultural workforce to provide the most concentrated source of agricultural production anywhere in the world. A quarter of the world's most productive land (class A soils) is located in Iowa. Iowa leads the nation in corn and soybean production, produces 25% of the nation's pork, and is ranked in the top ten producing states in egg, dairy, turkey and beef production.

An Oak Ridge National Laboratory (ORNL) report dated January 2000 provided data on the 48 contiguous states, regarding the volume of available biomass. Figure 1 shows that Iowa and Illinois are clearly the leading states, with 50% more biomass available than third-ranking Nebraska.

The ORNL study (Walsh *et al.*, 1999) includes the following:

- Forest wood residues (*i.e.* logging residues; rough, rotten, and saleable deadwood; excess saplings and small pole trees).

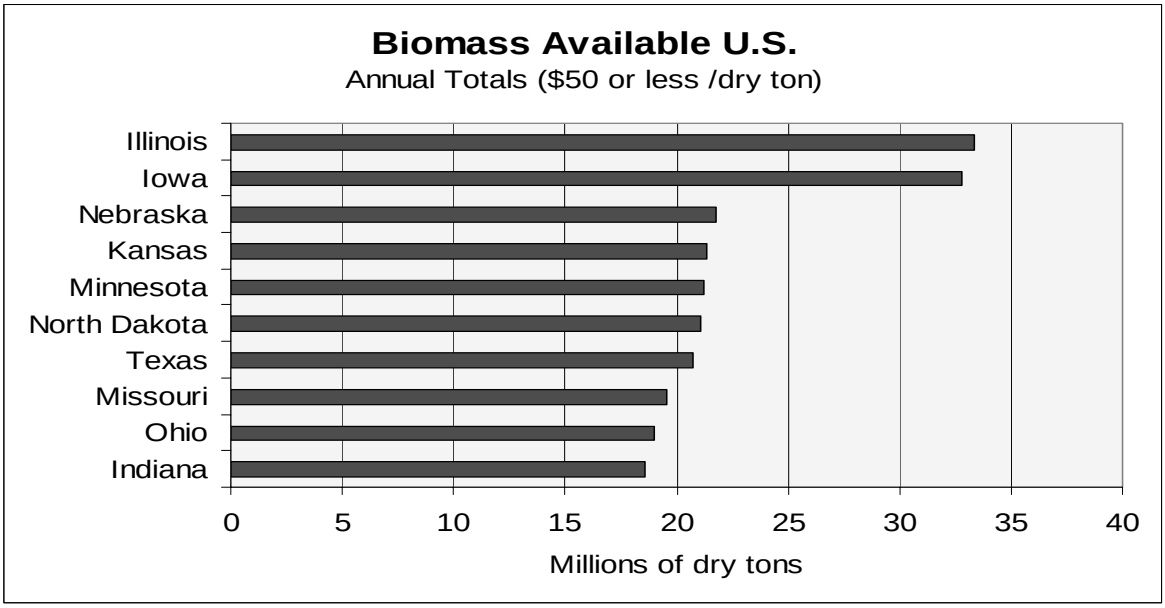
- Residues generated at primary wood mills (*i.e.* mills producing lumber, pulp, veneers, other composite wood fibre materials).

- Agricultural residues (*i.e.* corn, wheat, soybeans, hay, cotton, grain sorghum, barley, oats, rive and rye); in general 30-40% of the available residues were included based on state-specific calculations.

- Dedicated energy (*i.e.* short rotation woody crops [SRWC], such as hybrid poplar and hybrid willow and herbaceous crops, such as switchgrass (SG]).

- Urban wood wastes (*i.e.* yard trimmings, site-clearing wastes, pallets, wood packaging and other miscellaneous commercial and household wood waste and demolition and construction wastes).

Figure 1. Biomass availability in the United States



Source: Walsh *et al.*, 1999.

However, leading the way into the bioeconomy is about more than just having an abundant supply of raw material. Other resources that enhance Iowa's ability to lead this effort include:

- Efficient agricultural production systems;
- A solid base of small to medium-sized manufacturers and processors dispersed throughout the state;
- An efficient and dedicated workforce; and
- A system of educational and research resources of very high quality.

The combination of all these resources positions Iowa to be the leader in the formation of a vibrant bioeconomy in this country.

Current utilisation of biomass in Iowa

While the term "bioeconomy" may be a new one, many of the business activities that make up a biobased economy are not. In fact, many businesses in Iowa are already processing biomass to produce products like industrial chemicals, enzymes, lubricants, biocomposites, litter and much, much more. In the fuel category, ethanol is being produced in three facilities in Iowa: additional facilities are in planning and/or construction phases. Biodiesel is also starting to flow, and biomass is being used to generate power. The best example is the Chariton Valley Resource Conservation and Development (RC&D) project involving switchgrass being co-fired with coal to generate electric power at the Alliant Energy Ottumwa Generating Station.

Iowa compares favourably with nine other states in the upper Mid-west for the current level of biobased activity (Table 1). Based on sales dollars, Iowa ranks first in biobased products, second in fuel (behind Illinois) and fourth in power.

Table 1. Mid-west biobased sales (USD) and ranking

	POWER		FUEL		PRODUCTS	
	Sales (USD 1 000)	**Rank**	**Sales** (USD 1 000)	**Rank**	**Sales** (USD 1 000)	**Rank**
Illinois	118 370	3	980 847	1	1 418 951	2
Indiana	22 100	5	115 830	6	1 011 995	3
Iowa	54 100	4	414 555	2	1 804 231	1
Kansas	0	8	236 995	4	14 228	9
Minnesota	1 902 751	1	283 375	3	706 485	4
Missouri	4 400	6	66 000	7	64 157	6
Nebraska	3 000	7	231 400	5	25 198	7
North Dakota	0	8	5 600	10	22 800	8
South Dakota	0	8	55 097	8	134 670	5
Wisconsin	650 650	2	6 200	9	1 000	10

Source: Walsh *et al.*, 1999.

Iowa Vision and Roadmap process

Overview

The Iowa Industries of the Future project was a collaborative effort, funded by USDOE through the Iowa Department of Natural Resources and facilitated by Iowa State University Extension. The project was entitled “Industries of the Future/Agriculture” and has focused specifically on using biomass to produce biobased products and bioenergy.

Steering committee

An industry-led steering committee for the Iowa Industries of the Future (IIOF)/Agriculture project was established in July 2001. The steering committee is comprised of individuals representing industries that are leading the way in refining biomass, including agricultural producers and commodity organisations, processors, equipment manufacturers, financial institutions, development organisations and the university research community. The steering committee created a draft Vision Statement for the Iowa bioeconomy, a plan of action, and a list of deliverables for the project. A sub-set of the steering team met bi-weekly during the year to plan and implement steering committee and focus group meetings, develop the Vision and Roadmap Survey instruments, plan the symposium and develop the Vision and Roadmap document from focus group and steering committee input.

Regional focus groups

Eight regional visioning and roadmapping focus group workshops were held in Iowa between March and June 2002. Locations for the meetings were Harlan, Jefferson, Boone, Amana, Mason City, Cedar Rapids, Mount Ayr and Des Moines. Over 250 farmers, industry leaders, economic development professionals, environmental advocates and public officials participated in a process to develop a Vision and Roadmap to develop the bioeconomy in Iowa.

Participants at the regional focus group workshops:

- Completed Vision and Roadmap Surveys;
- Participated in small group discussions about the bioeconomy; and
- Prioritised ideas and research concepts for the bioeconomy.

The Vision and Roadmap Survey instruments were also included on the IIOF website for those who wanted to provide input for the process but were unable to participate in one of the workshops.

Findings from focus groups

The top five items on the Vision Survey with which the respondents agreed are as follows:

- Iowa should develop technologies and infrastructure to use dedicated crops and co-products from food and feed processing to produce biobased products;
- Reducing petroleum dependence should be a key consideration in an Iowa vision for biobased products;
- It is essential to have the co-operation of lending and venture capital institutions if biobased products are to become an important part of the Iowa economy;
- Iowa should develop the technologies and infrastructure to use crop residues in the production of biobased products;
- Improving farm profitability should be a key consideration in an Iowa vision for biobased products.

The top five priorities on the Roadmap Survey (according to respondents) regarding what needs to happen in Iowa to make the bioeconomy a reality include the following:

- Exploration and implementation of creative strategies for attracting investment capital to biobased industries.
- Development of a long-term strategic plan for maximising the economic returns of the bioeconomy for Iowa producers and rural communities.
- Education of lenders in Iowa about biobased products so they are comfortable lending money to producers for purchasing new equipment and investing in biobased industries.
- Development of mechanisms for co-ordinating the efforts of producers, processors and academic researchers.

Using input from the visioning and roadmapping workshops and website survey responses, the IIOF steering committee developed the Iowa Vision Statement and directional targets for the Iowa bioeconomy.

Iowa Vision

Box 1. A Vision of the bioeconomy in Iowa in 2020

- Iowa leads the Mid-west in developing the Bioeconomy. Iowa citizens embrace the Vision of the Bioeconomy and consistently exploit conditions and events that support the development of the Bioeconomy in their communities.
- Iowa citizens and businesses have developed mechanisms to capture significant value from all segments of bioproducts and bioenergy value chains.
- Iowa is experiencing significant economic growth. Iowa's quality of life is rated among the highest of any state in the United States, due to its pristine natural environment and its investments in other amenities.
- Iowa biorefineries provide exciting, challenging and lucrative jobs that attract young people to Iowa's communities.
- Iowa's superior resource base of 1) quality land, 2) weather conducive to crop production and 3) transportation and information infrastructure, are combined with its social resource of well-educated, hard-working, skilled people to serve as underpinnings for the biobased economy.
- Iowa has created an attractive tax structure for business development in the state that has lead to huge infusions of capital from both local and outside sources for biobased businesses.
- Iowa biobased businesses create superior products that enjoy tremendous worldwide demand.
- The economic benefits of the biobased products and bioenergy industries are widely dispersed among the people of the state and nation.
- Iowa biorefineries model production, processing, and merchandising practices and technologies that consistently improve the environmental conditions and ecological diversity of the state.

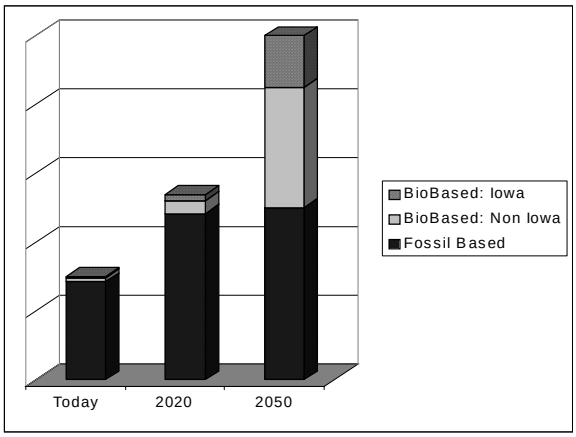
Directional targets for the successful progress of the bioeconomy in Iowa

Chemicals

1. By 2020, Iowa will be producing and processing 3% of US basic chemical building blocks for industry from biorenewable sources (30% of the national goal).

2. By 2050, Iowa will be producing and processing 15% of US basic chemical building blocks for industry from biorenewable sources (30% of the national goal).

Figure 2. Directional targets for biobased chemicals



Source: Walsh, 1999.

Fuels

1. *By 2020, Iowa will be producing 3% of US liquid motor fuel from biorenewable sources (30% of the national goal).*

2. *By 2050, Iowa will be producing 15% of US liquid motor fuel from biorenewable sources (30% of the national goal).*

Power

3. *By 2020, every Iowa biorefinery will produce 100% of its power requirements from co-products of the biorefinery processes or from agricultural residues and dedicated energy crops.*

4. *Iowa will rank first among states in tonnage of carbon annually sequestered in agricultural lands as a result of new land management practices.*

Materials

5. *By 2020, Iowa will increase production of biobased materials (from 2000 levels) by a factor of 20.*

Resources and products in the Iowa bioeconomy

Iowa's soil and climate make it ideally suited to produce crops and livestock. Iowa is a leading producer of corn in the United States. Although there is some debate as to whether corn is the ideal crop for production of fuels and chemicals, there is no doubt that it will be a mainstay in the early development of the bioeconomy of Iowa. The infrastructure for production, transportation and handling of this biorenewable resource is already in place. The workforce of Iowa is prepared to work with this resource. Thus, corn presents the most immediate opportunity for production of biobased products.

Agricultural processing of corn and oats generates large quantities of hulls, a high-fibre material currently of relatively little value. Because it has already been collected and is a clean, uniform material, it is attractive as an early entrant among lignocellulosic feedstocks in Iowa.

Corn stover, the agricultural residue left over from the harvesting of corn, will find increasing application in bioenergy and biobased products. Every bushel of corn harvested leaves 50-80 lbs of stover in the fields. Some experts believe up to half of this can be collected in many fields without compromising soil conservation. However, methods must be developed to harvest stover cleanly and store it, before it can become an economical source of lignocellulose. Lessons learned in developing corn stover as a biorenewable feedstock will also improve the longer-term prospects for dedicated energy crops such as perennial grasses, trees and industrial oilseed crops.

The incentive to use manure as a biorenewable feedstock will increase as environmental regulations become more stringent in livestock operations in Iowa. Processing of manure into bioenergy and biobased products has the added benefit of eliminating it as an environmental pollutant. Technologies are immediately available to convert it into biogas (a methane-rich gaseous fuel) with long-term prospects for extracting industrial chemicals such as organic acids and alcohols. However, transportation and storage are challenges in exploiting this resource.

