



OECD Sustainable Development Studies

Measuring Sustainable Production



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Foreword

This report contains the proceedings of an OECD workshop on *Sustainable Manufacturing Production and Competitiveness* held in Copenhagen, Denmark on 20-21 June 2007. The workshop was organised under the auspices of the OECD Horizontal Programme on Sustainable Development in conjunction with the OECD Committee on Industry, Innovation and Entrepreneurship (CIIE), the Environment Policy Committee (EPOC), and the International Energy Agency (IEA). Organisational support and facilities were provided by the Government of Denmark.

Promoting sustainable production and consumption is at the core of sustainable development, which depends on achieving long-term economic growth that is consistent with environmental and social needs. Sustainable production is one focus of the United Nations Marrakech Process and involves ensuring business attention both home and abroad to “triple bottom line” concerns – economic (costs, profits), environmental (pollution, waste, resource use) and social (safety and health, remuneration, worker rights).

The Copenhagen workshop explored how to define and measure “sustainable production”. It reviewed measurement approaches based on economic, environmental and social indicators and analytical techniques such as systems analysis, input-output analysis and energy efficiency analysis. Industry representatives presented their metrics for determining the sustainability of their operations, including Composite Indices which combine a range of indicators. The links between sustainable production and the enhanced efficiency, cost-effectiveness and competitiveness of firms were demonstrated based on findings from surveys, audits, cluster analysis and engineering analysis.

It should be noted that the papers in this volume reflect the views of the authors and not necessarily those of the OECD or its Member countries.

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Workshop Overview

Candice Stevens, OECD Sustainable Development Advisor

Introduction

The workshop on *Sustainable Manufacturing Production and Competitiveness* was held in Copenhagen, Denmark on 21-22 June 2007. Ken Warwick, UK Department of Trade and Industry and CIIE Chair, acted as Chair of the Workshop. It was opened by Connie Hedegaard, Danish Minister for the Environment, and Finn Lauritzen, Director General of the Danish Enterprise and Construction Authority in the Ministry of Economic and Business Affairs. Both stressed how Industry Ministries and Environment Ministries should strengthen ties in promoting sustainable business practices in the interest of increasing competitiveness.

The workshop focused on developing indicators and metrics for measuring sustainable production for use by business and policy makers. The development of benchmarks for sustainable production will give firms the ability to objectively assess their overall performance and countries the ability to measure the extent to which industry and markets operate in a sustainable way. The workshop results were reported to the UN Marrakech Process meeting on sustainable production and consumption held in Stockholm, Sweden on 26-29 June 2007.

Session 1: Measuring Sustainable Manufacturing

This session reviewed approaches to measuring the sustainability of manufacturing processes in economic, environmental and social terms. Different sets of indicators have been developed to measure sustainable manufacturing. These include, to varying degrees, economic (*e.g.* cost-effectiveness, R&D expenditures, profits), environmental (*e.g.* CO₂ emissions, energy and materials consumption, eco-efficiency) and social (*e.g.* safety and health, trade union rights, remuneration, corporate accountability) measures. A wide variety of measurement approaches are used, including those based on systems analysis, input-output analysis, energy efficiency analysis, and materials flow analysis. The unit of measure varies from countries to sectors, firms and individuals. The following are the main points of the presentations in this session:

Nabil Nasr, Director of the Sustainability Institute at the Rochester Institute of Manufacturing Studies, United States, advocated the use of a systems-based approach in the design and assessment of sustainable manufacturing. This involved an integrated view of the manufacturing process and its social, economic and environmental impacts. From this perspective, comprehensive and strategic design of production processes, management tools and products at the sectoral level, would enable companies to move

from regular sustainable manufacturing units (*i.e.* focusing on pollution prevention, environmental management systems, etc.) to closed-loop systems of sustainable production (cradle-to-cradle management, reuse, remanufacturing and recycling).

Mathis Wackernagel is Director of the Global Footprint Network which compares the environmental impacts of populations and countries based on indicators (on a per person basis) of ecological pressures in terms of the area of productive land and sea required to provide needed resources and to absorb waste. Estimates of ecological footprints show that current economic activities exceed the planet's regenerative capacity by 25%. "One Planet Business" provides performance measurement tools to allow individual companies to assess their environmental and social impacts and related costs in terms of such factors as water use, greenhouse gas emissions, exposure to risk, and stakeholder relations.

Cecilia Tam, energy analyst at the International Energy Agency (IEA), presented measures of energy efficiency and CO₂ emissions per unit of physical product on a sector-specific basis. Analysis shows that three sectors (iron and steel, cement, and chemicals and petrochemicals) account for 70% of industrial CO₂ emissions worldwide. Adoption of best-practice commercial technologies in these sectors could greatly increase energy efficiency and reduce CO₂ emissions. Analysis at country level shows that China accounts for a large portion of these emissions but also has extensive improvement potential.

Roland Schneider of the Trade Union Advisory Committee to the OECD (TUAC) described how trade unions have developed measures for assessing social concerns (*e.g.* occupational safety and health, remuneration, working conditions, gender dimensions, trade union rights, corporate accountability) on a country, sector and company basis. In the view that assessing the status of the workforce is key to sustainable manufacturing, the Sustainable Development Unit maintains a country-level data base comprising 216 indicators. In addition, more than 550 corporations have been evaluated through the company data base which assesses their social responsibility performance and compliance with the OECD Guidelines for Multinational Enterprises.

Lars Mortensen, Head of the Sustainable Production and Consumption Unit at the European Environment Agency (EEA), explained how input-output analysis is used to compare manufacturing sectors and product groups on their environmental pressures (*e.g.* emissions, acidification, ozone depletion, material flows). This approach is based on data from the 2006 NAMEA (National Accounting Matrixes with Environmental Accounts) survey of manufacturing sectors. It shows, for example, that manufacturing (specifically basic metals, coke, cement, chemicals, and refined petroleum products) contributes 22% of European greenhouse gas emissions.

Session 2: Sector Approaches to Measuring Sustainable Manufacturing

This session featured representatives of different companies presenting the measurement approaches they use to ascertain the sustainability of their operations. Despite the development of recognised measurement and reporting frameworks (*i.e.*, International Standards Organisation, Global Reporting Initiative), many companies have developed their own metrics for assessing the economic, environmental and social impacts of their facilities and products. Some are combining these into composites or simple indices which are more likely to get the attention of CEOs. Larger corporations are also formulating ways to assess the sustainability of their supply chains of smaller companies. The following are the main points of the presentations in this session:

Rajesh Kumar Singh, Manager at Bhilai Steel in India, presented a Composite Sustainability Performance Index developed to measure dimensions of sustainability at different steel production facilities within the company. Indicators include economic (net profits, turnover/inventory ratios, investments), environmental (energy consumption, emissions, wastes), social (employee satisfaction, safety and health, community interactions) as well as organisational governance (knowledge management) and technical aspects. An analytical hierarchy process (AHP) is used to determine the weights of the indicators, which are combined into sub-indices and aggregated to form a single measure per plant.

Wulf-Peter Schmidt, Vehicle Environmental Engineering, Ford of Europe, described how Ford of Europe uses a Product Sustainability Index (PSI) as a management tool to assess the potential impacts of motor vehicles on a range of factors. This is an engineering approach which combines eight indicators reflecting environmental (global warming potential, materials use), social (mobility, capability, safety) and economic (life cycle costs) vehicle attributes. Indicators are not aggregated into one ranking, but rather tailored to the departments of the motor vehicle company to enable full ownership, transparency and efficiency.

Ken Martchek, Life Cycle and Environmental Sustainability Manager at Alcoa, presented the company's Metrics of Corporate Responsibility used to assess the performance of facilities in environmental (energy consumption, recycling, greenhouse gas emissions) and social (health and safety, management systems) terms. The company is focusing on developing indicators of community involvement (initiatives to improve local health, education and environment), including the formation of formal mechanisms for consulting local communities. One target is that 100% of manufacturing locations will implement the Alcoa Community Framework by 2010.

Sabine Klages-Buechner, Manager of International Government Affairs at DuPont, described how the company uses quantitative targets to reduce its ecological footprint in terms of energy use, wastes, greenhouse gas emissions, etc. as well as its social footprint in terms of workforce health and safety. Cost-benefit analyses based on an 80/20 approach (80% reduction in wastes and emissions for 20% of total cost) are used to determine which projects are most effective in reducing this footprint. An Ethical People initiative is focused on enhancing corporate social responsibility and accountability.

Marina Franke, Manager of Global Sustainability at Procter & Gamble, emphasised sustainable innovation as the focus of the company's sustainability approach, which broadly encompasses environmental (pollution, resource management) as well as social (labour practices, stakeholder interface, supply chain management, transparency in reporting, communities, human rights, anti-corruption) concerns. Sustainability Guidelines for Supplier Relations stress human rights, health and safety standards, environmental quality, data privacy as well as prohibition of child or forced labour in firms which provide goods and services to P&G.

Koichi Akaishi, Executive Director of the Japan Machinery Center for Trade and Investment, which is an industrial association with 300 company members, focused on supply chain management. Green Procurement Requirements are placed on supplying companies to assure reduced environmental impacts in terms of wastes and emissions and the implementation of environmental management systems. The Japan Green Procurement Survey Standardization Initiative is developing codes of conduct and criteria for benchmarking supplier company performance.

Session 3: Sustainable Manufacturing and Competitiveness

This session explored the links between sustainable manufacturing processes and the enhanced efficiency, cost-effectiveness, and competitiveness of firms. Different techniques (surveys, auditing, cluster analysis, engineering analysis) are being applied to assess how sustainable manufacturing approaches contribute to firm performance. These analyses also provide insights for government policies. The following are the main points of the presentations in this session:

Nick Johnstone, Senior Economist at the OECD Environment Directorate, presented the results of firm surveys regarding links between environmental management systems and economic and innovative performance. An analysis of 4 000+ manufacturing facilities with more than 50 employees in 7 OECD countries found that there is a positive correlation between environmental performance and commercial performance, as occurs primarily through cost-savings and environmental R&D. The analysis also showed that environmental innovation is encouraged by flexible environmental policies (including economic instruments and performance standards), but that perceived policy stringency could influence commercial performance negatively.

Johanne Gelinas, Partner at Deloitte-Touche, explained how auditing improves the risk profile of companies and therefore their economic performance. Financial institutions are interested in the environmental and social aspects of companies to assure that they are viable investment vehicles. Audits examine the overall behavior and impacts of a firm to provide 3rd party verification of sustainability, which is increasingly being driven by the financial community. Initiatives such as the Carbon Disclosure Project, where carbon emissions and mitigation efforts are catalogued, are being combined with Corporate AccountAbility Indices to assess the “triple bottom line” of companies.

Jorgen Rosted, Director of FORA at the Danish Ministry of Economic and Business Affairs, presented analyses of the competitive benefits of environmental innovation and how governments can partner with firms in advancing eco-innovation and business performance. Cluster analysis was used to identify environmental technology strongholds in Denmark – wind turbines, water purification, biotechnology, biofuels and fuel cells. Company surveys of government framework conditions revealed the need for strategic partnerships between industry, government and universities to strengthen market-oriented R&D in these fields.

Hideki Kita of the Japanese National Institute of Advanced Industrial Science and Technology (AIST) described their analyses of “minimal manufacturing”, which aims at minimal energy and resource use and production of waste. Indicators of processes and products are used to measure advancement towards the goal of retarding entropy production rates through “exergy” approaches in process design. Studies show that the Minimal Manufacturing Index is positively correlated with competitiveness performance at firm-level and also with customer satisfaction with products.

Session 4: Conclusions

This session reviewed the findings of the Workshop and discussed what value-added the OECD could provide in future work on sustainable production. It was generally agreed that sustainability is a real opportunity for business since sustainable practices can both enhance performance and build markets, but that better measurement criteria are needed.

Saul Japson of the US Department of Commerce stressed the need for metrics and tools to help industry measure the sustainability of their activities and to benchmark sustainable manufacturing programmes. A toolkit of environmental metrics is needed including measures of: materials consumption, water, solid waste, and energy. Analysis of the economic costs vs. benefits of sustainable production could review job creation, long-term vs. short-term costs, the costs of implementing clean technologies and other factors.

Yuko Yasunaga, Director of the Research and Development Division of the Industrial Technology and Environment Section of the Japanese Ministry of Economy, Trade and Industry (METI), focused on the role of eco-innovation and its importance to new industries and society. He proposed that eco-innovation aim at promoting sustainable industrial structures, social infrastructures and lifestyles. The main elements are decreasing fossil fuel dependence and CO₂ emissions, decreasing materials consumption, and promoting eco-friendly engineering approaches. Sector-based strategies are needed in addition to enhanced communication on eco-innovation among industry, government and academia.

John Dryden, Deputy Director of the OECD Directorate for Science, Technology and Industry (DSTI), discussed the OECD Innovation Strategy, mandated by the OECD Ministerial Council Meeting in May 2007. Ministers “welcomed the incorporation of cross-cutting work on innovation to address global challenges, notably in the environmental domain...” Proposals for OECD work on eco-innovation include analysis of technologies to reduce environmental impacts, government policies to promote environment-friendly technologies, and good practice in environment-friendly business models.

Candice Stevens, OECD Sustainable Development Advisor, emphasised that sustainability should be measured in its economic, environmental and social dimensions. She made several suggestions for the future broad OECD work programme on sustainable production, recommending that the OECD: 1) develop toolkits of economic, environmental and social indicators for assessing sustainable production in firms by sector; 2) review approaches such as composite indices for benchmarking sustainability performance across firms and sectors; 3) analyse links between sustainable innovation and firm and sector-level performance; 4) examine the role of sustainable supply chains and SMEs; 5) analyse the effects of government environmental and industry policies on the sustainability performance of companies; and 6) identify links between sustainable production and sustainable consumption as a contribution to the UN Marrakech Process.