Crops modified through traditional or transgenic breeding programmes could also become important resources for the bioeconomy. Increasing the plant's natural production of a specific component already found in the crop (such as protein or fatty acid) can increase the ultimate yield of that component and thereby improve efficiency and reduce the cost of biobased product production. New breeding programmes could also change the chemical composition of plants to produce crops with new chemical compositions much closer to the final industrial product. It will be important to evaluate carefully the environmental, political and social considerations of these crops before they are grown and processed.

Focus products for Iowa biorefineries will include:

- Industrial chemicals;
- Ethanol;
- Enzymes;
- Biodiesel;
- Hydrogen; and
- Building materials such as fibre board, ceiling tiles, etc.

Stakeholders in the Iowa bioeconomy

Since corn and soybeans are primary biorenewable resources for Iowa, corn and soy producers and wet and dry grain millers (corn, soy and oats) will be among the first rank of stakeholders to be affected by feedstock supply-chain issues. The collection and movement of increased volumes of biomass feedstocks from farms to processing facilities will create increased pressure on transportation infrastructure, which will be of interest to federal, state and county transportation departments. Equipment manufacturers will also be important stakeholders. Fibre processors have immediate concerns about the year-round storage of relatively fragile agricultural materials used as sources of fibre. Chemical and pharmaceutical processors will become increasingly involved as markets develop for a wider range of biobased products. Environmental advocates and rural development professionals must be included in developing policies for plant breeding and production practices and sifting the infrastructure for transporting and storing biorenewable resources. Researchers will play an important role in developing technologies that allow increased economical transportation and storage of biorenewable resources without adversely affecting the environment or the quality of life in rural areas.

The Iowa Roadmap

Target areas for the Iowa Roadmap

The IIOF project focused on three specific areas for the purpose of defining the Iowa Roadmap for the bioeconomy:

- Optimisation of biomass and/or crop-based material production (including co-products from existing and new processing) to fit projected use situations;

- Addressing facilities, location, handling and delivery issues for plant-based feedstock supply chains, including mechanisms to enhance the economy of rural regions; and

- Accelerated development of new processing routes based on modified chemistry and/or bi-processes that are aligned with utilisation of plant/crop-based renewable feedstocks.

Technical goals of each target area

I. Optimisation of biomass and/or crop-based material production (including co-product from existing and new processing) to fit projected use situations

Plant science

Plant breeding programmes should be employed to produce desirable traits for specific characteristics including:

- Improved processing functionality;

- Improved expression of desirable characteristics;

- Improved plant vigour;

- Improved durability of feedstocks; and

- Improved manure characteristics.

The impacts of genetically enhanced crops should be assessed on a species-specific and eco-system level to ensure there are no negative impacts associated with the genetic alteration.

Production

Research is needed initially to better understand the results of crop residue removal. Environmental benefits should be codified and any related environmental issues must be appropriately addressed. Developing and integrating best management practices for identity-preserved crops and crop residues are critical (including handling systems for input materials and cultural systems for production). New concepts to accommodate the seasonal nature of feedstock generation, expand the growth of energy crops and assure the quality of feedstocks need to be explored. Cost-effective methods of harvesting, transporting and storing large amounts of biomass (including manure) also need to be developed and demonstrated.

Processing

Research is needed to enhance the process of fermentation and hydrolysis of fibre, oil, starch, and protein fractions of crop components and processing co-products. New fermentation technologies are needed to produce base chemicals, pharmaceuticals and chemical intermediates from the wide range of existing crop components.

Low-cost chemical and biological process methods need to be developed and/or demonstrated, including new chemistry and thermo-chemical synthesis that can treat and break down molecules and separate the resulting components into purified feedstock streams. Specifically, new fractionation and separation technologies are needed to:

- Fragment plant parts;
- Exploit fractionated components;
- Recover high yields of relatively pure chemical streams; and
- Enhance functionality and performance.

End use

Biorefineries that include multiple processing businesses/systems *could* efficiently produce a diverse and flexible mix of conventional products, fuels, power, chemicals and materials from biomass. Research is needed to further evaluate, develop, and deploy the biorefinery concept *at the local/regional level* that will:

- Enhance functionality/performance of local biomass resources; and
- Define applications that exploit specific local/regional products and markets.

II. Addressing facilities, location, handling and delivery issues for plant-based feedstock supply chains, including mechanisms to enhance the economy of rural regions

The areas of plant science, production, processing and utilisation all impact the development of plant-based feedstock supply chains. Iowa has identified specific goals for each of these areas.

Plant science

Advances in plant science will contribute to the development of reliable and cost-effective supply systems. Among the most prominent goals in plant science are to:

- Achieve uniformity of raw materials through high and consistent expression of desired traits;
- Develop pest resistance including weeds, insect and disease resistance, which contribute to reliability of feedstock supply;
- Increase yields of crops, which reduces the length of the supply chain; and
- Attain positive environmental impact, which improves public acceptance of additional transportation and storage infrastructure.

Production

A successful bioeconomy will not only expand output and profitability of production, but also eventually change its character. Important goals in production include:

- Crop management systems that are adaptable over wide geographical regions, to allow rapid expansion of the biobased products industry by providing adequate feedstock supplies;

- Technologies that broaden the window for planting and harvesting biorenewable resources to improve the reliability of supply;

- Storage systems that limit degradation and maximise desired traits and components;

- Improved field-to-market transportation systems so the state's highway system is not over-burdened;

- Increased yields of crops, which reduces the length of the supply chain;

- Agricultural machinery suitable for clean harvest of agricultural residues;

- Modified federal farm policy to encourage production of biorenewable resources; and

- Established marketing systems for crop residues and specialty crops.

Processing

Unless adequately addressed, transportation and storage will present a bottleneck to processing biorenewable resources. Improved processing technologies can contribute toward the solution of problems in transportation and storage. Key goals in this area are:

- Improving plant component separation, which may simplify storage and transportation of biorenewable resources;

- Making conversion processes more robust to variations in feedstock composition and quality;

- Establishing management and financing systems that encourage improvements in feedstock price, quality and availability; and

- Developing decentralised pre-processing technologies that increase feedstock density for transportation or feedstock durability for storage.

End use

End use impacts transportation and storage only peripherally. Policies and programmes that encourage consumption of biobased products will accelerate the construction of transportation and storage infrastructure needed for the bioeconomy. In this regard, specific goals related to end use include:

- Development of national policies that encourage domestic consumption of biobased products;

- Development of national policies that promote export of value-added products from agriculture; and

- Establishment of certification programmes that verify biobased content and product performance.

Other important considerations

In addition to plant science, production, processing and end use goals, other important considerations were identified:

- Development of highly integrated biorefineries that produce chemicals, fuels, power, materials and generate no waste streams;
- Analysis of rural development opportunities/challenges;
- Analysis of land use options; and
- Analysis of long-term environmental impacts of various technologies and cropping systems.

III. Accelerated development of new processing routes based on modified chemistry and/or bioprocesses that are aligned with utilisation of plant/crop-based renewable feedstocks

The integration of scientific areas will accelerate the pace of biobased product development. Some necessary research objectives for Iowa universities and Iowa companies are described below.

Plant science

The enhancements in plant science will have an impact on processing and plant production and utilisation. Some areas of opportunity include:

- Enhancing genomics (DNA analysis) capability;
- Developing better bioinformatics (computer-based search for commonalities in genetic composition) and advanced computer systems; and
- Advancing metabolomics (profiling plant composition) capabilities.

Production

Improvements in plant production will give rise to new opportunities in processing. This is a key area for the operation of biorefineries. Some areas of study include:

- Lower use of inputs (water, fertiliser, pesticides);
- Create wider planting and harvesting window;
- Expand no-till technology;
- Develop improved storage systems; and
- Improve transportation infrastructure.

Processing

Of the four areas, this area was viewed as needing the most work. Iowa universities and industry have the necessary capabilities to make important advances. Some areas of investigation include:

- Processing new materials with existing processes;
- Creating new catalysts (both biocatalysts and chemical catalysts); and
- Developing new separation methods.

End use

The utilisation area was also viewed as needing considerable enhancement in Iowa. Groups need to work together to:

- Identify markets (commodity *vs* niche); and
- Show the advantages of biobased products as compared to existing products (cost, durability, biodegradability).

Cross-cutting issues

Key cross-cutting issues in developing biobased supply systems include capital investment, policy, market development, standards and incentives, and technology development. Iowa has identified specific issues in each of these areas.

Capital investment

Iowa does not have the investment capital resources of many other states. Thus, for Iowa to take a leadership role in the nation's emerging bioeconomy, it must address issues of capital investment. These include:

- Developing public support for infrastructure development;
- Developing public support for research and development;
- Raising private investment;
- Identifying and implementing strategies to attract local investment;
- Identifying and implementing strategies to attract co-investment (from petroleum companies and others);
- Identifying and implementing strategies to attract national sources of venture capital; and
- Identifying and implementing strategies to create market "pull" to encourage investment.

Market development

Achieving the ambitious goals outlined in the Iowa Vision will require creative strategies to develop solid market "pull." Options could include:

- Federal and state environmental mandates that encourage the use of biobased products;
- Financial incentives for biobased products;
- Implementation of procurement policies that promote biobased products;
- Incentives to mitigate the risk of developing the supply and distribution infrastructure needed for biobased products;
- Public financial support for promising biobased technology at the proof-of-concept stage; and
- Investment programmes designed to stimulate small businesses in the area of biobased product development.

Special care must be taken when evaluating the instruments described above to ensure that federal and state incentives encourage a mix of biobased products that have high value (or potential highest value) in the marketplace. Poorly designed incentives and/or mandates could skew technological development in harmful ways (*i.e.* special programmes for large manure systems could create incentives for large manure structures that may have negative environmental consequences).

Policy

Federal and state policies that encourage the development of the bioeconomy will be important in the initial stages of development. Products from fossil resources are typically cheaper than those derived from biorenewable resources if environmental impacts, national security and economic development are not taken into account. Some policy issues that should be considered include:

- Adoption of carbon sequestration credits;
- Review of transportation and infrastructure regulations and funding;
- Establishment of rural development policies consistent with the bioeconomy;
- Establishment of USDA regulations and incentives that encourage production of biorenewable resources;
- Adoption of environmental regulations and incentives that make biobased products more attractive;
- Establishment of new educational and training programmes;
- Increase in federal and state funding to develop the industry; and
- Creation of special incentives for farmer-owned co-operatives in licensing technologies developed with government support.

Standards and incentives

A range of standards is needed to verify performance and improve marketability. Examples of standards include:

- Machinery and management practices;
- Environmental quality of feedstocks and conversion technologies;
- Energy content;
- Quality of feedstocks;
- Certification of biobased products for biobased content and performance; and
- Fleet standards, production tax credits, and federal procurement policies.

Education and outreach

Educational/pilot outreach programmes need to be designed and implemented to:

- Assist (model) new business arrangements *between* agricultural producers (co-operatives and/or alliances) that provide the necessary quantities of biomass for biorefineries;
- Develop creative business relationships between links of biobased supply chains;
- Negotiate intellectual property rights between industry and university research (with special consideration to farmer-owned co-operatives or alliances in licensing technologies developed with government support); and
- Develop educational initiatives to broadly inform consumers and the general public of the environmental sustainability and product-performance benefits associated with the increased use of biobased products and bioenergy systems.

Follow-through

Regarding Iowa's role in the bioeconomy, the Vision Survey tells us *what* we want to achieve in Iowa with respect to bioenergy and biobased products: the Roadmap lays out *the route*. Specific *Action Steps* were identified by *Action Teams* at the Biobased Products and Bioenergy Symposium held in Ames, Iowa on 4 September 2002.

Science and technology

Biobased science and technology developments will require multidisciplinary research efforts in order to address the complex requirements of integrated biobased products and bioenergy industries. It also seems clear that new relationships need to be developed between public and private entities. The Science and Technology Action Team outlined the following strategies for implementation in Iowa:

- Design federal and state funding programmes to encourage collaboration between public and private organisations;

- Develop and implement government mandates for purchasing renewable products;

- Develop a virtual system for people to share ideas and search for sources of biobased products;

- Design government funding programmes to encourage the development or expansion of co-operatives and joint ventures between companies; and

- Develop a regional centre that would combine the resources of industry, research and public support.

Capitalisation and markets

Developing the bioeconomy will require huge investments in physical assets and intellectual assets. What are the options for capitalising biobased products and bioenergy industries? How can Iowa take advantage of market niches where biobased products and bioenergy applications can be cost effective? The Capitalization and Market Development Action Team identified the following strategies for implementation in Iowa:

- Establish an entity with a specific "networking mission" which will facilitate the linkage of customer and industry relationships with the science and enterprise opportunities available or developing in Iowa (the idea is to get a head start in expanding biobased industries in Iowa);

- Establish an entity to identify, communicate with and build relationships with private sources of early stage funding (Friends of Iowa or Friends of Energy oriented venture capital firms);

- Research, develop and execute networking concepts as they might apply to value-based enterprise development in agriculture *re:* execution of business relationships; and the "science" of producer networks and their role in enterprise development.

Policy and education

Policies governing a wide range of areas from transportation to rural development, from agriculture to commerce, from environmental protection to energy security, and from land conservation to education will have impacts on the future of biobased products and bioenergy. The Policy and Education Action Team outlined the following strategies for implementation in Iowa:

- Establish a council that 1) analyses effects of federal policy and rules; 2) co-ordinates and communicates information; 3) works with state agencies *re:* taxes, regulations, public expenditures;

- Develop and implement specific policies including: 1) funding for research and development; 2) incentives for producers, industries and government to invest and purchase biobased products;

- Work with community colleges and industry to develop training programmes for technicians who will be needed to work in biobased industries; and

- Develop and carry out educational programmes about the bioeconomy for state law makers, K-12 classrooms (*i.e.* pupils from 5-18 years of age), and the general public.

Conclusion

To repeat, the Vision Survey for Iowa's role in the bioeconomy tells us *what* we want to achieve in the future in Iowa, and *where we want to go* with respect to bioenergy and biobased products: the Roadmap lays out *the route.* The action teams have identified *plans for the trip.* The Iowa Industries of the Future/Agriculture project has benefited from the working contributions made by many Iowans, and the team invites you to "join in the journey."

BIBLIOGRAPHY

Peters, G. (1994), USDOE [United States Department of Energy] National Renewable Energy Laboratory, private communication, 22 August.

USDOE (2001), *The Biobased Products and Bioenergy Vision* (draft, 7/18).

Walsh *et al.* (1999), *Biomass Feedstock Availability in the United States: 1999 State Level Analysis* (updated January 2000).

GENENCOR AND THE BIOBASED ECONOMY OF THE FUTURE: AN INTERNATIONAL BIOTECHNOLOGY COMPANY'S PERSPECTIVE ON BIOMASS AND AGRICULTURE

Jack Huttner[1]

Abstract

In summary, at Genencor we believe that industrial biotechnology can contribute significantly to progress towards industrial sustainability. We also take seriously the challenge this poses to individual companies. From its first days, Genencor has been devoted to applying the lessons of biotechnology to solving all kinds of problems, not just human health. Twenty years from now, we will look back and see that biotechnology has contributed much more to human progress than just curing terrible diseases. And, 20 from now, we think we will be living in a flourishing bioeconomy.

Genencor at a glance

Genencor International, Inc. (www.genencor.com) is a diversified biotechnology company that develops and delivers protein-based products and bioprocessing services into the health care, agri-processing, industrial and consumer markets. Genencor brings its leading protein-engineering capability to products delivering sustainable solutions to problems of everyday life.

- Its history can be traced to 1982.
- It earned USD 350 million in total revenues during 2002.
- It is the world's 10th-largest biotech company, based on 2001 revenues.
- It has eight manufacturing sites, with a total capacity of 4 million litres.
- Over 80 US patent applications were filed in 2002.
- It employs approximately 1 300 people worldwide (75 in Cedar Rapids).

1. Genencor International, Palo Alto, California, United States.

A "different" kind of biotech company

Unlike most biotechnology companies that focus on developing drugs, Genencor has spent the last two decades developing its biotechnology skills to solve industrial problems. Using its strong financial, commercial and technical base, Genencor has expanded the boundaries of biotechnology. Genencor believes strongly that the industrial application of biotechnology will make industrial processes more sustainable and deliver to society a high standard of living with a reduced environmental footprint. Genencor hopes to play the role of a catalyst in a new economy – a biobased economy, that is just starting to emerge. Unlike most other biotech companies, Genencor has substantial revenues and a history of profitability and positive cash flow from its operation.

- Diversified protein products and markets
- Proteins expanding the boundaries of biotechnology
- Potential solutions for big problems
- Catalyst of biobased economy™
  - Biochemicals
  - Bioenergy
  - Biomaterials
  - Silicon Biotechnology™ Alliance.

Transition to a biobased economy has already begun

In large part, we have already begun the transition to a biobased economy. Biotech enzymes, some made at our plant in Cedar Rapids, are already in wide use in numerous consumer and industrial products and processes. You probably don't know all of the places you already come into contact with Genencor's bioproducts every day:

- Our proteins help wash your clothes and clean your dishes.
- Our proteases help clean your contact lenses.
- Our cellulases give your jeans a soft feel and a stone-washed look.
- Our products convert corn starch to sweetener for your soft drinks.
- And, we increase the nutritional value of animal feed.

Enzymes are catalytic proteins. They cause a reaction without themselves being changed. Enzymes are nature's chemical factories and control nearly all the cellular-level chemistry that converts sunlight into carbohydrates, oils and fibre. They also control most other functions related to cell-division, reproduction, metabolism and growth, and are also involved with making other proteins every cell needs for life. As the OECD has reported, whenever a biocatalyst or a bioprocess replaces a chemical catalyst or process, energy is saved, waste is reduced and the raw material is converted more efficiently.

The need is obvious

The need for sustainable solutions is obvious. The industrial application of biotechnology can help deliver a more sustainable industrial system. This is very important because we desperately need to:

- Reduce dependence on fossil fuels and other non-renewable resources
- Reduce biodiversity depletion
- Reduce hazardous waste streams
- Reduce greenhouse gas emissions
- Improve product performance and productivity
- Turn over to future generations a world that can sustain them as well it did us, if not better.

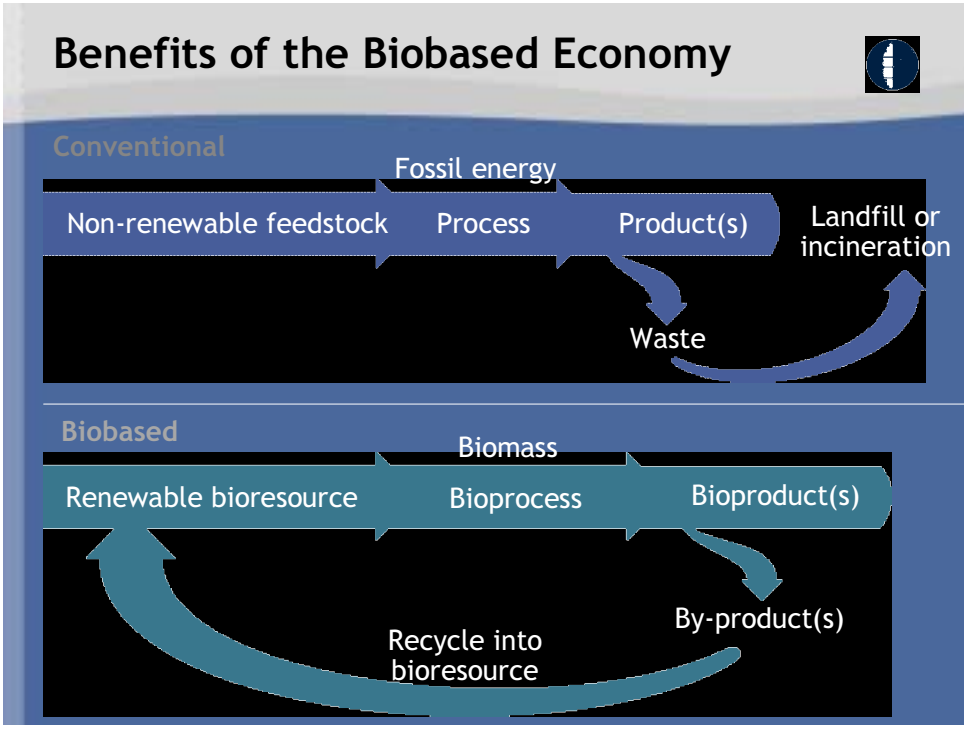
What is a biobased economy?

Progressive farming interests and research institutions like Iowa State University have done a lot of work developing the concept of a biobased economy to show how the future of the agricultural sector could contribute to economic development in Iowa. The biobased economy will use biotechnology to convert renewable raw materials derived from plants and crops into energy and products needed by advanced societies. In the biobased economy, renewable carbon from plants will replace fossil carbon from dinosaurs, biology will replace geology and we will till instead of drill for our raw materials. And, bioprocesses will replace chemical synthesis.

Using the power of biotechnology, we can convert agricultural raw materials, namely fibre, lipids (oils) and proteins into the products of advanced economies. We can use biocatalysts and bioprocesses to convert these materials into fuels, chemicals, solvents, monomers and polymers, adhesives and other materials needed by advanced economies. The benefit to rural economies and to energy independence will be increasingly profound. The new bioeconomy will also help developing economies in countries without oil reserves leapfrog classical chemical synthesis and its attendant environmental impact. The benefits of the biobased economy cover all three of the dimensions of sustainable development: economic, environmental and social. In the economic sphere, the biobased economy will reduce costs through improved production efficiencies. Biobased products will compete with incumbent products made from oil but they will also introduce innovative products that cannot otherwise be made. Finally, the biobased economy will start to free our economy from dependence on fossil fuels with all of the economic benefits that accrue. In the environmental sphere, the OECD and others have reported on the important ecological efficiency gained by switching from chemical synthesis to biosynthesis and bioproducts. Finally, in the social sphere, the biobased economy will improve the economic lot of farmers and re-invigorate rural economies. Developing countries will be able to use their renewable resources to meet their industrial needs as well as take advantage of cleaner bioproducts and bioprocesses for the production of material wealth.

The biobased economy uses renewable bioresources and eco-efficient bioprocesses to yield bio-products and also by-products that have value because they can be converted into other bio-products (Figure 1).

Figure 1. Benefits of the biobased economy



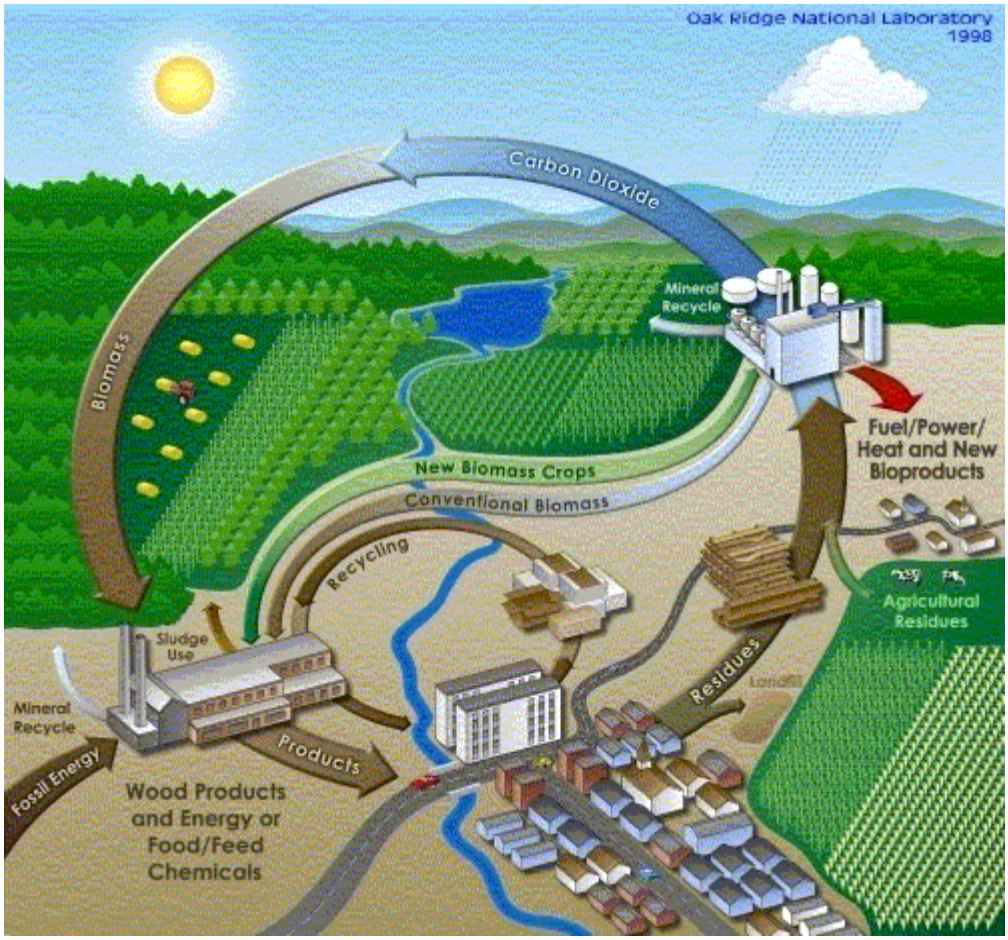
Source: Author.

The biobased economy mimics the efficiency of natural ecosystems. There is no such thing as "waste" – the by-products of one organism are the nutrients for another. When biomass is the starting material, waste products from bioprocessing can be reapplied to the fields, returning nutrient-rich material to the process. Some call this system – where the waste stream of one process is the raw material of another: industrial ecology. Industrial ecology is widely regarded as the most sustainable industrial scheme possible.

In the future, our biotech enzymes will enable biorefineries to take their place alongside oil refineries. Figure 2, from the Oak Ridge National Laboratory, shows an industrial ecosystem in a farming community. Farmers produce grains for food and feed. In the biobased economy, non-food parts of the plant are also valuable as raw materials. This is one of the primary ways that farmers will gain economic advantage. In this industrial ecosystem, carbon is recycled, resulting in a much lower emission of greenhouse gases.

The big obstacle to the development of biorefineries is the cost of fermentable sugars. Typical ethanol fermentation uses starch from the edible portion of important food crops. The only way that ethanol made in this way can be competitive with fossil fuel is through government tax subsidies. But, if we can reduce the cost of the sugars, biorefineries can take their place alongside oil refineries. The route to affordable renewable carbon is to use the non-food portion of plants – the waste products of the farming sector. Plants contain a lot of the complex polymeric form of sugar, cellulose. Biotechnology will enable us to convert that cellulose into fermentable forms of sugar.