Ken Warwick, Workshop Chair, summarised the discussions. Given that there now exist a diversity of approaches, methodologies and levels of analysis in measuring sustainable production, the OECD could play a useful role in bringing coherence to the compilation of indicators and measurement. Toolkits of sustainable production indicators, perhaps at sector level, accompanied by case studies to illustrate good practices might also be developed.

OECD work on indicators of sustainable production will need market research on the perceived business need. In the first instance, this could focus on environmental indicators which are more widely accepted and available. Any reporting system should be as specific as possible to the firm or even plant. Generic, one-size-fits-all approaches will give an appearance of comparability, but will not enable firms to effectively evaluate their own performance. There was consensus that smaller firms face barriers to

understanding the effects of their sustainable development efforts, which could also be a worthwhile focus for OECD work.

Part I. Keynote Addresses

Chapter 1. Sustainable Production as Good Business

Connie Hedegaard, Danish Minister for the Environment

Sustainable production is highly important in order to meet the environmental challenges we are now faced with. At the same time, a growing number of companies have found new business opportunities in sustainable production. But we need new ideas and new initiatives from all parties to enhance the development of even more win-win solutions. We need better insight into how sustainable production can contribute to the performance, profitability and competitiveness of business in order to get more companies on board. And it is important for governments to obtain knowledge from business on what is possible in practice.

The current climate debate is helping us by getting more focus on the environment. During the last year or so, climate change has moved to the very top of the global agenda. We are seeing pictures of starving polar bears, new warming records for months and years, more violent rains and floods in some parts of the world and widespread drought in others. All of this has made climate change a very tangible issue. The last report of the Inter-Governmental Panel on Climate Change (IPCC) has made it clear that climate change is man-made and will have serious consequences all over the world, particularly in poor countries.

We will see changes in rainfall patterns and more extreme weather events, melting glaciers and rising seas. The ice is melting much faster than envisaged just a few years ago. On Greenland, the ice is melting even faster than predicted by any of our models. The consequences of climate change involve every nation on earth, every business and every household.

The economics of global warming were turned up-side down by the Stern Report last year, which showed, that the “costs of inaction” would be at least five times higher than the cost of reducing emissions and keep warming at 2°C. The IPCC has estimated that we can keep the rise in average temperature below 2-2.8°C in 2030 at the cost of 0.12% of annual growth in the global economy or 3% of global BNP.

The question is no longer whether we have to act – but how we should act. Not to act is no longer an option. And I was encouraged by the sense of reality shown by the G8-leaders a few weeks ago, when they talked about a 50% cut in global emissions by 2050. It bodes well for the Conference of the Parties to be held in Copenhagen in 2009, where we will work hard to reach a global deal beyond Kyoto.

Climate change is driving the current change in global thinking about the environment. But it is not the only challenge we are faced with. OECD countries have made a lot of progress in the combat against pollution. We have a lot to offer the rest of the world when it comes to reducing pollution of air and water, dealing with solid waste

and hazardous chemicals, and the supply of clean drinking water. And the companies who come first with new solutions will have big advantages.

But we still face our own challenges in these areas and we are not doing much better than the rest of the world when it comes to protecting biodiversity and reducing our use of natural resources. We have improved our resource-efficiency, but not enough to make up for overall economic growth.

Our overriding challenge is to dramatically decouple economic growth from the use of natural resources and degradation of the environment. And, due to globalisation, we have to make a common effort that includes rich and poor countries alike. Worldwide exchange of goods and services means that our daily behaviour has an impact on people and ecosystems far from our borders, and vice versa. Political action at the national level is not enough nor even regional action, such as in the EU, or NAFTA or ASEAN. We need global agreements and long term global goals to guide the action.

Governments cannot do it alone. The private sector must take responsibility as well. I am happy to note that more and more business leaders recognize that they have a responsibility for the health and safety of their employees, (and the employees of their subcontractors) and for the environment both at home and abroad.

Global warming is the clearest example. And it has become something of a “must” for business to demonstrate responsibility for their CO₂ emissions: Airlines are selling CO₂ compensation, oil companies are going into renewable energy, the construction industry is moving towards low energy houses and car manufacturers are marketing more environmentally friendly cars. Those who are not taking climate change into consideration will be out of business in the long run.

For example, the American supermarket chain Wal-Mart – one of the world’s largest companies – has formulated a vision for itself: no waste, almost CO₂ neutral, and 100% driven by windmills and solar energy. Wal-Mart’s CO₂ emissions are about one third of Denmark’s, and when including suppliers, almost three times larger than that of Denmark’s. When a company like that takes action, it can really make a difference. And Wal-Mart expects it to be good business, of course.

Large Danish companies are also directing their business strategy towards the environmental challenges. Novo Nordic – one of the world’s largest producers of diabetes care products – recently made a partnership with the biggest Danish energy supplier DONG Energy. DONG will help Novo Nordic reach its ambitious CO₂ reduction target. Novo Nordic will buy “green energy” from DONG Energy and in this way contribute to the build-up of Danish wind energy.

Another Danish example is Danfoss, – a large company that sells thermostats all over the world. It has redefined itself as a “cleantech” company – working to help its customers save electricity and, at the same time, develop new CO₂ reducing technologies. And the Director of Danfoss recently convened a meeting for world business leaders in Copenhagen in order to establish a “Copenhagen Climate Council.” The idea is to formulate a charter on climate friendly business and help gain support for a global climate agreement in Copenhagen in 2009.

There are many more examples of environmental improvement and good business going hand in hand. We no longer look at environmental protection as an expenditure that damages the competitiveness of companies and countries. Customers, employees, financiers and society at large expect companies to act responsibly and to do their part.

Economic growth is not possible without taking care of the environment – environmental protection is not a luxury. And there is a large and growing market for eco-efficient technologies. The world market for these environmental technologies was estimated at €1 000 billion in 2005 and is expected to grow by 50% to about €1 500 billion in 2010.

Business has a crucial role in developing new, environmentally effective technologies and bringing them to the marketplace. In the European Union, governments are supporting their efforts in terms of financing research and development and other forms of co-operation. In Denmark, we have made an action plan in order to assist our firms in delivering solutions to worldwide problems in which Danish research and business has a cutting edge.

Partnerships between the public and private sector – including companies, research institutions, venture capital and authorities – seem to me a very promising way of making environmental progress and strengthening our competitiveness. We have established such partnerships in several areas – water technology and windmills for example – and it seems that former competitors are now willing to co-operate on new solutions. There are substantial benefits from taking environmental sustainability systematically into production strategies.

Chapter 2. Sustainable Production as Industrial Policy

Finn Lauritzen, Director General, Danish Enterprise and Construction Authority

The fact that this workshop on sustainable production has attracted participants from nineteen different countries and three continents underlines the importance of the workshop topic. It is no coincidence that the workshop is hosted here at the Danish Enterprise and Construction Authority (DECA), which is a central part of the Danish Ministry of Economics and Business Affairs. We are in charge of both administering and developing a modern industrial policy for Denmark.

Only one or two decades ago, industrial policy was very much about protecting, nursing and often even aiding domestic enterprises. Today, industrial policy is completely different. We no longer see foreign competition and globalization as a threat. To us, competition not protection promotes competitiveness and long term prosperity. And we use different tools today such as private-public partnerships, knowledge diffusion, prudent regulations and establishing design and innovation infrastructures.

Similarly, when we talk about environmental issues, sustainability and competitiveness are no longer seen as opposing objectives. They can be reconciled, if not united. One of the key issues for us all is to make sure that this happens. There are many obvious reasons why sustainable production is becoming increasingly important.

- First of all, the global population continues to grow. In 1802, we were one billion. In 1987, we were five billion. In 2050, the UN expects us (or our children) to be nine billion people.
- Secondly, and luckily, we are getting richer. Income per capita grows, which of course must be welcomed, not least in developing countries. This will increase total energy demand; demand for other depletable, limited and non-renewable resources; and other environmental costs, *e.g.* those connected to waste handling or dealing with traffic jams. Sustainability is not only about energy and CO₂ emissions, although global warming and energy sustainability is at the core of our environmental problems. The growing demand will lead to higher prices and will thus make it more attractive to develop energy and resource efficient ways of producing goods and services. We can already see how rising oil prices have led to increased focus on renewable energy sources and more energy efficient vehicles.
- Thirdly we can see the rise of the political consumer who is starting to make new demands on companies. For a growing proportion of consumers, it is no longer enough that products are of high quality and have the right price. They must also be sustainable.

An increasing number of companies are responding to the demands of the political consumers. Starbucks is selling Max Havelar certified sustainable coffee. Richard Branson (Virgin) has announced that he wants to invest heavily in sustainable enterprises and products. Many more companies are taking similar initiatives.

One of the fascinating things about sustainability is the fact that more often than not the focus on sustainable production turns out not to be a burden but rather a new business opportunity. Increased focus on resource efficiency often leads to big savings and thus a better bottom line. Let me give you an example.

When Texas Instruments in 2005 was building a new processor factory in Texas, they decided to focus on energy efficiency. They thus managed to reduce the factory's energy consumption by 80% compared to an ordinary factory. In addition, they managed to save 30% of the building costs because the use of reflecting roofs reduced the need for air conditioning.

The focus on sustainability also makes new business models possible. At the moment, we are seeing the rise of a number of energy service companies that help other companies or public institutions become more energy efficient. And they do it for free. They just insist on getting a proportion of the energy savings. And I am sure that innovative entrepreneurs and companies will find many more ways of making money on being sustainable.

The fact that an increasing number of consumers are willing to pay more for products and services that are sustainable implies that sustainability can be a unique selling proposition. This is for instance seen in Denmark in recent years where the demand for organic products has exploded. Last year, demand for organic products grew by 20%, which now make up 6.5% of all food sold in Denmark.

But we shouldn't overlook the fact that higher sustainability standards can lead to higher costs at least in the short term. This is a challenge that policy makers should bear in mind. Especially when we deal with developing countries with growing populations that are demanding a higher quality of life in terms of economic prosperity.

I am an optimist. I believe that it is possible to have economic growth and sustainable development at the same time. But we should not be naïve. It is not something that will happen by itself. Policy makers, businesses and citizens need to act. It is also clear to me that sustainable production is a global challenge and that the developed world has a special responsibility. I therefore think the OECD is just the right forum to take some steps forward and I hope this workshop and the OECD project on sustainable production and manufacturing can help take some of these steps.

As we speak, we have many more questions than answers. We only know how little we know, to cite a Greek philosopher.

- First of all, I think we have to develop a more common definition of what we really mean by "sustainability".
- Secondly, we should discuss which means and methods of legislation and regulation should be used in order to improve environmental standards without undue economic costs. How do we give enterprises the best incentives to invest in new production methods? What are best "policy practices"? Here, the OECD has a natural role to play.

- Thirdly, what can enterprises do if they want to be above what is necessary to comply with legislation and want to use sustainability in their marketing and branding efforts? This is very important, as we cannot expect governments to do the whole job. I think there is a market for living up to the requirements of the political consumer.

An international framework will make it clearer for businesses which political demands they have to fulfill. What businesses fear most is not strict environmental standards. It is uncertainty about what standards they will need to live up to.

It can be a daunting task as a consumer to decide what a sustainable product is and there are unfortunate examples where a supposed sustainable company has turned out not to be sustainable when the veils of marketing are removed. International standards will help to make life easier for consumers and give them the tools to decide what products – and thus what companies – they will support through their purchases. If this workshop can give us only a little more insight into some of these questions, it will be very productive.

Part II. Workshop Presentations

Chapter 3. Developing Indicators of Energy Efficiency

Cecilia Tam, International Energy Agency (IEA)

Introduction

The leaders of the Group of Eight (G8) countries and the governments of International Energy Agency (IEA) Member countries have asked the IEA to contribute to the Dialogue on Climate Change, Clean Energy and Sustainable Development. The aims of the G8 Dialogue and Plan of Action are to:

- 1) Promote innovation, energy efficiency, conservation, improve policy, regulatory and financing frameworks, and accelerate deployment of cleaner technologies, particularly lower-emitting technologies.
- 2) Work with developing countries to enhance private investment and transfer of technologies, taking into account their own energy needs and priorities.
- 3) Raise awareness of climate change and our other multiple challenges, and the means of dealing with them; and make available the information which business and consumers need to make better use of energy and reduce emissions (G8, 2005).

As part of the G8 Plan of Action in the industry sector, the IEA was asked to “...develop its work to assess efficiency performance and seek to identify areas where further analysis of energy efficiency measures by the industry sector could add value, across developed and interested developing countries”. After consultation with IEA delegations and incorporating views expressed by its Member countries, the IEA Secretariat has extended the scope of its G8 work from energy efficiency to also include CO₂ emissions reduction (IEA, 2005).

The IEA’s work on industry is organized into three parts:

- 1) An analysis of current energy efficiencies and related CO₂ emissions worldwide.
- 2) An analysis of energy efficiency and CO₂ emission reduction potentials from technology options.
- 3) Identification of policies that can result in an uptake of these options.

Scope of indicator analysis

This analysis focuses on indicators for industrial energy efficiency and CO₂ emissions and is a contribution to part one. Historic trends and current efficiencies are considered. It does not consider the impacts of emerging technologies or future energy use and CO₂

emissions. Estimates of improvement potentials are assessed based on indicators for energy efficiency at a country level in key manufacturing industry sub-sectors.