Figure 2. Biorefineries will transform industrial production and help rural economies



Source: Oak Ridge National Laboratory, 1998.

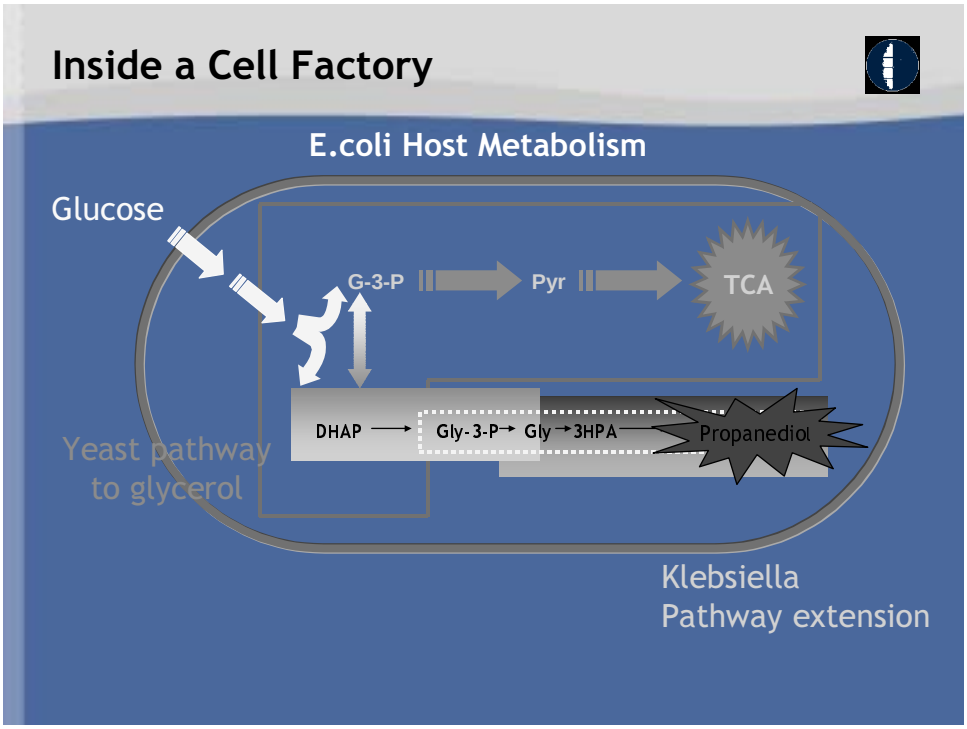
Cellulases are the class of enzyme that breaks cellulose into smaller sugar molecules that can be digested by the yeast in the fermentation vessels. The US Department of Energy (USDOE), through its National Renewable Energy Laboratories, has contracted with Genencor to develop a new generation of cellulase enzymes that will economically convert agricultural waste streams, such as corn stalks and wheat straw, into fermentable sugars for conversion into bioethanol and other chemicals (for results of a multi-party stakeholder dialogue involving representatives of agricultural, technical and chemical sectors in a formal process sponsored by the USDOE, see: "Vision for the Year 2020" and "Plant/Crop-Based Renewable Resources 2020: A Technical Roadmap To Get There", www.oit.doe.gov/agriculture/visions.shtml). You've seen cellulases at work in nature. They're responsible for the disintegration of fallen trees in the woods. Biotechnology enables us to produce that protein at commercial scale and to make it hundreds of times more effective.

Biorefineries will also use custom-designed cell factories to convert sugars into molecules of commercial value like plastics, chemicals and biomaterials. Perhaps you have heard about the plastic made from corn by Cargill-Dow in Blaire, Nebraska. Over the past few years, Genencor has developed two custom cell factories: one to produce ascorbic acid (or vitamin C); the other to produce

propanediol for DuPont to convert into a high-performance polyester called Sorona™. DuPont has very ambitious goals for the sale of this product. Today, DuPont manufactures this product using a petro-chemical process. But, working with Genencor researchers, we have reduced the cost of manufacturing 500-fold and make these products from glucose by biological means. Sorona has a number of features that differentiate it from other polyesters. It has excellent stretch-shape recovery and drape characteristics. It has a good "hand" and is easily dyed. The first target market is carpets.

Figure 3 shows a custom cell factory designed for DuPont. Using an e-coli bacterium as the backbone, we used genes from three other micro-organisms to take glucose and convert it in three steps into propanediol, which DuPont then converts into Sorona. Obviously, when you can use a cell factory that grows and reproduces in a water-filled steel vessel at room temperature and ambient pressure, you have an environmentally benign process.

Figure 3. Inside a cell factory



Source: Author.

In the future, as the cost of biomass sugars are reduced and biorefineries become more and more competitive with oil refineries, we will be able to produce a wide range of the chemicals and materials needed by advanced societies, including:

- Bulk chemicals
- Ethylene
- Ethanol
- Acetic acid
- Adipic acid
- Polymers

- Nylons
- Polyesters
- Plastic additives
- New biomaterials
- Fine/specialty chemicals
- Flavours and fragrances
- Pharmaceutical intermediates and aromatic compounds.

Policy initiatives are accelerating the bioeconomy

There are numerous societal developments and policy initiatives gaining momentum around the world to support and accelerate industrial biotechnology. The OECD has been playing a major role in defining the benefits of industrial biotechnology and engaging member-country policy makers in dialogue. OECD has announced a two-year project to develop scenarios for biobased economies, and to analyse the subsequent/possible economic and environmental impacts. The European Union is now starting to pay considerable attention to this subject and several policy frameworks are progressing through the process. Just to mention two: the Environmental Technologies Action Plan links the objectives of the Gothenborg and Lisbon European summits, linking environmental technology and employment growth to sustainable development. The biofuels directives under debate will set some expectations regarding the use of renewable fuels in member states.

Of course, in the United States, the past three years have seen considerable concrete developments in policy-making, including the enactment into law of the Sustainable Fuels and Chemicals Act, sponsored by Senator Lugar. The US Farm Bill, sponsored by Senator Harkin, included for the first time an energy section that made the development of biorefineries a national goal and provided incentives to stimulate the development of the bioeconomy, including significant investments in technology development and demonstration projects.

- Sustainable Chemicals and Fuels Act;

- Biomass R&D Technical Advisory Committee (for more information on the US Biomass R&D Technical Advisory Committee, see: www.bioproducts-bioenergy.gov/pdfs/FinalBiomassRoadmap.pdf;

- 2002 Farm Bill, Energy Title.

BIBLIOGRAPHY

Lee Lynd, *et al*. (2002) “Bioenergy: Background, Potential & Policy”: www.csis.org/tech/Biotech/other/Lynd.pdf.

European Union Policy Action Programme of EuropaBio is described at: www.europabio.org/pages/ne_wb_100403.as.

US Department of Energy Biomass Program is described at: www.bioproducts-bioenergy.gov.

3. Other OECD Countries

Page

The Australian Approach to Biomass
Richard Sisson, Minister-Counsellor, Delegation of Australia to the OECD, France *541*

The New Zealand Policy Approach to Enhance Bioenergy
Ralph E.H. Sims, Massey University, New Zealand *547*

Biomass Nippon Strategy in Japan – Why "Biomass Nippon" Now?
Yasuhiko Kurashige, Ministry of Agriculture, Forestry and Fisheries, Japan *559*

THE AUSTRALIAN APPROACH TO BIOMASS

Richard Sisson[1]

Abstract

Australia has vast energy resources. This strong natural resource base underpins the Australian economy, providing sizeable export earnings, significant employment and relatively cheap energy. As a consequence, Australia is highly reliant on fossil fuels. At the same time, however, it seeks to address climate change and reduce its greenhouse gas emissions.

Australia recognises the potential of renewable energy sources to contribute to the nation's economic, environmental and social goals. These renewable energy sources include biomass. In Australia most biomass in agriculture and forestry is presently a by-product of primary production activities; little bioenergy production is from dedicated short rotation crops.

The Government is keen to establish policies that encourage renewable energy. Several initiatives involving a mixture of sectoral policies and market-based instruments have been introduced to stimulate renewable energy production, including from biomass. For the agricultural sector these measures have the added benefits of increasing farm diversification and employment opportunities in rural areas.

Government funding, often with matching industry contribution, aids the development and establishment of projects. Ultimately, however, projects must be commercially viable, profitable and sustainable.

Australia's natural resources profile

Natural resources based industries underpin economy

Australia is unique among developed nations in that its economy and trade profile, in common with that of developing countries, are underpinned by its strong natural resources based industries.

Australia is a leading producer and global supplier of quality food and agricultural products, with around 70% of its total agribusiness production being sold to overseas markets. Rural exports contribute more than 23% of the total goods exported from Australia, with a value in 2000-01 exceeding AUD 31 billion.

Australia has vast energy resources. The total value of its coal, oil, gas and uranium energy reserves is conservatively estimated at AUD 76 billion. In 2001-02 Australia exported 10 509 PJ (petajoules) of total energy production, which contributed 21% to the nation's export earnings. Black coal accounts for over half the total value of energy exports (52.2%), followed by crude oil (25.2%) and liquid natural gas (10.3%).

1 . Delegation of Australia to the OECD, France.

High domestic dependence on fossil fuels

Australia's size and demographics, coupled with its abundant natural resources, have shaped the nation's reliance on fossil fuels. Its population of 20 million is concentrated in two widely separated coastal regions, with dispersed regional production centres found across a large continent of 7.7 million square kilometres. Over 90% of total energy consumption is based on energy sources derived from fossil fuels, reflecting their ready availability and relatively competitive costs.

Three major sectors dominate energy consumption: electricity generation (28.3%), transport (25.2 %) and manufacturing (24.9%). Australia's main energy sources are oil (34%), black coal (29%), natural gas (18%) and brown coal (13%). Energy from renewable sources accounts for 6% of the total.

Exposure to climate change

A small emitter (1.4% of total world emissions) in the global scale, Australia nevertheless seeks to reduce its greenhouse gas emissions and address climate change issues. Australia's competitiveness rests on industries that are high emitters of greenhouse and/or based in natural resources that are most susceptible to the effects of climate change.

Opportunities for biomass utilisation

Growing interest in renewable energy sources

The combustion of fossil fuels contributes over 70% of Australia's energy-related greenhouse gas emissions. Electricity generation contributed 50% of these emissions, followed by transport activity at about 25%. This is of concern as Australia is committed to contain greenhouse emissions while minimising the economic impacts on the competitiveness of its natural resources based industries.

In this context, the potential of renewable energy sources to contribute to sustainable development, environmental health and greenhouse gases abatement, as well as to promote new economic activities through new industries, is well recognised both by industry and government. The range of renewable energy sources includes hydro, wind, solar voltaic, solar thermal, biomass, municipal solid waste and wastewater, marine and geothermal.

Using biomass as an energy source is an emerging activity

Agricultural and forest industries in Australia generate a significant amount of biomass residues as by-products of primary production activities. However, due to economic considerations there is currently little or no bioenergy production in Australia from dedicated short rotation crops (agricultural or silvicultural). It is mostly biomass residues or by-products from crop growing or crop processing which are being used for stationary energy generation or liquid fuels production. Renewable energy technologies utilising biomass offer the opportunity for value-adding and market diversification through use of products that previously yielded little or no return. Australian rural industries are increasing their awareness and have begun to exploit arising opportunities.

Government support for bioenergy production

The Australian Government is strongly committed to increasing the domestic use of renewable energy, as a way to meet the nation's increasing energy needs without adding to its greenhouse gas emissions and has implemented policy measures to assist an emerging renewable resources sector.

Examples of biomass projects underway in Australia

AUD 60 million biomass power station

Babcock & Brown and National Power have announced plans for an AUD 60 million biomass power station to be built in South Australia's south-east. The facility will be built at Tantanoola (Millicent - Mt Gambier region) and will use plantation and other timber waste to generate renewable electricity. The project will create 150 direct and indirect jobs and will have a substantial multiplier impact on the regional economy. A total of 280 000 tonnes of woodwaste will be required annually to operate the 30 MW (megawatt) biomass plant, which is expected to be operational by 2005.

AUD 70 million waste recovery and waste-to-energy project

Waste Service New South Wales has entered into a partnership with Global Renewables Limited to construct the first "Urban Resource - Reduction, Recovery and Recycling" facility at Eastern Creek (Western Sydney). Construction is set to begin in early 2003, with the plant expected to be fully operational by mid-2004. The plant is capable of diverting 80% of waste from landfill and reducing greenhouse emissions.

The plant will generate 17 000 MWh (megawatt-hours) of electricity per year using methane recovered from processing organic matter in waste. The balance of organic matter will be processed into some 60 000 tonnes of compost products with a small amount of residues going to landfill.

Pilot power station fuelled by weed biomass

A pilot power station in the Northern Territory will be fuelled using *Mimosa pigra*, one of the Territory's most noxious weeds. It will be located at the edge of the Adelaide River floodplain, which has 17 000 ha of *Mimosa pigra* infestation. Annually, about 80 ha of the weed will be removed, chipped and treated, to prevent decomposition and seed spread, before being converted to electricity. The power plant is expected to generate a minimum of 350 kW of electricity. Removal of the mimosa is aimed at returning the weed-infested pastoral land to agricultural production.

Source: Bioenergy Australia's monthly newsletter.

Policies and measures to help an emerging bioenergy sector

In January 2001 the Mandatory Renewable Energy Target was introduced. This requires that electricity retailers purchase an additional 9 500 GWh (gigawatt-hours) per annum from eligible renewable energy sources by 2010. Legislation ensuring the generation over the next 10 years of new renewable electricity to supply the residential needs of a city of 4 million people came into force on 1 April 2001. Biomass has a substantial potential to contribute to the mandatory renewable energy target. Eligible sources of renewable energy include bagasse co-generation, black liquor, woodwaste, energy crops, crop waste food and agricultural wet waste and co-firing of biomass.

This initiative is being achieved by establishing an innovative market in renewable energy certificates, and is expected to deliver in excess of AUD 2 billion of new investment in renewable energy in Australia.

The Australian Government has committed AUD 377 million in programmes to support the commercialisation and deployment of renewable energy technologies and related industry development (see the Australian Greenhouse Office's website: www.greenhouse.gov.au).

Renewable Energy Commercialisation Program (RECP)

Under the Rennewable Energy Commercialisation Program (RECP), funding of AUD 50 million over five years is being provided to foster the development of the renewable energy industry in Australia. With two components – commercialisation and industry development – the programme supports and promotes strategically important renewable energy technology initiatives that have strong commercial potential, and supports projects that will contribute to the development of a sustainable, internationally competitive renewable energy industry in Australia.

A range of renewable applications has been funded, such as biomass, wind, solar, thermal and solar photovoltaic, wave energy, hot dry rock and enabling technologies.

Examples of biomass utilisation projects funded under the RECP include:

- *The Renewable Energy-Organic Conversion Centre* – a project by Biomass Energy Services Technology – will be built in the Australian Capital Territory to showcase world-leading technologies that process urban green waste (such as lawn clippings and plant prunings) into renewable energy, commercial quality charcoal and clean-burning briquettes as a firewood substitute.

- *The Integrated Mallee Processing Demonstration Plant* – a project by Western Power that involves building a demonstration plant in Narrogin (WA) to process mallee trees to produce renewable energy, activated carbon and eucalyptus oil. This project is particularly attractive from the points of view of sustainability and farm diversification. The trees are grown in alleys and damage to the soil is limited as growing the trees in coppices means that the roots are not removed. The trees are harvested every five to ten years, with the leaves being used to produce oil, the stalks and stems going to energy production (carbon) and the wood for timber.

- *Food Biomass Waste to Green Energy* – a project by EarthPower Technologies that involves the construction of an anaerobic digestion facility to recycle industrial and commercial food into biogas for electricity generation and to produce high-quality fertiliser.

- *Harvesting Camphor Laurel For Energy* – a project by State Forests of New South Wales, it involves using camphor laurel tress (an invasive woody weed) to supply year-round energy to a power station at the Condong Sugar Mill. This project fulfils two objectives: the destruction of invasive weeds and the production of energy. It is envisaged that once the weeds are removed they will be replaced by blue gums.

- *Green Gasifier Generator* – a project by the CSIRO, JC Smale & Co and Capstone Turbine Corporation that involves the development of a micro gasifier turbine system to generate electricity from fuel wood.

More information on biomass projects funded under the RECP can be found in the publication "Renewable Energy Commercialisation in Australia" by the Australian Greenhouse Office, see the website at: www.greenhouse.gov.au.

Renewable Energy Industry Development (REID) Program

The Renewable Energy Industry Development Program is a sub-programme of the RECP. It has funding of AUD 6 million over four years. Projects supported include:

- the funding of a national facility dedicated to testing and accrediting renewable energy systems;

- Australian Pork Ltd. has received a grant to investigate the technical and economic feasibility of converting pig wastes to electricity;

- the National Association of Forest Industries has won a grant to review the global use of woodwaste as a source of renewable energy, identify the capacity of the Australian forest and timber industry to participate in the renewable energy industry and develop information and educational packages.

Renewable Energy Equity Fund

The Renewable Energy Equity Fund provides venture capital for small companies seeking to commercialise innovative renewable energy technologies. The Australian Government provides AUD 17.7 million in funding, which is boosted to about AUD 26.6 million by private-sector capital.

Biofuels

The Australian Government is developing a strategy to lift domestic biofuels production (ethanol and biodiesel for use as transport fuels) to 350 million litres per annum by 2010. This effort acknowledges the potential of a viable domestic biofuels sector to contribute to economic growth, regional development and environmental goals.

The Biofuels Strategy provides the potential for additional value adding to Australian agricultural production. This is particularly important due to the corrupted world trade market faced by Australian farmers.

Bioethanol is made primarily from the fermentation of sugar derived from grain starches or sugar crops, while biodiesel is produced through processing of any vegetable oil or animal fat.

The Australian Government has recently announced an excise exemption for biofuels which will apply over the next five years, to be removed in stages over a further five years.

New technologies to manufacture ethanol from biomass are being assessed, through joint industry and government efforts, to decrease production costs and improve greenhouse outcomes. For example, the ZeaChem fermentation technology to produce ethanol from sugarcane is being evaluated under local conditions. It is expected to double yields and halve costs, as well as being more “greenhouse friendly” than conventional methods. The Australian Government has contributed AUD 400 000 to the cost of accelerating this research, which is also being funded by private partners.

Biofuels can contribute to improved environmental outcomes as well as offering Australian farmers an opportunity to access additional markets.

THE NEW ZEALAND POLICY APPROACH TO ENHANCE BIOENERGY

Ralph E.H. Sims[1]

Abstract

New Zealand has a free market economy with no agricultural subsidies. The exception is plantation forest production by small landowners, which has been encouraged by all planting and maintenance costs being tax deductible against any other income. Large areas of new plantings have resulted in future carbon credit revenue from these forest sinks. Until now successive New Zealand governments have not seen any benefit in providing subsidies, grants or other support mechanisms for encouraging the implementation of renewable energy projects. However, the National Energy Efficiency and Conservation Strategy 2001 has a target of 30 PJ of new additional renewable energy. This is in addition to the 137 PJ of renewable energy supply already anticipated by 2012 from existing hydro, wind, biomass and geothermal as well as from new "business-as-usual" projects. Meeting the target will return the share of renewable energy available to meet the total consumer energy demand back to around 32% (assuming that the energy efficiency target will successfully slow energy demand growth as predicted). Mechanisms to enable the target to be reached are now being developed.

Two key mechanisms will soon be offered to encourage the uptake of renewable energy including biomass. *National greenhouse agreements* will be established between the government and any firms claiming to be "competitive-at-risk" if asked to pay a small carbon charge on fossil fuel use of up to NZD 25 (EUR 13)/tonne CO_2 equivalent after 2006. Also, a proposed innovative *projects mechanism* will provide support in the form of government-guaranteed "promissory notes" arising from the forest sink carbon credits and based on the future international trading value of carbon for any approved project that can show greenhouse gas emissions avoidance above 10 000 tonnes CO_2 equivalent per year. As a result, bioenergy projects will probably be implemented to a greater degree than under business as usual, particularly in the heat and transport fuel markets. The biomass feedstock will probably be based more on utilising forest residues than on growing energy crops or collecting agricultural residues. Nevertheless, the uptake of additional biomass projects is likely to result, but without the need for providing direct grants or agricultural subsidies.

Early policies and subsidies

In 1984, nearly 40% of the gross income of New Zealand farmers came from government subsidies. These were first introduced in the 1960s when Britain, its major export customer at the time, joined the European Economic Community. By 1985 virtually all of these subsidies were withdrawn without prior warning. Today few farmers, if any, would want government handouts in this form to be reinstated. Their independence in not having to farm to maximise subsidies decided somewhere in Wellington is fiercely defended (Federated Farmers, 1995). This approach has resulted in respect and admiration from city-dwellers who previously had treated subsidised farmers with envy and derision.

1. Massey University, Palmerston North, New Zealand.

The early intervening years following subsidy removal were challenging and a number of farmers became bankrupt or underwent mortgage sales by the banks. Later analysis, however, showed many of these cases were those farming marginal land, or carrying excessive debt loads, or simply incompetent. Farm expenditure overall declined and stayed low for several years afterwards as did farm profits, though the average level was sufficient to provide a good return on investment and an above average standard of living.

Stock numbers did not decline as predicted, but farmers soon realised that their management decisions had to make good business sense rather than just aim to maximise production at any cost. As a result, land prices are now based on genuine earning capacity and New Zealand farmers are more efficient and competitive than ever before. Another benefit was that environmental impacts were lessened by reducing wasteful fertiliser practices (thereby improving water quality) and by moving away from unsustainable farming practices conducted on truly marginal land (Rae, 1996). Interestingly, the carcass weight of lambs did not reduce as a result of these influences. Farm supply and servicing companies were also forced to become more productive as farmer purchases became more discerning. Later market reforms and deregulation policies, however, led to beneficial farm cost reductions due to cheaper transport costs, lower but fairer labour rates, reduced import duties on farm machinery, etc. The entire agricultural industry became more professional and efficient.

This same market-led philosophy has been the reason there have been no subsidies for energy crops or other renewable energy projects to date. Even so, several notable projects have been developed but have been based on purely commercial analysis. One example was the 32-MW (megawatt) Tararua wind farm which has been operating successfully since 1999 on an excellent site. Another is the 39-MW_e (MW power electricity) biomass co-generation plant using bark and residues from Carter Holt Harvey's pulp and paper mill at Kinleith (Sims, 2002).

This paper describes the current policies of the New Zealand Labour government (partly influenced by the Green Party to varying degrees) which may well support future biomass production activities and bioenergy projects in the future – not as a support mechanism for the farming community, but as a practical and economic means of climate change mitigation.

The current energy market

New Zealand's natural gas fields have contributed around 30% of primary energy supply for the past two decades, including thermal power generation, but reserves are now dwindling faster than anticipated. The hydro power plants have very limited water storage capacity so are constrained in dry years, which have become more frequent, with occurrences in 2001 and 2003. Electricity demand continues to grow at around 2% per year in spite of successful energy efficiency programmes being in place. Hence more electricity shortages are predicted into the future. An abundance of coal reserves could be used to provide greater security of supply and appease businesses which are threatening to move off-shore if their historic cheap supplies of heat and power can no longer be delivered. However, the use of more coal (as now seems inevitable to avert power outages this winter) will challenge the nation's Kyoto Protocol obligation to return to 1990 levels of greenhouse gas emissions, on average, during the first commitment period 2008-12. The future solution is to encourage rapid implementation of more renewable energy and bioenergy projects, together with reducing the energy demand growth through greater energy efficiency levels in all sectors. However, in this free market economy some innovative policy mechanisms (other than direct government subsidies) to increase project implementation are needed. The common mechanisms to support renewable electricity projects are varying feed-in tariffs for specific technologies and the issuing of renewable energy certificates (Sims and Dyson, 2002). These were both considered but decided against in favour of other more innovative options so that heat supply and alternative transport fuels could also be included. This approach has proved to be potentially beneficial for encouraging biomass projects.

Most of New Zealand's 4 million people have few concerns about energy use so long as they can fill up their car fuel tank at any time and the lights always come on at home at the flick of a switch. They and the majority of businesses are yet to be convinced that the era of cheap fossil fuel-based energy is over. Surprisingly, some even remain yet to be convinced that fossil fuel use has been the major instigator of climate change and that this is becoming a real threat to future generations.

Renewable energy supply

New Zealand has long been envied for its historically cheap renewable energy which currently accounts for around 30% of primary energy supply (Figure 1). Around 70% of electricity is generated annually from hydro power plants and 5-6% from geothermal generation, first produced in 1956 and now with four main commercial base-load plants and more planned. (Note that the conversion efficiency from heat to power for geothermal generation is only around 10% and that, in spite of several initiatives, there is little demand near the geothermal fields to use the available direct heat, other than for one pulp and paper mill and a small prawn farm. Therefore, around nine-tenths of the 14% of total geothermal heat as shown in Figure 1 is not utilised.)

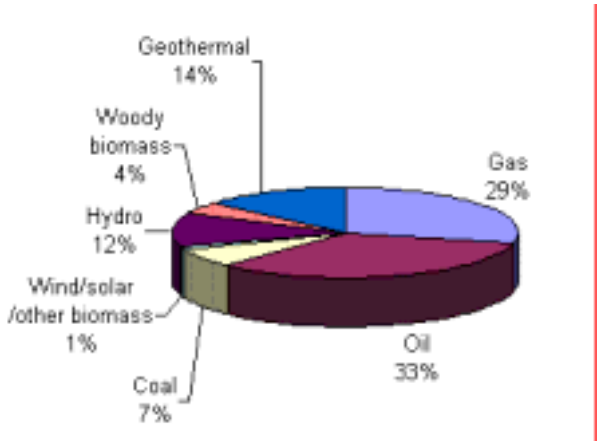
Woody biomass from forest residues, when used for bioenergy purposes, contributes approximately 4-5% of the total consumer energy supply mix, mainly via combustion in co-generation plants located on wood processing sites and in pulp and paper mills. It also provides fuelwood both for the domestic and industrial markets. Wind power, mainly from the 32-MW Tararua wind farm (the largest in the southern hemisphere) has been generated successfully since 1999. An excellent wind resource exists, with many other sites also exceeding 10m/s mean annual wind speeds having recently been prospected. However, only another 3.5-MW wind farm has been developed to date, due to there being no government support available. There is very little contribution at this stage from solar electricity or solar thermal inputs, in spite of the average sunshine hours being around 2 000 hours per year. Hence, the overall contribution to the electricity supply from wind and solar, together with a handful of "other biomass" landfill gas and biogas plants, remains below 1% (Figure 1).