The present study has benefited from the input of a large number of experts from industry, research institutes and academia. Their contributions have been documented in workshop presentations and proceedings. These include Ammonia, Cement (IEA/WBCSD, 2006a), Chemicals and Petrochemicals (IEA/CEFIC, 2007), Iron and Steel, Pulp and Paper (IEA/WBCSD, 2006b) and Motor Systems (IEA, 2006b).

In order to develop useful indicators for industrial energy use and CO₂ emissions, a sound understanding of how energy is used by industry is needed. This study provides an overview of global industry energy use; a discussion of indicator methodology issues; energy use and CO₂ emissions in the chemical and petrochemical, iron and steel, non-metallic minerals, pulp and paper and non ferrous metals industries and assesses key systems such as motors and recycling. Key energy consuming industries are concentrated in a few countries. Current and future data collection should be concentrated in these countries.

Apart from increased data collection for energy use in industry, this study aims to establish relevant and valid indicators that permit analysis of the main trends on a country level by looking at the technology mix within an industry and that allow a credible comparison of efficiency data on a subsector level between countries. Indicators refer to the average efficiency of a sub-sector or process operation on a country level. Benchmarking implies the comparison of the energy efficiency and CO₂ emissions of individual installations based on a point reference, often “best available technology” (BAT). The term “best available technology” is taken to mean the latest stage of development (state-of-the-art) of processes, facilities or methods of operation which include considerations regarding the practical suitability of a particular measure to enhance energy efficiency. However, data for individual facilities are often confidential because of anti-trust regulations or other concerns. Moreover, data collection is resource and time consuming.

Prior IEA analysis focused on industrial energy use per unit of value added (IEA, 2004). This work is being updated and a publication (Energy Use in the New Millennium) is planned for September 2007. The analysis here takes a different approach to examine energy use per unit of physical production, *e.g.* energy use per tonne of product.

As a next step, the physical indicators analysis will be merged into the general set of IEA indicators. Work on physical energy intensity indicators is not new. A significant body of literature exists and this analysis builds on it. This study uses data from open literature, industry sources and analyses based on IEA statistics.

An important finding is that energy use in industry is different from other sectors since industrial processes and technologies are not very dependent on the climate, geography, consumer behaviour and income levels. This facilitates a comparison across countries. At the same time, certain factors such as resource availability, resource quality, production scale and age of the capital equipment stock can explain differences in energy efficiency. Such factors are usually not governed by economics and should therefore be taken into account when the improvement potential is assessed.

This study sets out a new set of indicators for country level efficiency analysis that balance methodological rigour with data availability. Discussions with industry experts regarding the best approach are underway, and therefore the indicators should be

considered as a “work in progress”. The indicators need to be validated and their utility needs to be assessed.

Given the preliminary character of these energy indicators, the country comparisons may be of secondary importance. More refined analysis may lead to different country rankings in the future. An important finding in this study is that the need for data detail and the availability of data should be balanced with the new indicators developed. The authors of this study take the view that the methodology should complement available data. If more data were available, different indicators might have been employed. A second important finding is that there is no single “true” indicator for energy efficiency and CO₂ emissions intensity. Different indicators for the same industry may result in a different ranking, but they may provide different insights regarding improvement potentials. Therefore, policy makers should not focus on the country ranking, but rather on the various improvement options that have been identified.

Energy and CO₂ saving potentials

The range of potential savings on a primary energy basis are shown in Table 3.1 as “sectoral improvements”, *e.g.* cement, and as “systems/life cycle improvements”, *e.g.* motors and more recycling. Improvement options in these two categories overlap somewhat. Also system/life cycle options are more uncertain. Therefore, with the exception of motor systems, only 50% of the potential system/life cycle improvements have been credited for the total industrial sector improvement potential shown in Table 1. The conclusion is that manufacturing industry can improve its energy efficiency by an impressive 18 - 26%, while reducing the sector’s CO₂ emissions by 19 - 32%, based on proven technology. Identified improvement options can contribute 7 - 12% reduction in total global energy and process-related CO₂ emissions.

A two-step approach was applied to develop the estimates. First, energy saving potentials were estimated for final energy in industrial sub-sectors and for systems. Next the final energy savings were translated into primary energy equivalents, accounting for losses in power generation and in steam generation. In addition, corrections were applied for chemicals and petrochemicals and for pulp and paper as both industries already have a high share of combined heat and power (CHP). Moreover in both industries, CHP competes with steam saving technologies. Conservatively, CHP was completely excluded for both industry potentials in the primary savings potential (while this is included in the final energy estimates).

Recycling and energy recovery potentials have also been excluded for all industries. This accounts for the fact that the analysis shows that the efficiency of energy recovery from waste varies widely, and recycling energy benefits decrease as the recycling share increases. Also, electricity savings were excluded for chemicals and petrochemicals because they overlap with motor system savings. These corrections result in a conservative estimate of the technical savings potential. A proper detailed analysis that accounts for the interactions of various options will require a model that covers the full energy system (IEA, 2006a).

Some of these savings will occur outside the manufacturing industry sector. For example, CHP will increase the efficiency in power generation. Energy recovery from waste will reduce the need to use fossil energy for power or heat generation. Increased recycling of pulp and paper leaves more wood that can be used for various bioenergy applications. So these figures are not suited to set targets for sectoral energy use.

The CO₂ potentials show a wider range than the energy saving potentials because in many cases it is not clear which type of energy carrier would be saved. Particularly in situations where the savings are in electricity, the assessment is complicated. To deal with this uncertainty, natural gas and coal have been assumed as extremes, which give almost a factor two difference in the carbon intensity of energy. In other cases, an expert estimate of average carbon intensity has been applied that varies by industry, depending on the global average fuel mix. For cement manufacturing, it is assumed that 300 Mt cement clinker (about 15%) can be substituted by slag, fly ash and pozzolans. This contributes to the energy savings and it increases the CO₂ saving potential substantially. For pulp and paper, an option such as increased recycling results in reduced total energy use, but the savings are in bioenergy while additional fossil fuels might be needed. Depending on the alternative use of the saved wood, there may or may not be a carbon saving effect. Similar contentious system boundary issues exist for energy recovery. The CO₂ potential figures are therefore only indicative.

Table 3.1. Savings from Adoption of Best Practice Commercial Technologies in Manufacturing Industries

(Primary Energy Equivalents)					
	Low – High Estimates (Final energy, includes overlap) EJ/yr	Low – High Estimates of Technical Savings Potential (Primary energy, excludes overlap) EJ/yr Mtoe/yr Mt CO ₂ /yr			Total Energy & Feedstock Savings Potentials %
<i>Sectoral Improvements</i>					
Chemicals/petrochemicals	4.0 – 11.0	5.0 – 6.5	120 – 155	370 – 470	13 – 16
Iron and Steel	2.0 – 4.0	2.3 – 4.5	55 – 108	220 – 360	9 – 18
Cement	2.2 – 2.7	2.5 – 3.0	60 – 72	480 – 520	28 – 33
Pulp and paper	1.0 – 2.4	1.3 – 1.5	31 – 36	52 – 105	15 – 18
Aluminium	0.1 – 0.6	0.3 – 0.4	7 – 10	20 – 30	6 – 8
Other non-metallic minerals and non-ferrous metals	0.4 – 0.8	0.5 – 1.0	12 – 24	40 – 70	13 – 25
<i>System/life cycle Improvements</i>					
Motor systems	2.6	6 – 8	143 – 191	340 – 750	
Combined Heat and Power	4.5	2 – 3	48 – 72	110 – 170	
Steam systems	3.3	1.5 – 2.5	36 – 60	110 – 180	
Process integration	2 – 5	1 – 2.5	24 – 60	70 – 180	
Increased recycling	3 – 4.5	1.5 – 2.5	36 – 60	80 – 210	
Energy recovery	3 – 4.5	1.5 – 2.3	36 – 55	80 – 190	
<i>Total</i>		25 – 37	600 – 900	1 900 – 3 200	
Global improvement potential - share of industrial energy use and CO ₂ emissions		18 – 26%	18 – 26%	19 – 32%	
Global improvement potential - share of total energy use and CO ₂ emissions		5.4 – 8.0%	5.4 – 8.0%	7.4 – 12.4%	

Note: Data are compared to reference year 2004. Only 50% of the estimated potential system/life cycle improvements have been credited except for motor systems. The global improvement potential includes only energy and process CO₂ emissions; deforestation is excluded from total CO₂ emissions. Sectoral final savings high estimates include recycling. Sectoral primary savings exclude recycling and energy recovery. Primary energy columns exclude CHP and electricity savings for chemicals and petrochemicals. Primary energy columns exclude CHP for pulp and paper.

The single most important category is motor systems, followed by chemicals and petrochemicals on an energy savings basis. The highest range of potential savings for CO₂ emissions is in cement manufacturing. The savings potential under the heading system/life cycle improvements is larger than the individual sub-sectors in part because those options apply to all industries. Another reason is that these options have so far received less attention than the process improvements in the energy intensive industries.

These potentials are based on a comparison of best country averages with world averages, or best practice and world averages. They do not consider new technologies that are not yet widely applied. Also they do not consider options such as CO₂ capture and storage and large-scale fuel switching. Therefore, these should be considered lower range estimates of the technical potential for energy savings and CO₂ emissions reductions in the manufacturing industry sector.

These potentials do not consider the age profile of the capital stock, nor regional differences in energy prices and regulations that may limit the short- and medium-term improvement potentials. Further, this study does not consider process economics explicitly in the assessment of improvement potentials. So the economic potential will be substantially lower than these technical potentials. However, changing market conditions and values for CO₂ can affect the process economics significantly.

Therefore the technical potential is an important indicator. The fact that a certain process is economic in parts of the world is taken as an indication that the process can be economic in real world conditions. However, this does not mean that a major energy efficiency improvement of a certain industry sector is economic worldwide in the near or long term. Such analysis would require assumptions regarding future energy prices and CO₂ policy regimes, which is beyond the scope of this analysis.

Also the role of technology and resource quality as a key explanatory factor is acknowledged. The technology mix often provides important insights regarding industrial energy use, as a certain technology implies a certain level of energy efficiency. Therefore, it is proposed to use the technology mix as an additional indicator for the energy efficiency level in cases where the actual energy use data are not available. Moreover, efficiency estimates based on technology can serve as a valuable crosscheck for indicators based on energy statistics. In a number of cases this cross-check has resulted in the discovery of discrepancies in the energy statistics.

This study does not consider the introduction of new technologies that are still in the research and development (R&D) or demonstration stage. As these options have been excluded, the results underestimate the long-term efficiency potentials. The analysis allows the identification of best practice on a technical level and the gap between country averages and best practice. Note that best practice reflects not only the level of technology but also the energy economics of a country. In a country where energy is expensive, energy efficiency will generally be higher. This study does not discuss the economics and past sector developments that may explain the observed differences in energy efficiency. International competitiveness issues are not considered in this analysis.

In certain areas this study found that the data that countries submit to the IEA do not correspond to those contained in national statistics, or they do not correspond with industry statistics. In some cases the energy intensity per unit of physical product data are evidently in error, *e.g.* below the theoretical minimum. The fact that such statistical problems have been identified shows the usefulness of physical indicators compared with value-added based indicators.

Next steps

Modelling and scenario development plays an important role in the industry analysis. As a first response to the G8 request, the IEA has developed new scenarios that analyse impacts of technology related policies in the period to 2050 (IEA, 2006a). It concluded that substantial global energy efficiency potentials remain based on current technology and different operational techniques.

The new sets of indicators presented in this study are to provide a basis for discussion for development of meaningful indicators of energy efficiency and CO₂ emissions in the industrial sector. They can be useful for industries, governments and others for better forecasting of industrial energy use; provide a realistic basis for target setting and effective regulation and serve to identify sectors and regions for more focused analysis of improvement potentials. This study shows that the methodology can be improved and that better data is needed. Suggested next steps in this direction are:

- IEA energy data should be validated for industrial sub-sectors and countries. In particular, data for developing countries and transition economies need improvement.
- The IEA statistics category “other industries” needs to be refined for meaningful indicators in co-operation with the national statistical bureaus and industry.
- The treatment of combined heat and power (CHP) in IEA statistics needs to be complemented with better data on current CHP capacity, use and generation, as well as through improved presentation of CHP in energy balances and statistics.
- Currently the IEA collects only data of economic activity in monetary terms. Industrial physical production data should be collected by the IEA on a regular basis, notably for energy-intensive commodities. Physical production data already are collected on an annual basis by other government and industry bodies. Therefore, it is a matter of improving and institutionalising the existing co-operation and exchanges.
- More detailed data for industry are needed than those available from IEA statistics. A comprehensive framework should be developed including indicators, benchmarking, capital stock age data at a plant level and in certain cases on a process level. Part of these data need to be treated confidentially, but country level data should be public.
- Various international data collection and analysis activities should be closely co-ordinated and be further developed into a system that allows periodic data collection.
- An independent non-commercial trusted party should be appointed to oversee the data collection and analysis. This could be done on a sub-sector basis.
- Data regarding the technical characteristics of the industrial capital stock should be collected on a regular basis.
- This work should be done in close collaboration with industry federations.

Manufacturing industry energy use and CO₂ emissions

Total global primary energy supply was about 469 exajoules (EJ) (11 213 Mtoe) in 2004. Industry accounts for nearly one-third of this energy use at more than 147 EJ (3 510 Mtoe) including conversion losses from electricity and heat supply.