In 2000, of the 453 PJ (petajoule) total national consumer energy demand (including transport fuels), around 130 PJ or 29% was supplied by renewable energy sources (Figure 2). By comparison, renewables provided around 33% of consumer energy in 1990.

The Ministry of Economic Development (MED) predicted that to support the anticipated GDP growth of around 3% per year, a future business-as-usual (BAU) growth of 1.7% in energy demand per year could be assumed (MED, 2002). If proved correct, by 2012 the renewable energy share of the 550 PJ anticipated consumer energy demand could slip further to around 25% because the increase in energy demand will probably out-strip the new renewable energy (RE) projects that are anticipated to have been developed by that time (Figure 3).

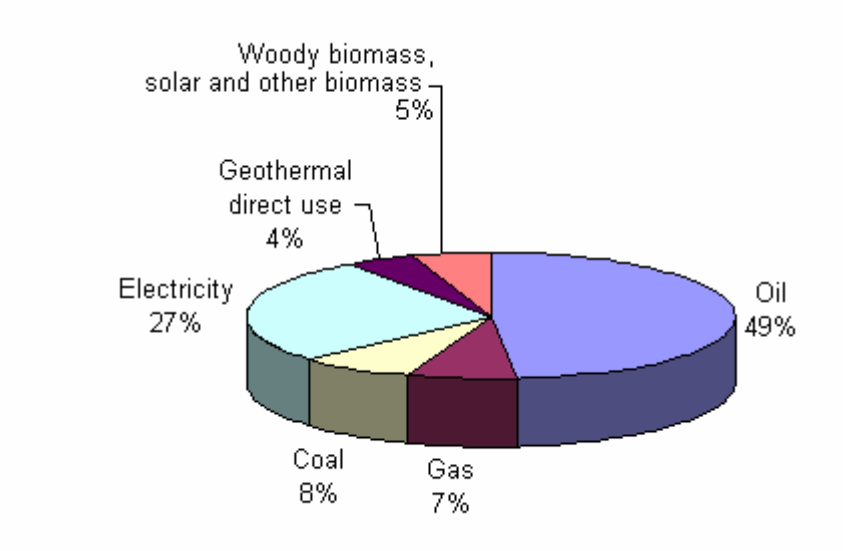
Fossil fuel use to meet consumer demand has risen from 250 PJ in 1990 to 320 PJ in 2000, with a similar increase in carbon dioxide emissions as a result. Under BAU, this will probably increase to over 400 PJ and make New Zealand's Kyoto obligations to return greenhouse gas emissions back to 1990 levels very difficult to achieve.

Figure 1. New Zealand's total primary energy supply comes mainly from imported oil for transport fuels and indigenous natural gas supplies, with renewables accounting for around 30% of the total



Source: MED, 2002.

Figure 2. Renewable energy (hydro, geothermal and some wind and bioenergy) provides around 75% of electricity demand in New Zealand, together with around 40% of high and low grade heat demand from woody biomass and geothermal direct use

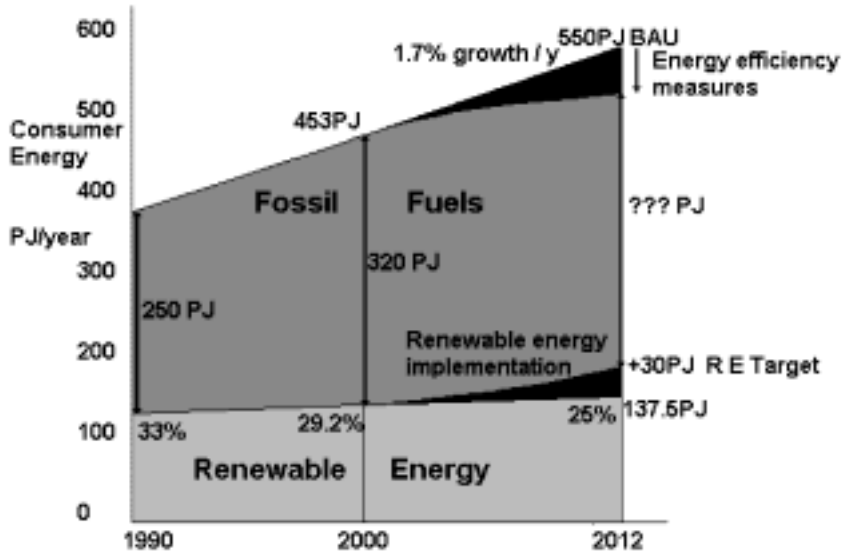


Source: MED, 2002.

To overcome this problem, the National Energy Efficiency and Conservation Strategy (NEECS) was introduced in 2001 as a result of the National Energy Efficiency and Conservation Act (2000). Two targets must be met by 2012:

- improve energy efficiency activities and outcomes in all sectors by 20%; and
- increase the share of consumer energy coming from new renewable energy projects by 30 PJ (Figure 3).

Figure 3. New Zealand total consumer energy demand met by fossil fuels and renewables between 1990 and 2000, with predictions until 2012 under a business-as-usual scenario



Source: Author.

Fossil fuel demand will be decreased if current energy efficiency measures and renewable energy targets prove successful. Together, these will bring the share of the energy-mix for renewables back up to over 30% of consumer energy demand. As a result of the demand for fossil fuels declining, much score is being held by politicians that the Strategy will enable the Kyoto target to be met. Conversely, the fossil fuel industry remains largely opposed to the Strategy measures.

Encouraging more renewable energy projects

Most OECD countries have established a range of policies and mechanisms (such as feed-in tariffs or renewable energy certificates) to encourage the implementation of more renewable electricity projects, but often from very low base levels. In addition, existing farm subsidies such as the set-aside land grants can also provide incentives to grow energy crops. By contrast, subsidy-free New Zealand, with its mature hydro and geothermal plants (owned by both private companies and state-owned enterprises) is still grappling with how best to encourage new and emerging renewable energy projects providing heat and transport fuels, as well as electricity, without unfairly advantaging or disadvantaging existing energy suppliers or power generation plant owners. A newly formed Climate Change Office has inherited this responsibility.

The National Energy Efficiency and Conservation Act (NEECS) (2000) was introduced following a private members' bill led by Jeanette Fitzsimons, co-leader of the Green Party (which in 2003 had 9 out of 120 MPs in the House of Representatives and at times has held the balance of power). Fully supported by the Labour-led government, the Act resulted in the development of the NEECS (EECA, 2003). Initially, a renewable energy target range between 25 PJ to 55 PJ was proposed after consultation with the Treasury and the Ministry of Economic Development, which

actually wanted no more than a 10 PJ target. Eventually, 30 PJ was agreed as a compromise. However, meeting this target could be a formidable challenge even with fiscal incentives in place, given that the two existing wind farms generate only around 0.5 PJ of electricity per year, and that even if 100 000 solar water heaters were to be installed on 7-8% of the 1.4 million dwellings, these would collectively displace only around 1 PJ per year of electricity.

The 30 PJ target includes at least 2 PJ of biofuels (being approximately 50 million litres per year) which will most likely be from bioethanol produced from the surplus whey by-product of the dairy industry (0.7 PJ/year being available now, and from biodiesel methyl esters processed using the tallow by-product from the meat processing industry (3.4 PJ/year available). If further biofuel resources are needed, then the waste lignocellulose resource could be collected from the increasing area of maturing plantation forests and then processed using an enzymatic hydrolysis process. Alternatively, specific energy crops such as oilseed rape could be grown to meet the demand, though probably at a higher cost/GJ of fuel. In 2003, EECA (the Energy Efficiency and Conservation Authority) submitted applications to the Environmental Risk Management Authority to enable both bioethanol and tallow esters to be used as blends in road vehicles.

A small portion of the target will be met by new solar water installations which are being encouraged through a new grants scheme aimed at installers who can apply competitively to use grant funds to help promote innovative ways to expand the market. With annual sales of around 1 000 domestic units per year in 2003, the solar water heating manufacturing and importing industry association hopes to reach 10 000 sales a year by 2012.

Other measures identified in the NEECS for encouraging renewable energy include further education on energy use and easing planning constraints for renewable energy projects under the fairly stringent Resource Management Act (1990). This is an all-embracing, largely successful, environmental legislation based on a high level of public consultation and the development of regional and district plans by the authorities. However, it has recently been criticised by developers and landowners for the time and cost often needed to obtain a resource or planning consent for projects, such as a bioenergy processing plant, which are outside those defined in the local district plans. There is a large backlog of cases in the Environment Court. The Act is under review and it is anticipated that greater consideration will be given to the carbon dioxide emission reduction potential when projects are proposed that is currently not taken into account.

Climate change "projects" mechanism

A more general fiscal incentive currently being developed is an innovative climate change *Projects Mechanism* aimed to reduce greenhouse gas emissions in whatever ways possible. The objective of the mechanism is to secure improvements in emissions management that would not otherwise be economical to undertake. Incentives will be given for new initiatives that will deliver defined reductions of greenhouse gas emissions in any sector of the economy.

Businesses will be encouraged to seek commercial opportunities to develop and adopt technologies and processes that will reduce or slow the growth of their emissions. Any organisation can seek support funding from a pool by submitting a proposal for a project which can be shown to reduce greenhouse gas emissions by at least 10 000 tCO_2 equivalent during the first Kyoto commitment period (2008-12), but which would not otherwise proceed commercially without such support. It is acknowledged that this will be difficult to prove in some instances. Companies and industry associations will be invited to tender proposals in mid-2003 and successful applicants will then need to settle agreements with the government prior to development. For the first round, due to the current threat of power outages (resulting from another dry year for the hydro plants and the

demise of that natural gas reserves for the thermal plants) only projects resulting in increased electricity generation will be considered. Further rounds will be held annually, but it is not yet clear whether other projects such as bioenergy for heat, solar thermal, energy efficiency, or biofuels could be supported in this manner in following years.

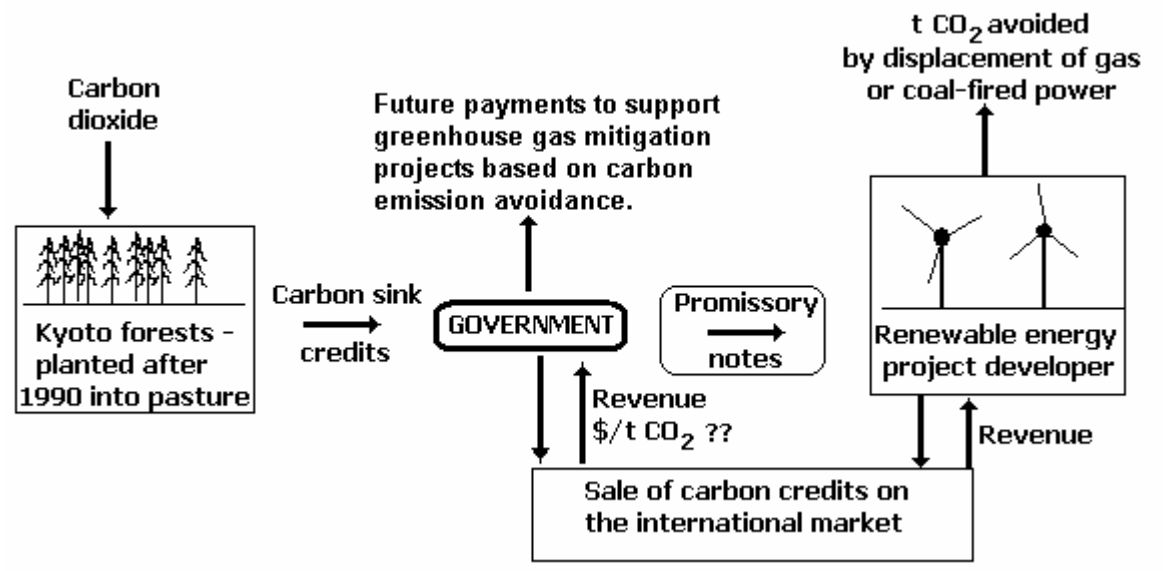
The original minimum qualifying level proposed of 100 000 tCO_2 equivalent was set to reduce the number of individual projects in order to minimise the high individual transaction and monitoring costs. However, it was identified during the consultation process with industry that, even allowing for accumulating individual company project proposals together under a joint industry umbrella (five wind farm developers working together, for example), this would eliminate all but the largest of projects. Developers of new large-scale hydro or geothermal projects would have been able to compete successfully at the base level of emissions envisaged whereas smaller projects, such as a typical bioenergy heat plant, would have been ineligible. For example, a typical 20-MW coal-fired boiler to provide process heat in a large meatworks consumes around 8 000 tonnes of coal per year. If converted to be fuelled totally by woody biomass instead, it would give an emission reduction of only around 40 000 to 50 000 tCO_2 over 5 years.

The total amount of the "Projects" funding pool available is yet to be determined. It will mainly stem from the future sale of carbon sink credits arising from New Zealand's plantation forests planted into hill country pasture or cropping land after 1990. Since around then, this land use change has averaged new plantings of over 50 000 ha/year of *Pinus radiata*, a species which matures to a 30-m tall, 700-mm diameter tree in under 30 years under New Zealand growing conditions. Most of these "Kyoto forests" are owned by small landowners or city dwellers investing for their retirement superannuation. It has been calculated that 110 million tonnes of additional carbon dioxide will be absorbed by these growing forests during the first Kyoto commitment period. Consequently, under the Kyoto mechanisms, these forests sinks will be eligible to receive carbon credits and the anticipated revenue from their sale on the international market will occur from the beginning of the first commitment period of the Kyoto Protocol in 2008, if not before, informally, since carbon trading is already well advanced.