Total final energy use by industry was 113 EJ in 2004 (Table 3.2). The data include oil feedstocks for the production of synthetic organic products. Industry also uses substantial amounts of wood as feedstock for the production of pulp and structural wood products. Approximately 1 000 million tonnes (Mt) of wood feedstock used by industry, equivalent to 16 - 18 EJ of biomass, is not accounted for in these figures. The use of about 10 Mt of natural rubber is also not included, this is equivalent to 0.3 EJ per year. If these quantities were considered, the total energy demand in the industry sector would increase further. The totals in Table 3.2 exclude energy use for the transportation of raw materials and finished industrial products, which is important.

Table 3.2. Industrial Final Energy Use, 2004

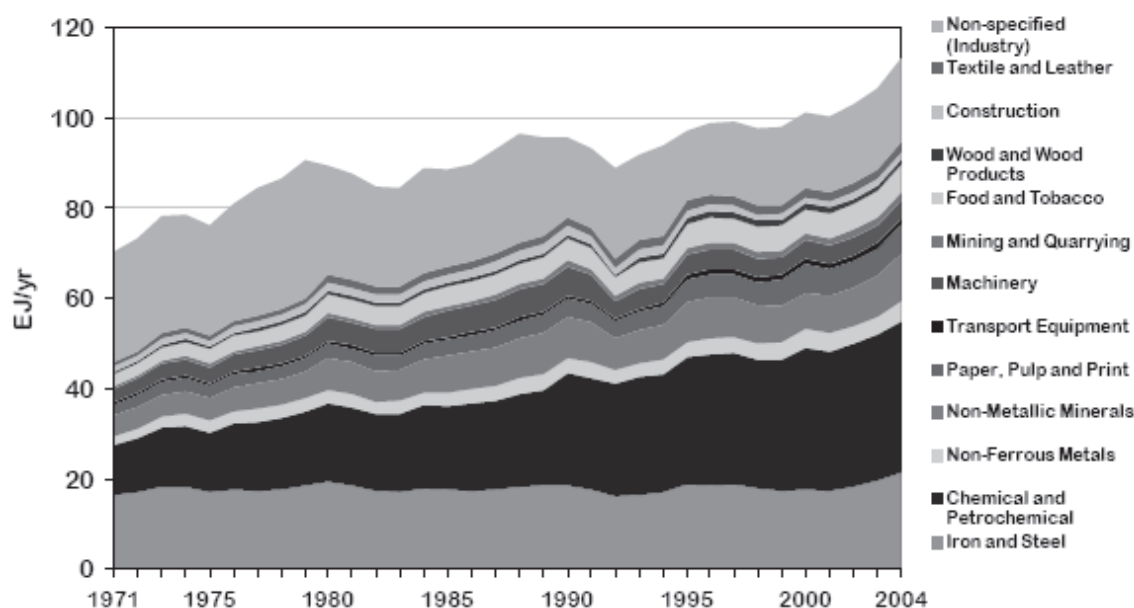
	AFR	AUS	CAN	CEU	CHI	CSA	FSU	IND	JPN	KOR	MEA	MEX	ODA	US	WEU	World
Chemical and Petrochemical	0.47	0.21	0.85	0.64	4.53	1.43	2.42	1.09	2.35	1.50	2.50	0.48	2.06	7.65	5.45	33.62
Iron and Steel	0.39	0.19	0.23	0.62	7.11	1.24	3.11	1.04	1.89	0.72	0.06	0.23	0.42	1.46	2.74	21.44
Non-Metallic Minerals	0.08	0.09	0.04	0.23	4.53	0.40	0.62	0.42	0.31	0.24	0.02	0.06	0.80	1.07	1.70	10.61
Paper, Pulp and Print	0.01	0.06	0.72	0.11	0.66	0.40	0.03	0.11	0.37	0.09	0.00	0.04	0.09	2.24	1.52	6.45
Food and Tobacco	0.02	-	-	0.17	0.77	0.86	0.43	0.34	0.18	0.07	0.01	0.10	0.36	1.24	1.30	5.98
Non-Ferrous Metals	0.11	0.35	0.24	0.09	0.93	0.38	0.86	0.03	0.08	0.01	0.03	0.00	0.00	0.52	0.57	4.21
Machinery	0.00	-	-	0.08	1.11	0.01	0.66	0.02	0.36	0.15	0.00	0.00	0.17	0.85	0.82	4.25
Textile and Leather	0.01	-	-	0.04	0.91	0.07	0.08	-	-	0.15	0.00	0.00	0.19	0.26	0.40	2.17
Mining and Quarrying	0.20	0.12	0.43	0.03	0.35	0.12	0.12	0.04	0.03	0.01	0.01	0.07	0.06	0.09	0.13	1.81
Construction	0.08	0.03	0.06	0.04	0.39	0.01	-	-	0.15	0.02	0.00	0.01	0.03	0.08	0.35	1.41
Wood and Wood Products	0.00	0.05	0.02	0.05	0.13	0.00	-	-	-	0.01	-	-	0.01	0.48	0.23	1.36
Transport Equipment	0.00	-	-	0.03	0.34	0.00	-	-	-	0.10	0.00	0.01	0.01	0.40	0.37	1.28
Non-specified	2.35	0.05	0.47	0.19	0.72	1.62	1.34	1.94	0.95	0.12	2.43	0.48	3.27	1.09	1.62	18.65
Total	3.72	1.33	3.06	2.31	22.48	6.56	10.22	5.08	6.66	3.18	5.06	1.48	7.48	17.43	17.20	113.25

Note: Includes coke ovens and blast furnaces. Sub-sector values in excess of 1 EJ/yr are marked in bold. CSA – Central and South America; CEU – Central and Eastern Europe; FSU – Former Soviet Union; MEA – Middle East; ODA – other developing Asia; WEU – Western Europe.

Most industrial energy use is for raw materials production. The sub-sectors covered in this study are the main manufacturing industries: chemical and petrochemicals, iron and steel, non-metallic minerals, paper and pulp, and non-ferrous metals. Together, these industries consumed 76 EJ of final energy in 2004 (67% of total final industrial energy use). The chemical and petrochemical industry alone accounts for 30% of industrial energy use, followed by the iron and steel industry with 19%. The food, tobacco and machinery industries, along with a large category of non-specified industrial uses, account for the remaining 33% of total final industrial energy. However, some of the energy that is reported under non-specified industrial users is in fact used for raw materials production, which increases its share above two-thirds of total industrial final energy use.

Industrial energy intensity (energy use per unit of industrial output) has declined substantially over the last three decades across all manufacturing sub-sectors and all regions. In absolute terms, however, energy use and CO₂ emissions have increased worldwide. Industrial final energy use increased 61% between 1971 and 2004, an average annual growth of 2% (Figure 3.1). But the growth rates are not uniform. For example, in the chemical and petrochemical sub-sector, which is the largest industrial energy consumer, energy and feedstock use has doubled while energy use for iron and steel production has been relatively flat, despite strong growth in global production.

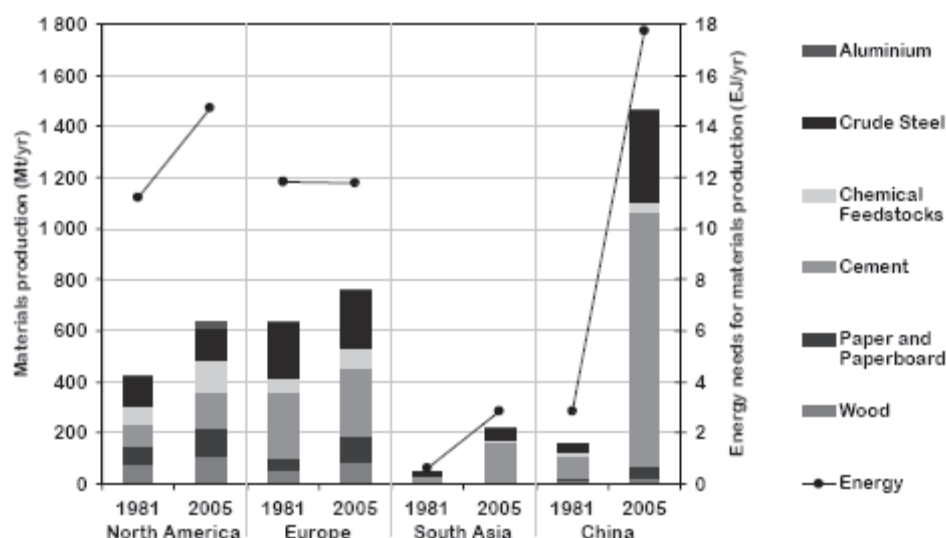
Figure 3.1. Global Industrial Energy Use, 1971 – 2004



Note: The discontinuity around 1990 is caused by developments in Eastern Europe and the FSU that resulted in a rapid decline in industrial production.

Key point: Industrial final energy use increased by 61% between 1971 and 2004, an average annual growth of 2%.

China accounts for about 80% of the growth in industrial production during the past 25 years, and for a similar share in industrial energy demand growth for materials production, about 16 EJ (Figure 3.2). Today, China is the largest producer of commodities such as ammonia, cement, iron and steel and others. The energy efficiency of production in China is generally lower than in OECD countries and it is largely coal-based.

Figure 3.2. Materials Production Energy Needs, 1981 – 2005

Note: North America includes Canada, Mexico and US. Europe includes EU27 excluding three Baltic States, and including Albania, Bosnia, Croatia, Iceland, Former Yugoslav Republic of Macedonia, Norway, Serbia, Switzerland and Turkey.

Key point: China accounts for the bulk of energy demand growth for manufacturing in the past twenty-five years.

The United States, Western Europe and China together account for half of total global industrial energy use, followed by the Former Soviet Union and Japan. An analysis of current energy use therefore must concentrate on these regions.

No detailed statistics are available that allocate industrial energy use for the various steps in manufacturing. Rough estimates suggest that 15% of total energy demand in industry is for feedstock, 20% for process energy at temperatures above 400°C, 15% for motor drive systems, 15% for steam at 100 - 400°C, 15% for low-temperature heat and 20% for other uses, such as lighting and transport. Detailed information on energy and materials flows and on process activities are not readily available. In many cases these data are regarded as confidential. Better data are needed on the spread in energy efficiencies and on the age and size of production equipment in all regions. The IEA Secretariat plans to commence new data collection activities in the framework of the G8 Dialogue on Climate Change, Clean Energy and Sustainable Development. This study uses data from open literature, industry sources and analyses based on IEA energy statistics.

The share of industrial energy used for basic materials production has been quite stable for the last thirty years, but the shares of sub-sectors have changed significantly. The share of crude steel production, for example, has declined from 24 - 19% since 1971, while the share of ammonia, ethylene, propylene and aromatics has increased from 6 - 15% (IEA, 2006).

Table 3.3 shows a global breakdown of industrial energy use by fuel and energy carrier. The amounts of coal, gas, oil and electricity used are similar. Combustible renewables and waste is lower and is largely biomass use in the pulp and paper industry.

Table 3.3. Final Energy Use by Energy Carrier, 2004

	EJ/yr	Gt CO ₂ /yr
Coal & coal products	28.9	2.72
Natural gas	23.6	1.32
Oil & oil products	28.0	0.73
Combustible renewables & waste	7.0	
Electricity	21.5	3.59
Heat	4.2	0.29
Other	0.0	
Process emissions		1.08
Total	113.3	9.73

In many sectors of the economy, CO₂ emissions are closely related to energy use. However, in the industry sector the distribution of CO₂ emissions is very different from the distribution of energy demand. The main reasons are:

- Large amounts of fossil carbon are stored in petrochemical products.
- CO₂ emissions unrelated to energy use are large in some sectors, especially in cement production.
- CO₂ emissions differ by fuel, and the use of fuels is not evenly distributed across industrial sub-sectors.

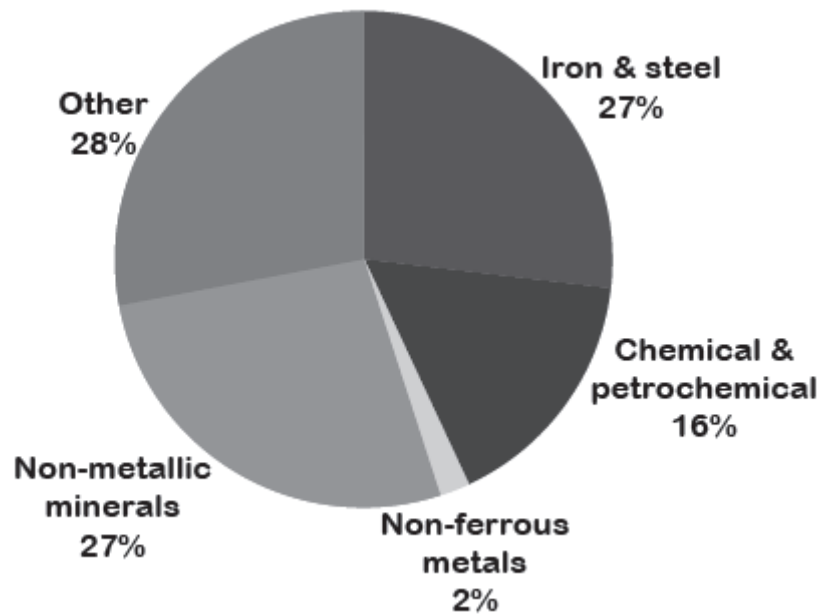
Total CO₂ emissions from industry were 9.7 gigatonnes (Gt) in 2004 and accounted for 36% of total global CO₂ emissions (this includes coke ovens and blast furnaces that are reported as part of the transformation sector in IEA statistics). It also includes CO₂ emissions from power generation and process emissions. Three sub-sectors were responsible for 70% of the direct industrial CO₂ emissions: iron and steel, non-metallic minerals, and chemicals and petrochemicals (Figure 3.3). These data exclude upstream CO₂ emissions from the production of electricity and downstream emissions from the waste treatment of synthetic organic products.

It should be noted that energy use and CO₂ emissions related to power generation are allocated to the electricity sector in IEA statistics. In the case of industrial combined heat and power (CHP) plants, all fuel use and CO₂ emissions are allocated to the transformation sector, except for fuel use and emissions related to heat generation that is not sold, which are allocated to industrial energy use. As a consequence, sub-sector energy use and emission data based on company emission data may differ from the figures in the IEA statistics.

Another special factor is blast furnace gas that is delivered by the iron and steel industry to power generators or that is used on-site in CHP plants. The specific CO₂ emission factor for blast furnace gas is very high, as this gas already contains substantial amounts of CO₂ originating from coal gasification and coal gas use in the blast furnace. Typically, 4.8 gigajoules (GJ) of blast furnace gas is generated per tonne of hot metal. The carbon content of this gas is equivalent to 0.8 Gt CO₂ emissions worldwide. About 25% of the energy content of this gas was used for power generation in 2004; the remainder was used within the iron and steel industry. Depending on the allocation approach, between 0 and 0.2 Gt of CO₂ should be allocated to power generation.

Figure 3.3 allocates 60% of the CO₂ emissions from blast furnace gas use to the iron and steel industry.

Figure 3.3. Industrial Direct CO₂ Emissions by Sector, 2004



Note: includes coke ovens, blast furnaces and process CO₂ emissions

Key point: Three sectors: iron and steel, non-metallic minerals, and chemicals, and petrochemicals account for 70% of industrial CO₂ emissions.

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Chapter 4. Measuring Social Dimensions of Sustainable Production

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Introduction

Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (UN, 1987). It is built on the integration of three underlying pillars – economic, environmental and social. However, sustainable development has not become truly operational owing to difficulties in fully incorporating the social dimension. This includes considerations such as human rights, education and health, and gender diversity in economic planning and policies. On the other hand, environmental economics has made great progress in integrating the economic and environmental spheres.

With regard to sustainable manufacturing production, advancing on sustainability concerns fuller attention to the role of the workforce in helping attain the triple bottom line – maximising profits, people and the planet. The workforce requires adequate incomes, training and social protection, among other factors. These ingredients will contribute to the sustainability and competitiveness of manufacturing enterprises. It is the role of trade unions and their international bodies to promote and ensure the welfare of the manufacturing workforce and their full contributions to sustainable production in both environmental and economic terms.

Measuring the social pillar

The new science of sustainability has developed a large variety of indicators. Measuring sustainable development is a preoccupation of most governments, who are developing lists of sustainability indicators in the economic, environmental and social spheres. International organisations, including the OECD, the United Nations and Eurostat, are comparing national lists and attempting to formulate shorter, more comparable measurement approaches across countries (OECD, 2005).

The social dimension is not only the most difficult to integrate, but also the hardest to measure. The standard social measures at the national level are those enumerated by the United Nations (Table 4.1). In the context of the “capital” approach to sustainability measurement, attempts are being made to develop more robust measures of “human capital” based on variables such as education and health. Even more difficult is quantifying the concept of “social capital” which refers to society’s trust in institutions and corporations as well as the extent of social services and crime. Recent efforts are

directed to measuring “happiness” which encompasses various aspects of well-being, including education outcomes, child welfare, health status, avoidance of crime and more subjective measures of personal happiness.

Table 4.1. United Nations Sustainability Indicators

Environmental indicators	Social indicators
Greenhouse gas	Poverty
Ozone layer	Gender equality
Air quality	Nutrition
De-forestation	Child mortality
Desertification	Sanitation
Agriculture	Health
Bio-diversity	Education
Toxic chemicals	Housing
Non-renewable material	Crime
Hazardous waste	Population
Waste volume	Employment
Water	

Source: United Nations Division for Sustainable Development.

With regard to firms, and particularly manufacturing companies and facilities, reports on the sustainability of their operations rarely include the social dimension. Many companies are issuing corporate reports which stress governance aspects and environmental practices, but tend to overlook the role of the employees or workforce. Yet, studies show that investments in human and social capital can deliver important benefits such as increased firm productivity, more innovation, and reduced costs. At the macro level, this can lead to more investment and higher growth and competitiveness.

This oversight may be due to measurement difficulties. The social aspects of corporate responsibility include difficult-to-measure items such as attention to human rights and gender diversity, respect for collective bargaining, and interactions with local communities. There are a minority of firms, mostly larger multinationals, who are developing metrics for tracking the social performance of their companies, branches and units along these lines. There is a need for more quantitative work in this area to increase the comprehensiveness and reliability of corporate sustainability reporting.

Labour market indicators

The workforce tends to be missing in most configurations of the factors influencing manufacturing production and sustainability. Yet, decent work is at the heart of the social dimension of sustainable development. The right to decent work consists of employment which: 1) is productive and secure; 2) is respectful of labour rights; 3) provides an adequate income; 4) offers social protection; and 5) includes social dialogue and union freedom, collective bargaining and participation.

In measuring the quality and sustainability of the workplace and workforce, the International Labour Organisation (ILO) has enumerated 20 key indicators (Table 4.2) which provide a good basis for assessing the social dimension of sustainable

manufacturing production at country level. However, these need to be modified and applied to company or facility level.

Table 4.2. ILO Key Indicators of the Labour Market (KILM)

KILM 1. Labour force participation rate	KILM 11. Unemployment by educational attainment
KILM 2. Employment-to-population ratio	KILM 12. Time-related underemployment
KILM 3. Status in employment	KILM 13. Inactivity rate
KILM 4. Employment by sector	KILM 14. Educational attainment and illiteracy
KILM 5. Part-time workers	KILM 15. Manufacturing wage indices
KILM 6. Hours of work	KILM 16. Occupational wage and earning indices
KILM 7. Employment in the informal economy	KILM 17. Hourly compensation costs
KILM 8. Unemployment	KILM 18. Labour productivity and unit labour costs
KILM 9. Youth unemployment	KILM 19. Employment elasticities
KILM 10. Long-term unemployment	KILM 20. Poverty, working poverty and income distribution

Source: International Labour Organisation.

Role of trade unions in sustainable development

Trade unions have worked consistently for the past twenty years to bring employment and the world of work into the scope of sustainable development. In the early 1990s, as part of the preparatory process for the 1992 Rio Summit, trade unions and the International Labour Organisation (ILO) helped to draft Chapter 29 of Agenda 21 for “strengthening the role of workers and their trade unions”. Activities to organise workers, defend trade union and human rights, and promote public and occupational health are now part of overall sustainable development efforts. Over 400 trade unionists participated in the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, which resulted in social elements being more fully integrated into concepts of sustainable consumption and production.

Key achievements since 2002 include the establishment of the *Sustainlabour* Foundation and the creation of the Trade Union Sustainable Development Unit. Efforts are focused on strengthening the linkages between occupational and public health, trade union rights and worker participation, livelihood and poverty-employment transitions, and workplace action and worker training. Specific activities are directed to a triangle of clusters: 1) climate change and energy, including green jobs, 2) banning of asbestos and involvement in chemical issues, and 3) addressing HIV/AIDs and public health.

The *Sustainlabour* Foundation, in co-operation with the United Nations Environment Programme (UNEP), organised the first International World Trade Union Assembly on Labour and the Environment in January 2006. Among other things, UNEP, the ILO and the World Health Organisations (WHO) endorsed trade union participation in protecting the environment. The final resolution defined a focus for future co-operation on climate change, chemicals, occupational and public health, corporate social responsibility as well as equity and access issues affecting poverty.

Trade Union sustainability measurement activities

The Trade Union Sustainable Development Unit was launched in July 2006 by the International Confederation of Free Trade Unions (ICFTU), Global Unions Research Network (GURN), and TUAC. Its main function is develop and publish data and indicators by country on a wide range of sustainable development issues, including energy, climate change, and occupational safety and health. In addition to environmental variables, more attention is given in this database to measuring the social dimensions of sustainable development.

The country by country profiles are available on a special website www.tradeunionsdunit.org/profiles whose primary purpose is to provide internationally-linked, country-level information to facilitate trade union campaigns and lobbying efforts. Background information is given for all countries and selected regions, industrial sectors and specific company groupings. Countries are compared on a total of 216 indicators, including:

- 1) human development and sustainability, *e.g.* poverty, health, education and gender;
- 2) record of ratification of core environmental, social and labour standards and instruments;
- 3) qualitative assessment of human and labour rights record;
- 4) government oversight and employer accountability.

In 2004, trade unions at the annual meeting of the UN Commission on Sustainable Development (UNCSD) presented each government delegation with an evaluation profile of their country's performance along selected environmental, social and workplace performance indicators, inviting their feedback on the results of the analysis. The main purpose of the trade union country profiling exercise is to seek government support for engaging workers, trade unions and employers in every country in joint workplace actions for change towards sustainability. Workplace assessments which apply to all production and consumption issues can facilitate change in the work and daily lives of all people.

The Trade Union Sustainable Development Unit also maintains a company database to provide an overview on the worldwide locations of multinational enterprises (MNEs) and current trade union actions related to them. This database also allows the identification of trends in the relationship between framework agreements and corporate social responsibility agreements and environmental, occupational safety and health, and sustainable development provisions.

The company database has data on 550 multinational enterprises according to the following variables:

- 1) global locations;
- 2) sector;
- 3) trade union campaigns at the national, regional or global level;
- 4) presence in Financial Time Global 500, Dow Jones Sustainability Index and first 500 companies of the Forbes 2000;
- 5) involvement in a national contact point (NCP) case related to the OECD Guidelines for Multinational Enterprises;
- 6) participation in sustainability initiatives such as the Global Compact, Global Reporting Initiative, SA8000, and Veritas;
- 7) membership in the World Business Council for Sustainable Development (WBCSD).

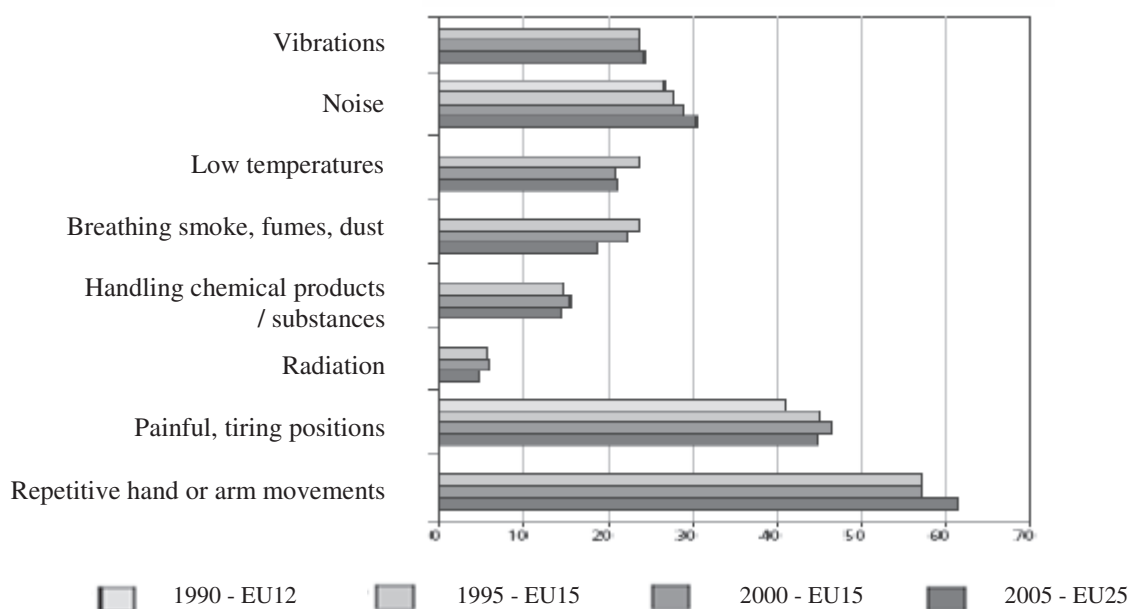
European Working Conditions Observatory

Set up in 2003, the European Working Conditions Observatory (EWCO) provides regular information on the quality of work and employment issues in the European Union (EU) Member States and at EU level. This is done through annual surveys of workers. The Observatory is supported by an extensive network of correspondents covering all EU countries, plus Norway. Four main aspects have been identified to be taken into account:

- 1) *career and employment security* – employment status; earned income; social protection, particularly mechanisms for covering workers that facilitate better career paths throughout working life; workers' rights, particularly with regard to information, consultation and participation; and equal opportunities;
- 2) *health and well-being of workers* – health problems; risk exposure; work organisation;
- 3) *developing skills* – qualifications; training; learning organisation; career development;
- 4) *work-life balance* – double workloads; time management; social infrastructures.

New data from the Fourth European Working Conditions Survey provides a unique insight into the views of around 30 000 workers in 31 countries on a wide range of issues including work organisation, working time, equal opportunities, training, health and safety, and job satisfaction (EWCO, 2005).

Trends for most physical risks have remained within a narrow range across the four surveys since 1990. The proportion of workers exposed to repetitive hand or arm movements at least one quarter of the time has actually increased over the last five years. This is the most commonly cited physical risk, with 62% of the working population reporting exposure (Figure 4.1).