The windfall revenue from this source will be administered by the government, regardless of the ownership of the forests. It will retain the future international carbon sink value of these forests but has stated it will use the revenue for the national good. The first example of this is support for the first greenhouse gas-reducing "projects". This will be in the form of promissory notes based on the future international value of carbon (Figure 4). These "P-notes" (or "peanuts", as some sceptical industry representatives have tagged them!) have already been offered to two wind farm developers who claim they are unable to proceed with otherwise viable projects due mainly to the competing traditional low cost of wholesale electricity (usually being less than EUR 2 cents/kWh average).

The need to support wind farms appears to conflict with the fact that the two existing projects commissioned in 1999 (without any subsidies) are in fact profitable enterprises. However, the Danish *Vestas* turbines at Tararua and the German *Enercon* turbines at Hau Nui (3.5 MW) were both purchased in 1998, when the NZ dollar was relatively high. Even though the power outputs are achieving world records for that size of turbine due to the excellent wind resource, the lower NZ dollar value today and the slightly decreased wholesale electricity price since the industry reforms began in earnest in 1998 now make new investment more risky. However, a proposed 38-MW extension to the existing 32-MW Tararua wind farm by its owners, Trust Power, and a new 80 to 90-MW installation located nearby, announced in 2003 by the state-owned power utility, Meridian Energy, are proceeding, since resource consents have been secured. A number of bioenergy projects could well follow.

Figure 4. Carbon credits from forest sinks will be retained by the government rather than the forest owner and the future revenue from their sale on the international market will be used to support climate change mitigation projects. Until their value is realised, promissory notes will be offered to support various projects such as wind farms.



Source: Author.

Developers would generally prefer a cash grant that is "bankable" for easier financing of the project, whereas the government prefers offering the promissory notes to reduce its risk, as their "value" is based on an unknown future international carbon value. A combination of the two might be a future option with the proportion yet to be determined.

The selection criteria to identify and rank successful projects are still being developed but *"dollar investment per tonne of carbon equivalent avoided"* is likely to rate highly. This would enable a variety of projects to be compared, such as replacing an old coal boiler with a more efficient design, introducing a bioethanol component as a blend with petrol, or reducing ruminant enteric methane levels by chemical injection or gut bacterial modification. So bioenergy projects will have considerable competition for what no doubt will be limited available funding.

Under the threat of immediate power supply shortages, at the time of writing a greater use of coal-fired power plants has been proposed as the interim solution. This would result in increased greenhouse gas emissions, but the threat of power outages and the electricity spot market power price spikes, which are causing industries to shut down for periods, are of national concern. Dry years appear to be more frequent (possibly as a result of climate change) and it will take several more years before the newly discovered (but relatively modest) gas supplies can be brought on-stream. Thus, the only practical medium-term solution to provide energy security and to meet the Kyoto obligations appears to be to encourage more renewable energy generation from all sources. This could include some bioenergy co-generation plants, but most of the available biomass resources will be most economically used to supply heat plants in the first instance (EECA, 2003).

Negotiated Greenhouse Agreements

A second mechanism to encourage greenhouse gas reductions is aimed at large companies which are classed as "competitive-at-risk". Where a large company can make a case to show paying this charge would disadvantage it in terms of reduced export sales or competing imports from countries with less stringent climate change policies (carbon leakage), it would have the opportunity to undertake a *Negotiated Greenhouse Agreement* (NGA) with the government. Under an NGA, a firm can make a business case showing how it will reduce its greenhouse gas emissions over a given period instead of paying the promised carbon emissions charge due to be implemented in 2007 (CCO, 2003). Together, the firm and government authority will identify practical and economic emissions intensity targets based on "world's best practice" in order to reduce the greenhouse gas emissions by an agreed amount within a certain period, or possibly by off-setting them as a result of investment in renewable energy supplies. This should provide a good opportunity for bioenergy use for process heat.

Eligibility will be tight to ensure the agreement is only made available when a clear need exists. A firm will have to show it is subject to international competition from producers facing less rigorous climate change policies and:

- it will face a significant increase in costs where energy represents more than 20% of total expenses; or
- the EUR 13/tonne CO_2 charge to be implemented on fossil fuels in 2007 would decrease the firm's profitability by more than 10%; or
- this carbon charge would result in a return on investment below the appropriate internationally accepted industry investment hurdle (though quite how this is to be determined is not clear).

Thus successful negotiation will exempt a firm from the relatively small carbon charge which will be based on the international value at the time but capped to be no more than EUR 13/tonne CO_2 emitted. Since NGAs will be expensive to negotiate and subsequently monitor, they will only be made available where true issues of competitiveness arise. Exemptions to the carbon charge could be full or partial and firms with various business activities may only receive an exemption on those parts of the business deemed to be at risk. The negotiation process will no doubt evolve with time, but since the policy was developed following extensive consultation with industry there is hope it will serve its purpose free from legal challenges.

Future opportunities

As the large (by relative world standards) Maui natural gas field finally depletes, it is anticipated that gas from smaller fields waiting to be developed will become available in due course but at significantly increased prices. The doubling of the gas price will increase the wholesale price of electricity by around EUR 0.5c/kWh and, together with the proposed carbon charge, will make renewable energy systems more competitive.

There is no doubt that a large renewable energy resource exists in New Zealand. Many excellent wind sites have been identified, as have numerous small hydro sites. Biomass resources will increase significantly once the "wall of wood" comes on-stream as large areas of plantation forests mature during the next few years. The forest residues resulting from the timber extraction and processing of logs will equate in total energy to the energy content of a new natural gas field. Using the waste biomass products first that are already concentrated at a given site (such as forest process residues at a

sawmill or municipal solid wastes in landfills) will be more economic than having to collect and transport residual biomass material (such as cereal straw or forest arisings). Integrating the harvest of the main products (timber or grain) with the energy by-products is a worthy solution needing further evaluation. Growing energy crops such as miscanthus, coppice willow or cereals for bioethanol will probably remain the most expensive options in terms of $/GJ for the foreseeable future, assuming no additional government subsidies are offered.

Distributed generation

The recent "Programme of Action" for *Sustainable Development for New Zealand,* released in January 2003 by The Department of Prime Minister and Cabinet (www.beehive.govt.nz) focused on four key directions the government wish to take early action on:

- water quality and allocation;
- sustainable cities;
- child and youth development; and
- energy from sustainable and reliable resources.

The overall aim of the last point is "to ensure the delivery of energy services to all classes of consumer in an efficient, fair, reliable and sustainable manner". This will be achieved by ensuring that:

- energy use will become progressively more efficient and less wasteful;
- consumers will have a secure supply of electricity; and
- renewable energy sources will be developed and maximised.

The greatest opportunity for increasing the uptake of bioenergy in the longer term perhaps will be at the small scale to implement the global trend towards distributed energy (Sims and Gigler, 2002). Many rural communities in New Zealand are concerned that after 2013 there is no legal requirement for an electricity lines company to continue to supply power to its current customers. Since around half of the 29 regional network companies are privately owned (the other half being trust owned with perhaps more social priorities), there are few, if any, commercial incentives to maintain existing rural lines and poles which deliver power to the more remote areas where there is insufficient demand to warrant investment in the network. Studies at Massey University are evaluating several rural communities in an attempt to develop a decision-making model (Sims and Murray, 2002). The aim of the model is to, within a short period of time, be able to assist a rural community to:

- enable the local renewable energy resources to be assessed;
- calculate the seasonal and daily heat and power demands of community members;
- ascertain if the local energy resources can be matched to meeting these demands;
- identify the potential for exporting surplus power to the grid thereby encouraging the lines to be maintained; and
- evaluate the economic social and environmental benefits from using these local renewable energy resources.

In many cases, the local lines distribution company could be interested in becoming a stakeholder in the proposed embedded generation investment in order to avoid upgrading any of their lines if near to maximum carrying capacity. Transpower, the state owner of the major high-voltage transmission grid of New Zealand, also has a potential interest, particularly in regions where grid constraints exist and significant investments will be needed to overcome them by increasing the carrying capacity. Therefore, there could be a greater opportunity for a rural community to stay grid-connected than to become independent of it, and to benefit from the revenue to be gained from selling excess power. However, much research is still needed in order to convince the electricity industry of the benefits to be had from such a paradigm shift.

Conclusions

The government of New Zealand supports a sustainable development future. However, supplying energy at competitive rates from biomass and other renewable energy sources is proving to be a challenge. Successfully meeting the renewable energy target of the National Energy Efficiency and Conservation Strategy will partly depend on increased use of biomass. This will need to be achieved without the possible threat to food and fibre exports as a direct result of higher energy costs for their production and processing operations. Direct farm grants and farm subsidies are not an option to encourage bioenergy projects in this free market economy. Instead, greenhouse gas-mitigating policy mechanisms now being introduced will be the incentive needed for greater biomass production by landowners and its utilisation by energy users. Due to the cost differentials in terms of $/GJ as delivered to the conversion plant, existing available processing waste biomass resources will be used before growing specific energy crops, which would be more expensive.

BIBLIOGRAPHY

CCO (2003), Negotiated greenhouse agreements, Climate Change Office, Wellington, New Zealand: www.climatechange.govt.nz.

ECCA [Energy Efficiency and Conservation Authority] (2003), Wellington, New Zealand: www.eeca.govt.nz.

Federated Farmers (1995), *Life after subsidies - the New Zealand farming experience,* Federated Farmers of NZ (Inc), Wellington, New Zealand, August.

MED [Ministry of Economic Development] (2002), *Energy data file 2002,* Wellington, New Zealand: www.med.govt.nz/ers/en_stats/edfonlin/edfjan2003/index.html.

Rae, A.N. (1996), *Agriculture can survive unilateral reforms – lessons from down under,* conference on Food and Agricultural Policy Challenges for the Asia-Pacific and APEC, Phillipine Institute for Development Studies, Manilla, October.

Sims, R.E.H. (2002), *The brilliance of bioenergy – in business and in practice*, James & James Science Publishers, London, United Kingdom.

Sims, R.E.H. and T.J. Dyson (2002), *Renewable energy mechanisms – international collaboration urgently needed*, RE Focus May/June, 36-43, Elsevier.

Sims, R.E.H. and J. Gigler (2002), "The brilliance of bioenergy – small projects using biomass", *Renewable Energy World*, James & James Science Publishers, London, United Kingdom, Vol. 5, No. 1, pp. 56-63.

Sims, R.E.H. and P.E. Murray (2003), *Distributed generation for rural communities in New Zealand – economic, social and environmental issues*, Proceedings of World Sustainable Energy Day conference, Wels, Austria.

BIOMASS NIPPON STRATEGY IN JAPAN – WHY "BIOMASS NIPPON" NOW?

Yasuhiko Kurashige[1]

Abstract

In December 2002, the Japanese government agreed a "Biomass Nippon Strategy". Several ministries participated in formulating the Strategy, including the Ministry of Agriculture, Forestry and Fisheries, the Ministry of the Environment and the Ministry of Economy, Trade and Industry. The Strategy consists of three parts: Background, Goals and Basic Strategies. Concerning the background, four reasons are identified, including a necessity to create a "recycling-oriented society". The Strategy sets three types of goals *i.e.* technical, regional and national. The basic strategies include those for production, collection and transportation, conversion technologies, and stimulation of demand for energy use or material use. The implementation of the Strategy is just getting started and there remain a lot of challenges to be tackled, including demand stimulation of biomass products. But the utilisation of biomass will continue to be an important policy issue in Japan.

Background

In the wake of the oil crises of the 1970s, Japan instigated various research and development (R&D) plans in the field of biomass utilisation. In reality, these plans did not bring about the hoped-for changes in people's daily lives because of the restabilisation of oil prices. However, by 2002, the momentum for taking action on biomass utilisation had grown so strong that the strategy was established with the consensus of the entire government. The strategy defines biomass as a "renewable, organism-derived, organic resource, excluding fossil resources", and identifies the following four reasons why Japan should tackle biomass utilisation as a national project:

Prevention of global warming

The use of "carbon-neutral" biomass should be promoted as a substitute for some energy and products currently derived from fossil fuels, and thus mitigate carbon dioxide emissions.

Creation of a recycling-oriented society

Limited resources should be used in an ecological manner by increasing the utilisation of renewable biomass, thus accelerating society's progress towards sustainable development.

1. Ministry of Agriculture, Forestry and Fisheries, Tokyo, Japan.

Fostering of new strategic industries with competitive edges

The industrial competitiveness of Japan should be restructured by fostering biomass-related enterprises as a strategic industry unique to Japan.

Activation of agriculture, forestry and fisheries, as well as associated rural communities

The abundant natural sources of biomass in Japan should be used to re-activate agriculture, forestry and fisheries, as well as the rural communities involved in these activities.

Goals of the Biomass Nippon Strategy

In order to promote the development of a common understanding, the Strategy presents both the evolutional direction of biomass utilisation and the evolutional direction of the technology used for biomass utilisation. It also indicates specific goals as guidelines to encourage the commitment of the parties involved and to evaluate progress in the realisation of the Strategy. Regarding these goals, while it is difficult to make an accurate forecast on energy prices over a prolonged period of time (and these goals will be taken into account by industry whenever it invests in biomass utilisation), the Strategy aims, for the time being, at the target year 2010, which corresponds with the mid-point of the first commitment period of the Kyoto Protocol.

Direction of evolution for biomass utilisation

Biomass is produced by organisms; therefore it has a characteristic of existing widely. Thus, both the cost involved in harvesting biomass and conversion efficiency – which may vary, depending on the amount harvested – will have significant effects on the availability of biomass.