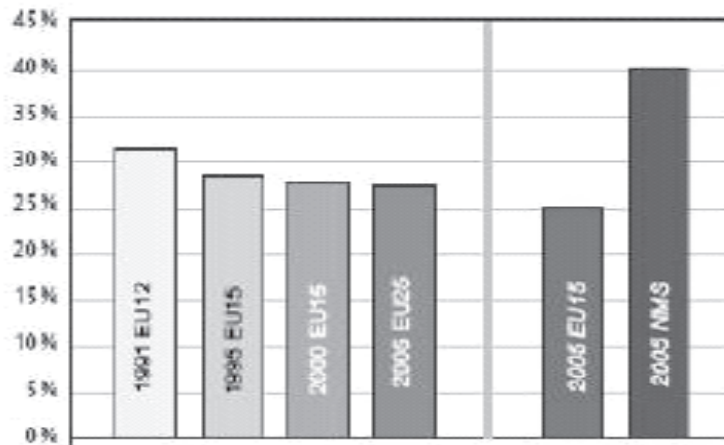
Figure 4.1. Exposure to Physical Risks*, 1990-2005 (%)

Note: No data is available for 1990 for some of the risks, as questions on these were only introduced in later waves of the survey.

Source: European Working Conditions Observatory

With regard to work intensity, an increasing proportion of EU workers report working at a very high speed or to tight deadlines. It is important to note the substantial reduction in the proportion of people reporting never working at very high speed (from 36% to 21%) and never working to tight deadlines (from 31% to 19%).

With regard to health and safety, slightly more than one in four EU workers considers their health and safety to be at risk (Figure 4.2). This proportion has slightly declined over the last 15 years from 31% in 1991 to 27% in 2005. There is a striking difference between the EU15 and the new Member states (NMS): whereas 25% of EU15 workers consider their health and safety at risk because of work, the percentage jumps to 40% in the NMS. But when looking at specific job hazards and risks, the actual exposure to risks seems to have remained relatively stable or even increased slightly, especially in the case of physical strain factors (tiring or painful positions and carrying or moving heavy loads).

Figure 4.2. Perception that Health and Safety is at Risk because of Work

Source: European Working Conditions Observatory

With regard to job satisfaction, in general, European workers report high levels of satisfaction with their working conditions. These levels are similar to those of workers in most other advanced industrial economies. In 2005, more than 80% of EU workers declared being either “satisfied” or “very satisfied” with their working conditions. However, Americans are growing increasingly unhappy with their jobs, according to a February 2007 Conference Board report. The decline in job satisfaction has occurred over a period of two decades, with little to suggest a significant reversal in attitudes anytime soon. Today, less than half of all Americans say they are satisfied with their job; down from 61% twenty years ago. This report is based on a representative sample of 5 000 U.S. households

Supply chain management

Supply chain management is about getting the right things to the right places at the right times, largely for a profit. But the sustainability aspects and particularly the social dimensions of global supply chains are being largely neglected. The supply chain is made up of many interrelated firms: parts suppliers, component suppliers and subassembly suppliers, largely sending components to larger multinationals. Logistics costs have trended downward, *e.g.* in the United States, from about 16% of GDP in 1981 to around 8.5% today. Transportation costs have declined by nearly 25%, whereas inventory carrying costs have declined by more than 65%.

Questions for the research and policy agenda include addressing the social dimension of global production networks. There has been limited analysis of how global production networks are impacting on work, the quantity and quality of employment as well as sustainability. For example:

- 1) *How does the structure of these production systems affect employment, income and conditions of work across the global value chain? What are the implications for policies?*

- 2) *What is the social impact of business process services off shoring?*
- 3) *Are governments engaging in policy competition to attract investors and what is the nature of the regulatory discounts that are being offered?*
- 4) *What opportunities are there to promote international decent work in these global production systems?*
- 5) *What are the roles of employers and companies?*
- 6) *Do larger companies set sustainability standards for their suppliers?*

Conclusions

According to the Brundtland Report, the pursuit of sustainable development requires: 1) a political system that secures effective citizen participation in decision making; 2) an economic system that is able to generate surpluses and technical knowledge on a self-reliant and sustained basis, 3) a social system that provides for solutions for the tensions arising from disharmonious development; 4) a production system that respects the obligation to preserve the ecological base for development, 5) a technological system that can search continuously for new solutions; 6) an international system that fosters sustainable patterns of trade and finance, and 7) an administrative system that is flexible and has the capacity for self-correction (WCED, 1987).

This prescription from “Our Common Future” emphasises the interlinkages between the economic, environmental and social dimensions for achieving sustainable development. Measurement issues and the development of sustainable development indicators are critical for setting targets and monitoring progress. A variety of efforts are being made by governments, international organisations, business and also trade unions to develop sustainability indicator sets. These apply at different levels – countries, regions, localities, sectors, firms and workplaces.

So far, the weakest link tends to be measuring the social aspects at all these levels. From the trade union point of view, the social pillar is the most crucial and its composition and contributions need to be better defined and measured at both country level and company level. With regard to the workforce, workplace assessments based on solid criteria are key. This is a process whereby trade unions and employers together assess workplace performance according to agreed checklists of environmental, resource, occupational and social criteria.

The results of this assessment can lead to joint plans of action to identify and resolve problems ranging from the simple (*e.g.* workplace water, energy and resource use and wastes) to the complex (*e.g.* improving workplace conditions, employment issues or matters related to social security, public health or technology matters). Such environmental and social assessments involving employers and employees can promote sustainability at both the macro and firm levels.

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Chapter 5. Measuring Ecological Footprints

Mathis Wackernagel, Global Footprint Network

Introduction

Sustainability in the environmental sense is a simple idea. It is based on the recognition that when resources are consumed faster than they are produced or renewed, the resource is depleted and eventually used up. In a sustainable world, society's demand on nature does not exceed nature's capacity to meet that demand. But how much of nature's capacity is now being used by human activities? This is the underlying research question behind the Ecological Footprint. This resource accounting tool allows us to measure the demand placed on nature by individuals, cities, countries, business activities, etc. It is increasingly being used by firms in manufacturing and other sectors to understand the context of a resource-constrained world, and its implications for its operations, both in terms of risks and opportunities.

Ecological footprint

The Ecological Footprint is a resource management tool that measures how much land and water area a human population requires to produce the resources it consumes and to absorb its wastes under prevailing technology. The Footprint calculates the biologically productive land and water an entity (an individual, a city, a firm, a country) needs to obtain resources and dispose of waste. In this, it provides information to help manage ecological assets more carefully and to enable personal and collective actions that can move us towards truly sustainable development – living well, within the means of one planet.

The depletion of ecological assets systematically undermines the well being of our planet and the 6.5 million people whose lives depend on the health of our ecosystems. Livelihoods disappear, resource conflicts emerge, land becomes barren, and resources become increasingly costly or unavailable. This depletion is exacerbated by the growth in human population as well as by changing lifestyles that are placing more demand on natural resources. Keeping track of the compound effect of humanity's consumption of natural resources and generation of waste is central to achieving sustainability. The Footprint methodology addresses underlying sustainability questions by measuring the extent to which humanity is using nature's biological capacity faster than it can regenerate.

In social terms, the Ecological Footprint informs about the distribution of resource use: it ties to individuals' and groups' activities to ecological demands. It illustrates who uses how much of which ecological resources, with populations defined either

geographically or socially. It can show to what extent humans dominate the biosphere at the expense of wild species. These connections help decision makers shape more deliberately policy in support of sustainable development goals.

Ecological overshoot

Starting in the mid 1980s, humanity's Ecological Footprint – human demand on Earth's resources – has been bigger than what the Earth can supply. This ecological "overshoot" has continued to increase: by 1996, humanity was using 15% more resources in a year than the planet could supply, and today, humanity's overshoot is 30%. Business-as-usual scenarios, based on moderate projections of UN agencies, show humanity with an overshoot of 100% by 2050 (WWF/GFN, 2006). Reaching this level of overshoot, which equates to demanding 2 planets to meet our needs, may be ecologically impossible. Hence, how to live well within the means of one planet is the main research question of the 21st century.

The Living Planet Index, the London Zoological Society's measure of global biodiversity trends, shows that vertebrate species populations have declined by about one-third from 1970 to 2003. At the same time, humanity's Ecological Footprint has increased to the point where the Earth is unable to regenerate renewable resources at the rate we are using them: our current overshoot of 30% means that it now takes over one year and three months for the Earth to regenerate what we use in a single year.

The Carbon Footprint, which measures how much land would be required to absorb our emissions of carbon dioxide from fossil fuel (minus what is absorbed by the oceans), is almost half the total global Footprint. It is also the Footprint's fastest growing component, increasing more than 700% from 1961 to 2003.

Humanity is living off its ecological credit card. In addition to the growing depletion of non-renewable resources such as minerals, ores and petroleum, it is increasingly evident that renewable resources, and the ecological services they provide, are at even greater risk. Examples include collapsing fisheries, carbon-induced climate change, species extinction, deforestation, and the loss of groundwater in much of the world.

While this can be done for a short while, overshoot ultimately leads to liquidation of the planet's ecological assets, and the depletion of resources, such as the forests, oceans and agricultural land upon which economies and markets depend. Almost no country today meets the sustainable development challenge of having both a high quality of life and an average Footprint that doesn't exceed the biological capacity available per person on the planet.

Measuring sustainable development

Sustainable development can be assessed using the Human Development Index (HDI) as an indicator of socio-economic development, and the Ecological Footprint as a measure of human demand on the biosphere. The United Nations considers an HDI of over 0.8 to be "high human development". An average per person Ecological Footprint of 1.8 global hectares or less makes a country's resource demands globally replicable. However, most countries do not meet both minimum requirements (Figure 5.1). A global resource demand exceeding ecological supply by over 25% (in 2003) is fundamentally unsustainable (Table 5.1).

Getting out of overshoot will require policies to support the necessary Footprint reductions, which can be allocated among the world's regions in different ways. Ending overshoot will also take economic, social and technological innovations to learn to live well on a smaller Footprint. One important step is to avoid building long-lasting infrastructure that depends on a large throughput of resources to operate. The cities power plants and homes we build today, will either lock society into damaging over-consumption beyond our lifetimes, or begin to propel this and future generations towards sustainable living.

Figure 5.1. Sustainable Development: Where We Are Today

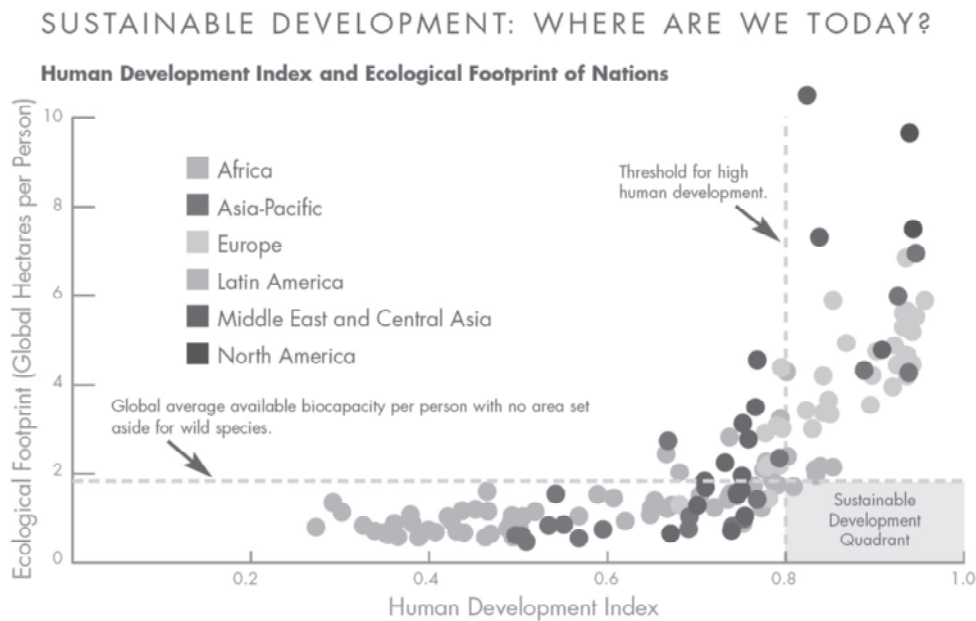


Table 5.1. Global Ecological Balance Sheet

(Global hectares/person, 2003 data)

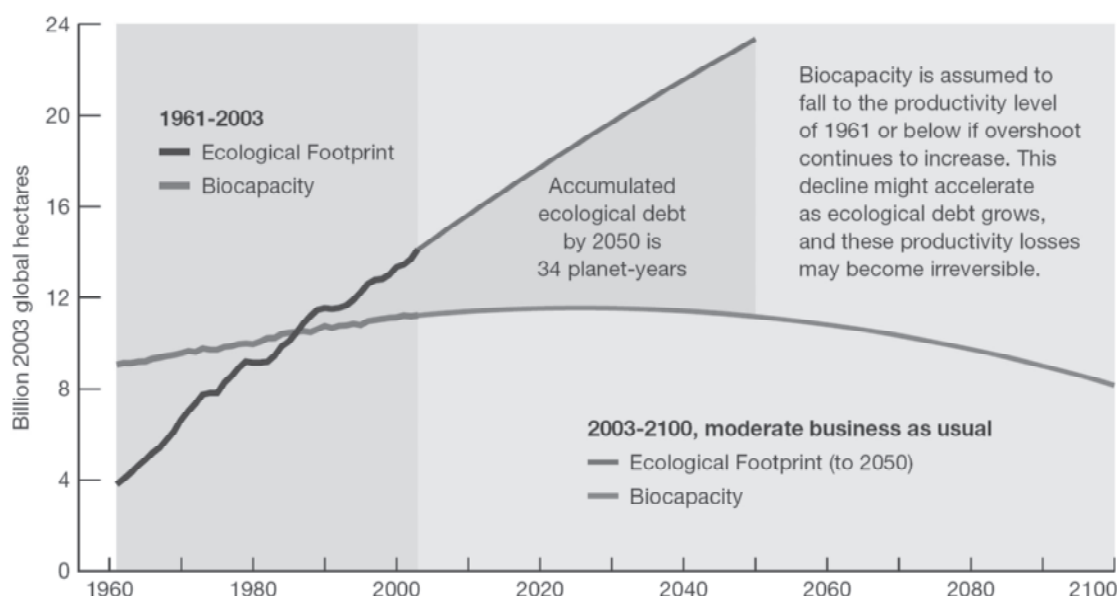
Human Demand (Ecological Footprint)		Ecological Supply	
Footprint areas for:		Biocapacity areas:	
Growing crops	0.49	Crop land	0.53
Grazing animals	0.14	Grazing land	0.27
Settlements and infrastructure	0.08	Built-up area	0.08
Producing timber and fuelwood	0.23	Forest	0.78
Absorbing excess CO ₂	1.14	Sinks	0.00
Harvesting Fish	0.15	Fishing grounds	0.14
Total Global Demand	2.20	Total Global Supply	1.80

Business applications

Global competition for resources, new environmental regulations and consumer demand for greener products are challenges that companies can turn into business opportunities. Analysis shows that a “business-as-usual” path will lead to growing ecological pressures in excess of the Earth’s biocapacity. The cumulative ecological debt of this scenario becomes 34 planet years by 2050 – or depends on depleting stocks of the size of what 34 years of planetary production can provide (Figure 5.2). Such a debt may be physically impossible to realize.

Hence, firms in manufacturing and other sectors need information on both their own and others’ impacts on the earth’s environment. This knowledge can be used by companies to improve their market foresight, set strategic direction, manage performance and communicate their strengths.

Figure 5.2. Footprint of Business-as-Usual Path



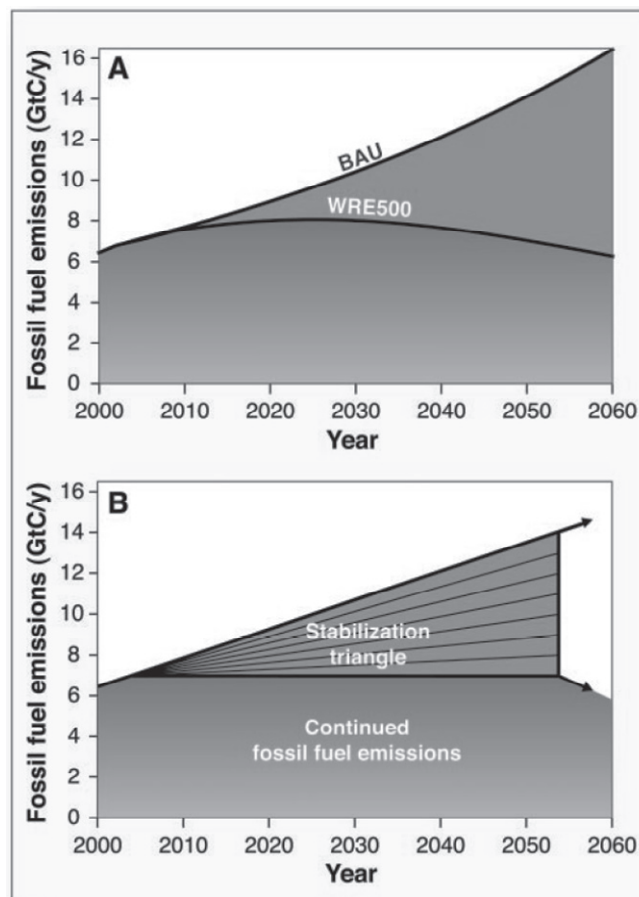
Source: WWF/GFN (2006)

Measuring a firm’s (or more precisely its activities) environmental demand on nature is based on translating the amount of resources used and wastes generated into units of biologically productive area, which is easy to understand and communicate to a broad set of stakeholders. Through these indicators, companies can find opportunities for innovation identify potential resource constraints and avoid costly business interruptions. They can make strategic choices in areas from R&D to marketing. For example, with information on ecological pressures generated by operations, companies can choose the best designs for products, programs and facilities. Using a common unit, businesses are able to establish benchmarks, set quantitative targets, and evaluate alternatives for future activities.

Applicable to any type of activity, this approach can be used to reveal when a company's products are "Footprint neutral", *i.e.* when their use results in a net reduction in overall demands on the environment in offsetting pressures created by other activities. It is compatible with all scales of company operations, and provides both aggregated and detailed results by sector and products, facilities, and processes. Similarly, analysis of a company's "carbon Footprint" will quantify impacts and identify opportunities to move to less carbon-intensive products and processes. In manufacturing, profit margins built on carbon-dioxide emitting fossil fuels will become an increasing liability.

For future planning, these indicators show where businesses or regions will be held back by increasingly limited forest, cropland, pasture and fishery resources, and help identify locations, products, and markets that will succeed in a resource-constrained world. The metrics allow the identification of what kind of products and services will be most needed in future markets, pointing the way to market opportunities for manufacturing and other firms (Figure 5.3). Businesses, particularly in the manufacturing sector, that can look ahead and that have measurement tools to manage ecological risks and opportunities can gain a competitive advantage. In presenting their operations as Footprint neutral, they can publicise their contributions to overall environmental sustainability and appeal to green consumers and markets.

Figure 5.3. New Markets beyond the Carbon Footprint



Source: Pacala and Socolow, (2004)

The measurement approach

In addressing environmental issues, a key business frustration is the lack of precision and clarity in the debate. Essential environmental challenges need to be translated into a framework that engages business and is usable by companies of different sizes. It should also be communicable and easily understood by the general public and consumers. The Ecological Footprint and other related economic, environmental and social indicators can form the basis for company sustainability reporting.

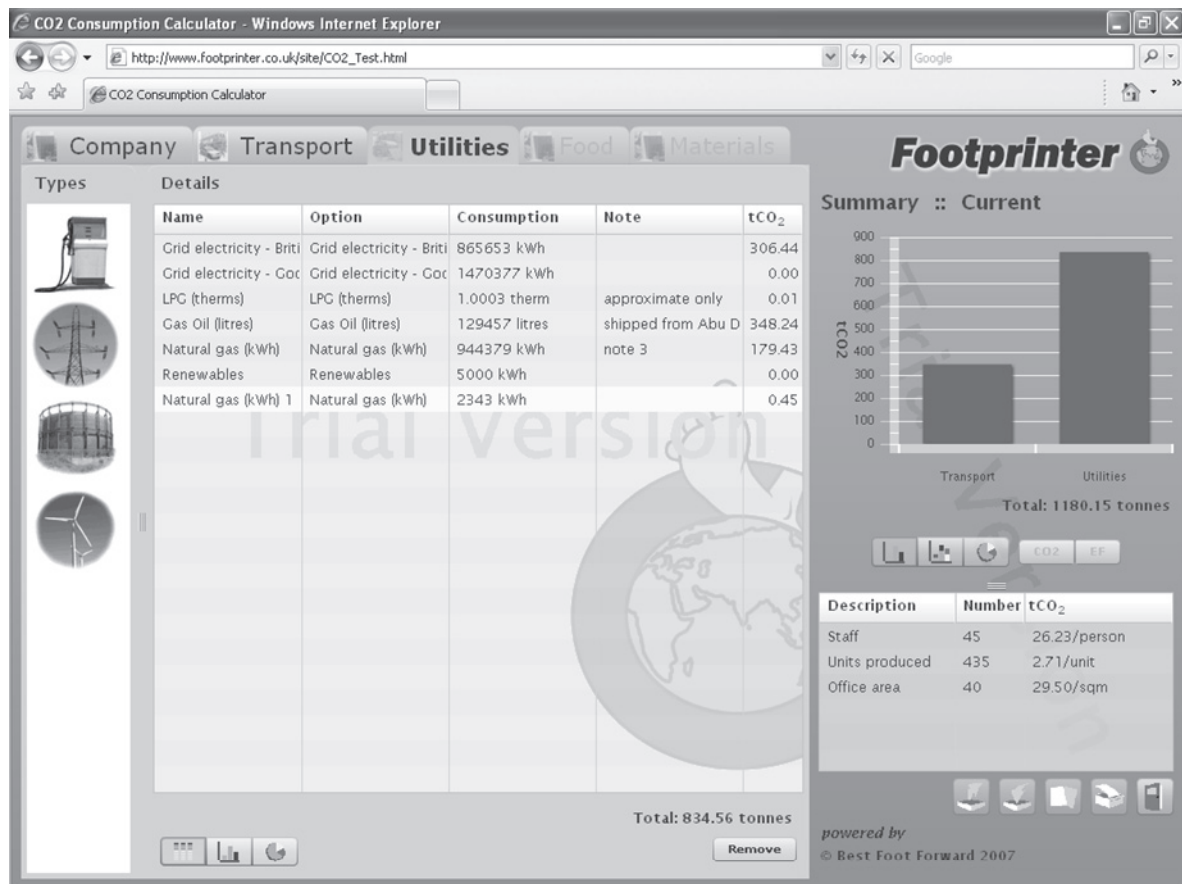
The Footprint approach measures the ecological demand of key areas of consumer demand such as mobility, food and housing, and the supply chains that meet these demands. This helps pinpoint the areas of most significant demand at the different levels of production and consumption. Such an approach allows to:

- focuses on consumer demand areas rather than specific industry sectors, thereby enabling an overall analysis of how particular demand areas might better be met outside existing technical and sector paradigms;
- enables companies to connect to the bigger picture by relating assessments of global overshoot to specific company activities and targets; and
- illustrates the importance of collective action and the need to change overall approaches to production and consumption towards sustainability.

Analyzing material flows, which underlies any Footprint assessment, is compatible with a number of analysis. Material flows measure flows of natural resources such as metal, construction materials and biomass from extraction to consumption. This data set then informs Ecological Footprint analysis. It is done by assessing the resources (and corresponding biocapacity) used through material consumption and waste generation. This means calculating quantities of different categories of land needed to produce resources and absorb waste, including land to absorb carbon dioxide; this also allows to assess carbon emissions – calculation of carbon dioxide emissions embedded in products and services which meet final areas of consumer demand;

An example of an organizational tool for Footprint analysis is “the Footprinter” developed to help companies and organisations measure their ecological and carbon demands (Figure 5.4). This is a next generation carbon accounting tool that enables the user to better manage and monitor their organisation’s Ecological and carbon Footprints. It can also model different “what if” scenarios and generate graphical reports and charts which can be incorporated into annual reports, web sites and other communications.

Figure 5.4. Footprinter, Calculation Screen-Shot



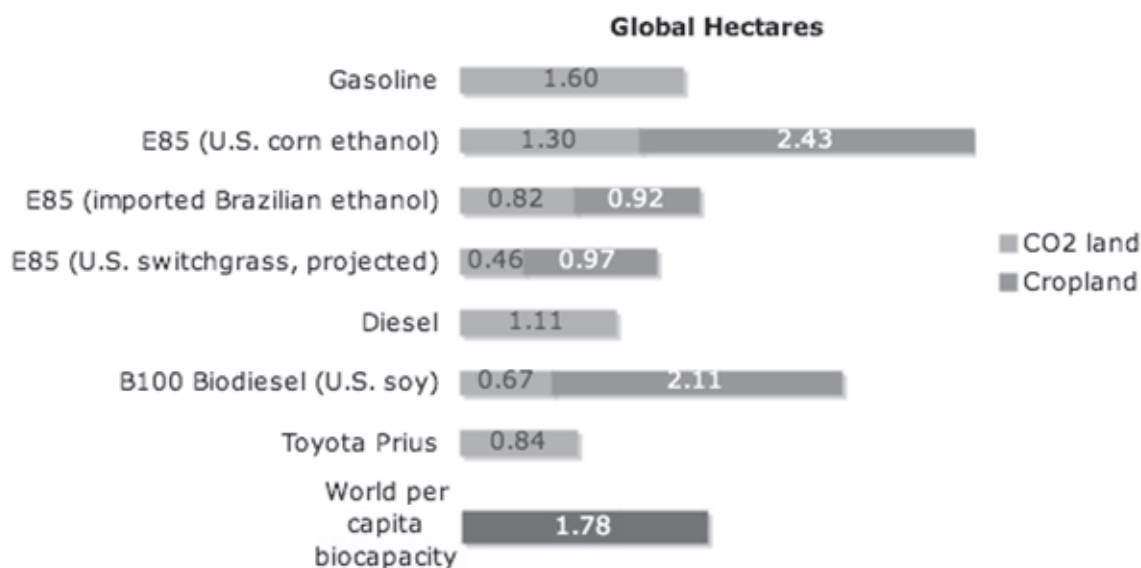
Supply chain analysis

These approaches provide the basis for analysis of supply chains which govern natural resource use. Supply chains comprising different industrial sectors currently satisfy many areas of human demand – from consumer goods to food products. The supply chain perspective helps to illuminate which industry sectors use how much of which global resources and allows comparisons of relative efficiencies across sectors. This analysis can help identify the most effective levers for reducing demand on the biosphere – for example, through changes to manufacturing standards or through consumer education – and the sectors where interventions would have the greatest demand on nature – those dealing with resource extraction, product design, manufacturing and assembly or retailing.