Waste Biomass: An increased utilisation of paper waste, livestock waste, food waste, construction-derived wood residues, black liquor and sewage sludge can be promoted relatively quickly.

Unused Biomass: By around 2010, the utilisation of biomass which had previously never been used will become apparent: *e.g.* unused portions of farm crops, such as rice straw or rice husk, and forestry residues left unused at sites, etc.

Energy Crops: By around 2020, energy crops will be widely cultivated as an energy or product source.

New Crops: By around 2050, newly developed crops, such as marine plants and genetically modified crops, will contribute to an increased production of biomass.

The total amount of intrinsic chemical energy content in waste biomass, unused biomass, and energy crops is approximately 1 300 PJ (petajoules) of energy equivalent (equivalent to 35 million kl of crude oil), or 33 million tonnes of carbon equivalent (equivalent to 3.3 times the total amount of carbon contained in the plastic materials produced in Japan).

Direction of development of technologies for biomass utilisation

Regarding the technologies associated with the conversion of biomass into energy and products, their development stages vary widely, ranging from those already in use, to others still in verification or the R&D phase. Thus, a wide range of technologies at different completion levels is now available, and R&D activities have been undertaken in many areas, including peripheral technologies.

Construction of a biomass refinery

In order to achieve the utilisation of biomass-derived energy and products across a broader range, the most effective approach would be to construct a "biomass refinery" which makes use of the characteristics of biomass, producing a diverse range of fuels and useful materials using biomass as raw material.

Cascade use of biomass

Alongside the development of individual relevant technologies, a cascade (multi-stage) use of biomass is required for the purpose of exploiting its use to the fullest by using it repeatedly; as many times as possible; from the top end to the bottom in terms of product value; and by burning it to generate energy at the last stage of this utilisation cascade.

Specific goals for the materialisation of Biomass Nippon

The Strategy sets certain goals from the technological perspective (energy conversion efficiency, cost target of process equipment/systems, etc.); the local community's standpoint (such as an increase in the number of communities which utilise biomass above a certain level), and also the nationwide viewpoint (such as posting a clear target level for biomass utilisation).

The technological perspective

i. Regarding the technology for converting biomass with a low water content into energy by direct burning or at a gasification plant, a technology will be developed to achieve the following goals:

   - Energy conversion efficiency of approximately 20% in terms of electricity, or 80% in terms of heat in the case of a plant with a daily process capacity of approximately 20 tonnes of biomass (assuming its installation in several city- or town-level local communities).

   - An energy conversion efficiency of approximately 30% in terms of electricity in the case of a plant treating 100 tonnes of biomass daily, in an environment in which a wide range of biomass collection is already applicable (assuming its installation at prefecture level).

ii. In the case of converting biomass containing a high water content into energy, as occurs with methane fermentation, a technology will be developed to achieve energy conversion efficiency of 10% in terms of electricity, or 40% in terms of heat for a plant with a daily capacity of approximately 5 tonnes of biomass (assuming its installation in small local communities, from village-, to town- or city-level).

iii. Regarding the technology used for converting biomass into products, a technology will be developed which will lower the price level of the biomass-derived plastic material which is already commercialised at JPY 200/kg (USD 1.7/ kg, USD 1 = JPY120), and will prepare more than 10 kinds of new products ready for commercialisation, in order to promote the effective utilisation of lignin and cellulose.

Regional perspective

Approximately 500 local municipalities will have a system utilising more than 90% of waste biomass in terms of carbon equivalent, or more than 40% of unused biomass in terms of carbon equivalent.

Nationwide perspective

More than 80% of waste biomass in terms of carbon equivalent, as well as more than 25% of unused biomass in terms of carbon equivalent is utilised. As for energy crops, approximately 100-1 000 tonnes of carbon equivalent are expected to be utilised.

Basic strategies for materialisation of Biomass Nippon

In an attempt to materialise Biomass Nippon at an early stage, the Strategy presents a specific action plan including primarily responsible ministries and implementation time frames concerning some major issues to be solved. The government will implement this specific action plan step-by-step, re-examining it, taking its evaluation results and changes in the socio-economical circumstances into full account, and thus promoting the comprehensive strategy worked out for Biomass Nippon.

General aspects on the promotion of biomass utilisation

- Establish a Biomass Information Headquarters, to work as the central base for information.
- Establish the Biomass Japan Comprehensive Strategy Promotion Council in order to facilitate a solid promotion of the relevant strategies.
- Study new laws needed for promoting the Biomass Nippon Strategy.
- Undertake R&D for designing a social system in which an efficient utilisation of biomass is encouraged; conduct a demonstration test for the envisaged outcomes.
- Implement a comprehensive package of measures in model communities under a co-ordinated programme headed by relevant government offices.
- Undertake steps towards the evaluation of possible merits and demerits of their introduction into Japan, taking into account Japan’s situation, in an attempt to establish new competition conditions for biodiesel fuels.

Strategies for the production, collection and transportation of biomass

- Formulate an efficient collection/transportation system for biomass.
- Explore possible means of expanding the boundaries of the recycling qualification of waste biomass which shall meet certain requirements; for example, the biomass should not decompose so easily.
- Produce biomass efficiently by utilising special zones for structural reform.

Strategies for conversion of biomass

- Develop conversion technologies, and promote their application.
- Support the establishment of a model facility.
- Explore any possible means to simplify the entire approval procedure required for the installation of waste treatment facilities intended for handling biomass of the same kind in terms of its properties.

Strategies for the use of biomass after its conversion

- Investigate a handling procedure to be applied to biomass-derived plastic materials as specific procurement items covered by the Green Purchasing Law.
- Arrange matters so that power generation from biomass can be handled in the same manner as other kinds of new energy under the New Energy Law.
- Assess the safety and effectiveness of products obtained through the biomass conversion, including compost.
- Promote the kind of agriculture which is oriented towards conservation of the environment.
- Facilitate power supply by means of locally distributed power sources, including biomass power generation.
- Undertake quality evaluation of biomass-derived automotive fuels, assess their safety and environmental performance, and conduct driving tests on those fuels as well as evaluating the merits and demerits of their introduction into Japan in view of Japan's situation.

Biomass and agriculture, rural development

Although poor in fossil resources, Japan is located in a monsoon region with temperate climate conditions and plentiful rainfall, and has therefore quite abundant in biomass, most of which grows in rural regions. Agriculture can actually be considered an industry which utilises the circulation of materials in an ecosystem. This circulation produces agricultural products from solar energy, soil, and water, thereby fulfilling the role of the primary stage of biomass recycling. Furthermore, this industry not only produces biomass, but also recycles the biomass consumed as food and feed which is transformed into compost, thus being capable of reproducing biomass. Also, since this industry can make use of nitrogen and phosphorus, which cannot be used as an energy source, the role of agriculture is quite important for biomass production. Furthermore, from the perspective of

accumulating carbon in the soil and using nutritive components in the soil effectively, and also from the perspective of ensuring sustainable biomass production, it is quite important to promote sustainable agriculture by implementing proper soil management, for example, by introducing compost into soil.

Improvement of economical efficiency due to the progress in technological development is, however, crucial to the development of agriculture-related biomass utilisation. At the same time, it is essential to create demand for the production of the raw material to be used as energy and as a source of useful products, which will then induce the commercial production of biomass operated by a private corporate entity with high economical efficiency. The Strategy proposes some specific action plans relating to agriculture and rural development, including the following:

- Promote organic agriculture by proper soil management through the introduction of compost into soil.
- Promote the use of biomass-derived energy and products in agriculture, such as a power source for agricultural facilities, fertilisers, etc.
- Run a popularisation campaign through technical training and education programmes, so that biomass-derived products can be used widely in the field of agriculture.
- Investigate the proper manner of producing resource crops well suited to any of the designated regions, taking into account a prospective improvement in the economic efficiency of the production of biomass as raw material for energy and products.
- Undertake further research on the cultivation of crops with a high yield of biomass.

Conclusion

As mentioned above under “Background”, there are four principal reasons which urge the government to take action on promoting biomass utilisation. Although each of these four reasons is important, the creation of a recycling-oriented society could be considered as an example of the basic philosophy or principle of biomass utilisation. In order to restrict the generation of waste, and to shift our society towards a recycling-oriented society in which limited resources are used effectively, it is necessary to reform the conventional social system in which merchandise is mass-produced from limited resources, consumed, and then thrown away. Advancing towards the formation of a recycling-oriented society, biomass, a sustainable renewable resource brought about by the blessings of nature, will take an important role.

The implementation of the Strategy is, however, just getting started and there remain a lot of challenges to be tackled. One of the most difficult, but important, is stimulation of demand for biomass-derived products. Since the existence of biomass (let alone its potential benefits) is not fully understood by members of the general public, it is essential to expand and enhance their need for biomass by providing relevant information. Financial measures would also be useful and it is necessary to investigate carefully which kind of policy-mix is the most effective for that purpose, in learning from the experiences in other countries.

As for biomass and agriculture, in addition to its conventional role of providing food and lumber material, the utilisation of biomass will bring with it a new possibility of supplying energy and industrial products, as well as promoting the sound co-existence of city areas and rural regions, enhancing exchanges between them. Through this process, biomass can become a key element for generating new development, leading to the revitalisation of the country as a whole.

ANNEX

FY 2003 BUDGET[1] FOR THE IMPLEMENTATION OF BIOMASS NIPPON STRATEGY

(USD million; USD 1 = JPY 120)

Research and Development	**10**
Community-based measures	
- Planning, Technical assistance/extension	**31**
- Biomass conversion facilities	**141**
	182

Note:

1. FY: fiscal year. The figures include the forestry- and fisheries-related budget.

Source: Ministry of Agriculture, Forestry and Fisheries, Tokyo, Japan.

Questionnaire on the quality of OECD publications

We would like to ensure that our publications meet your requirements in terms of presentation and editorial content. We would welcome your feedback and any comments you may have for improvement. Please take a few minutes to complete the following questionnaire. Answers should be given on a scale of 1 to 5 (1 = poor, 5 = excellent).

Fax or post your answer before 31 December 2004, and you will automatically be entered into the prize draw to **win a year's subscription to *OECD's Observer magazine***.*

A. Presentation and layout

1. What do you think about the presentation and layout in terms of the following:

	Poor	Adequate			Excellent
Readability (font, typeface)	1	2	3	4	5
Organisation of the book	1	2	3	4	5
Statistical tables	1	2	3	4	5
Graphs	1	2	3	4	5

B. Printing and binding

2. What do you think about the quality of the printed edition in terms of the following:

Quality of the printing	1	2	3	4	5
Quality of the paper	1	2	3	4	5
Type of binding	1	2	3	4	5
Not relevant, I am using the e-book	❑				

3. Which delivery format do you prefer for publications in general?

Print ❑ CD ❑ E-book (PDF) via Internet ❑ Combination of formats ❑

C. Content

4. How accurate and up to date do you consider the content of this publication to be?

1 2 3 4 5

5. Are the chapter titles, headings and subheadings…

Clear Yes ❑ No ❑
Meaningful Yes ❑ No ❑

6. How do you rate the written style of the publication (*e.g.* language, syntax, grammar)?

1 2 3 4 5

D. General

7. Do you have any additional comments you would like to add about the publication?

.....

.....

.....

Tell us who you are:

Name: ..... **E-mail:** .....

Fax: .....

Which of the following describes you?

IGO ❑ NGO ❑ Self-employed ❑ Student ❑
Academic ❑ Government official ❑ Politician ❑ Private sector ❑

Thank you for completing the questionnaire. Please fax your answers to: (33-1) 49 10 42 81 or mail it to the following address:
Questionnaire qualité PAC/PROD, Division des publications de l'OCDE
23, rue du Dôme – 92100 Boulogne Billancourt – France.

Title: Biomass and Agriculture

ISBN: 92-64-10555-7 **OECD Code (printed version):** 51 2004 01 1

* Please note: This offer is not open to OECD staff.

cover-.fm Page 3 Thursday, July 22, 2004 4:52 PM

OECD PUBLICATIONS, 2, rue André-Pascal, 75775 PARIS CEDEX 16
PRINTED IN FRANCE
(51 2004 01 1 P) ISBN 92-64-10555-7 – No. 53649 2004

© OECD, 1999.

© Software: 1987-1996, Acrobat is a trademark of ADOBE.

All rights reserved. OECD grants you the right to use one copy of this Program for your personal use only. Unauthorised reproduction, lending, hiring, transmission or distribution of any data or software is prohibited. You must treat the Program and associated materials and any elements thereof like any other copyrighted material.

All requests should be made to:

Head of Publications Service,
OECD Publications Service,
2, rue André-Pascal, 75775 Paris
Cedex 16, France.

© OCDE, 1999

© Logiciel, 1987-1996, Acrobat, marque déposée d'ADOBE.

Tous droits du producteur et du propriétaire de ce produit sont réservés. L'OCDE autorise la reproduction d'un seul exemplaire de ce programme pour usage personnel et non commercial uniquement. Sauf autorisation, la duplication, la location, le prêt, l'utilisation de ce produit pour exécution publique sont interdits. Ce programme, les données y afférantes et d'autres éléments doivent donc être traités comme toute autre documentation sur laquelle s'exerce la protection par le droit d'auteur.

Les demandes sont à adresser au :

Chef du Service des Publications,
Service des Publications de l'OCDE,
2, rue André-Pascal,
75775 Paris Cedex 16, France.