It is equally important to understand which actors in the value chain have the influence to reduce resource use and carbon dioxide emissions. In the food sector, for example, retailers potentially have the most influence to steer suppliers' performance and exert upstream pressure on consumers by phasing out their unsustainable products. Consumers also play an important role in shifting the impacts of food production. The current global shift from vegetable to meat consumption, for example, creates significant additional demand on ecosystems; shifting between crops can result in different land efficiencies and water demands.

The alternative supply chains that provide mobility and transport services also influence human demand on nature. Various energy technologies and sources – from fossil fuels to biofuels to wind turbines – have very different Ecological and carbon Footprints. Particularly, Footprint analysis can help compare biofuels amongst each other (Figure 5.5). Maximising efficiencies in meeting human demand will increasingly be a competitive factor in a carbon-constrained world. Carbon- and resource-intensive products and services will become more expensive, and consumer choices will change.

Figure 5.5. Comparing the Footprint of Gasoline and Bio-Fuel Technologies



Volkswagen Jetta Footprint based on the average U.S. mileage of 20,000 km / yr. and Prius (based on EPA 2006 fuel mileage rating system) (analyzed and produced by Jorgen Vos)

Business case stories

BC Hydro

BC Hydro, Canada's third largest electrical utility, is attempting to become Footprint neutral. Through an ambitious plan to control environmental impacts, the company is seeking to provide no-net environmental impact for 20 years, during which time peak customer demand is expected to rise 25-40 percent. To monitor this project, BC Hydro uses the Ecological Footprint as a single indicator to provide a quantitative measure of impacts and benefits that is intuitively simple for customers, staff, and decision makers to understand.

A baseline analysis was conducted of the total environmental impacts of the current operations of the utility. The analysis included physical land area, infrastructure (dams, reservoirs, and other existing power infrastructure) and operations/maintenance. A Distribution Line Ecological Footprint calculator was developed to compare the effects of various design choices for new power lines. BC Hydro updated the original study and is

building a tracker to monitor the company's environmental performance year to year and identify operational improvements to offset negative impacts.

GPT Group

The GPT Group, a multinational commercial real estate development company that owns and manages retail shopping malls in Australia, wanted to be able to compare the ecological impact of different building and interior design choices during remodelling. The company was interested in adopting a standardised method of measuring the environmental impact of its properties to meet operational sustainability targets of 20 percent impact reduction by 2009 for its retail division. Using detailed raw materials data for different categories of stores (fashion retailers, restaurants/food vendors, etc.), questionnaires were developed that calculate the Footprint implications of different design choices and encourage tenants to select low-impact elements.

The retail calculator provided a standardized metric by which the impact of different design possibilities can be compared. It translates commercial design elements into detailed accounts of material use and waste generation and can identify cost and impact saving options. The calculator allows GPT to identify target areas for major ecological performance improvement, and has allowed the company to measure progress towards its sustainability goals.

SITA

SITA, a part of the SUEZ Group, is one of largest waste management companies in France. The waste collection business in the Europe Union has become highly competitive and companies like SITA are seeking new ways to provide greater customer satisfaction at lower cost. SITA was looking for a tool to use as an internal operations indicator that could also be used to communicate with stakeholders – from citizens to policy-makers to businesses.

An interactive tool was created for calculating the Footprint of the waste collection portion of SITA's operations. SITA uses this to analyze their operational systems and to determine how to lower their ecological impacts and increase their operations efficiency (and reduce costs, especially in waste transport). SITA also uses this as a conceptual tool to help them and their customers understand the ecological value of waste as an opportunity for creating savings and recovering resources. By creating and actively marketing their Footprint calculator, SITA has successfully marketed themselves as green waste managers and can better compete for waste-management bids in their industry.

Conclusions

In order to avoid ecological catastrophe, business and its stakeholders must find ways to meet human demand within the limits of one planet. This is particularly true for the three areas of demand that place the most strain on the earth: housing, transport and food, which together account for 63% of the global Ecological Footprint, 65% of total emissions, and 72% of the world's material use.

Ecological Footprint and One Planet Business place “ecological overshoot” at its core to help the public and business grasp the reality of growing negative environmental impacts on the planet. The methodology allows business and its stakeholders to map

global ecological overshoot onto different consumer demands, industry sectors, companies and products. The indicators of a company's Ecological and carbon Footprints help the organisation identify where interventions in manufacturing processes, supply chains and/or products would best reduce unsustainable environmental impacts at the micro and macro levels. With regard to the latter, a company can become Footprint neutral by offsetting ecological impacts in other sectors or regions.

The key implications of “ecological overshoot” for business range from increased resource prices and the risk of investment withdrawal to supply disruptions and growing regulatory pressure. In a resource- and carbon-constrained world, a new framework for business decision-making is evolving where ecological limits are paramount and will be a key success criterion for future business operations. Companies that do not grasp this face being forced out of the market.

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Chapter 6. Using Environmental Accounts

Lars Mortensen, European Environment Agency (EEA)

Introduction

Unsustainable patterns of consumption and production, particularly in industrialised countries, are a major cause of global environmental degradation. This statement made by the United Nations in 1992 in the ground breaking *Agenda 21* was the seed of what 15 years on has become a major area of international and European policy. Sustainable Consumption and Production (SCP) – an economy wide search for more environmentally sustainable production processes and consumption behaviour – is a key priority area in the renewed EU Sustainable Development Strategy and is the theme of a future EU Action Plan.

Beginning in 2003, the European Environment Agency (EEA) and its European Topic Centre on Resource and Waste Management (ETC/RWM) have undertaken a series of projects examining environmental pressures including the use of resources from consumption and production in selected European countries. This paper is a first glimpse into some results of this research. It focuses both on environmental pressures from total production and consumption and more specifically at pressures from the manufacturing sector.

Insights from environmental accounts

One aim has been to explore how tools like Environmental Accounting and related Input-Output Analysis can produce information useful for the development of policies on sustainable consumption and production and on the sustainable use of natural resources. The *National Accounting Matrix including Environmental Accounts* (NAMEA) is a framework for documenting economic and environmental flows in a consistent way following the UN System of National Accounts established in 1953.

NAMEA collects data on environmental pressures in a way which is compatible with economic statistics making use of input-output matrices – national inventories of monetary flows between economic sectors (for example, between the food processing branch and the retail branch) and between them and final consumers. These inventories are then extended by adding information on material resource inputs to each sector and the pollutants they release back into the environment. NAMEA can show selected environmental pressures (climate change, air pollution, resource use) by economic sector (including manufacturing) and by consumption cluster.

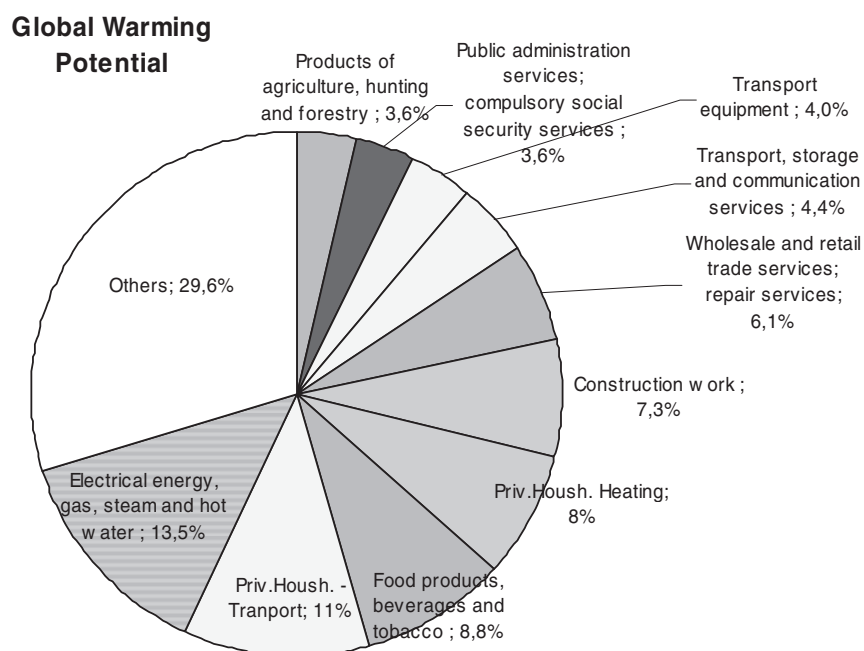
The project has compiled and analysed Environmental Accounts for eight European countries for which comprehensive data was available (Denmark, Germany, Hungary, Italy, the Netherlands, Spain, Sweden and the United Kingdom). The accounts are disaggregated to 31 distinct economic sectors. Supplementary data collected by Eurostat for a number of additional EU Member States have also been analysed. The environmental pressures analysed are:

- 1) global warming potential (greenhouse gas emissions)
- 2) acidification potential (emissions of SOX, NOX and ammonia)
- 3) tropospheric ozone forming potential (emissions of substances for ground level ozone formation)
- 4) resource use (direct materials input).

Consumption perspectives

Over the last decades, EU countries have experienced a steady consumption growth. NAMEA enables attributing the environmental pressures caused by consumption directly and indirectly (through production) to various consumption categories. The EEA-ETC/RWM study shows that the consumption categories which cause the highest environmental pressures from its life-cycle of production-consumption activities are housing (including infrastructure), food & drink, and mobility. Eco-efficiencies along the production-chain of similar product groups vary significantly from country to country, indicating room for improvement across the European Union as a whole. The direct and indirect pressures from consumption in the eight European countries are shown in terms of global warming in Figure 6.1 and materials use in Figure 6.2.

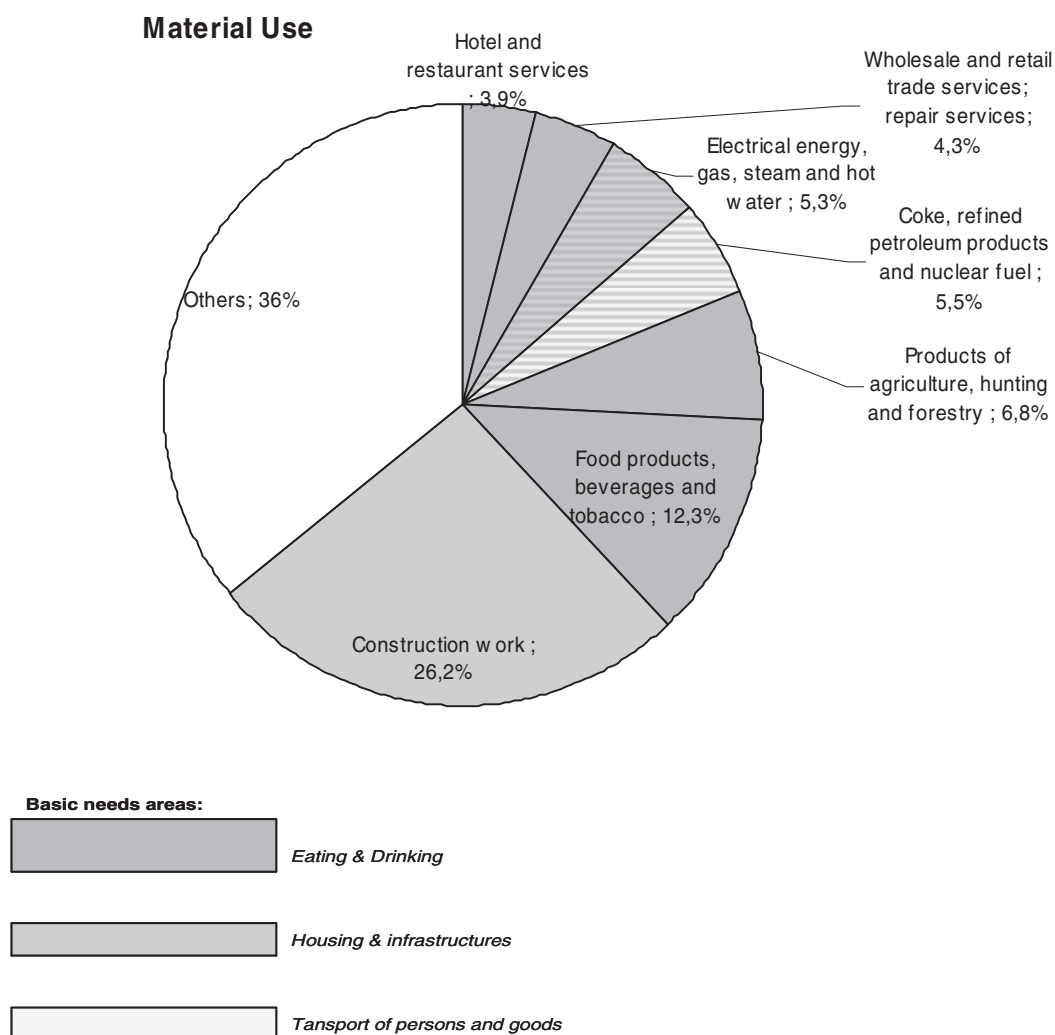
The production-consumption of activities related to housing, food and mobility cause 70% of the total global warming potential. The activities which on average contribute the most are electrical energy, gas, steam and hot water (13.5%), private household transport (11%) and food products, beverages and tobacco (8.8%).

Figure 6.1. Global Warming Potential by Consumption Category

Source: European Topic Centre on Resource and Waste Management (ETC/RWM)

The production-consumption chain of activities related to housing, food and mobility cause about 65% of total material use. The activities which on average contribute the most are construction works (26.2%), food products, beverages and tobacco (12.3%), and products of agriculture, hunting and forestry (6.8%)

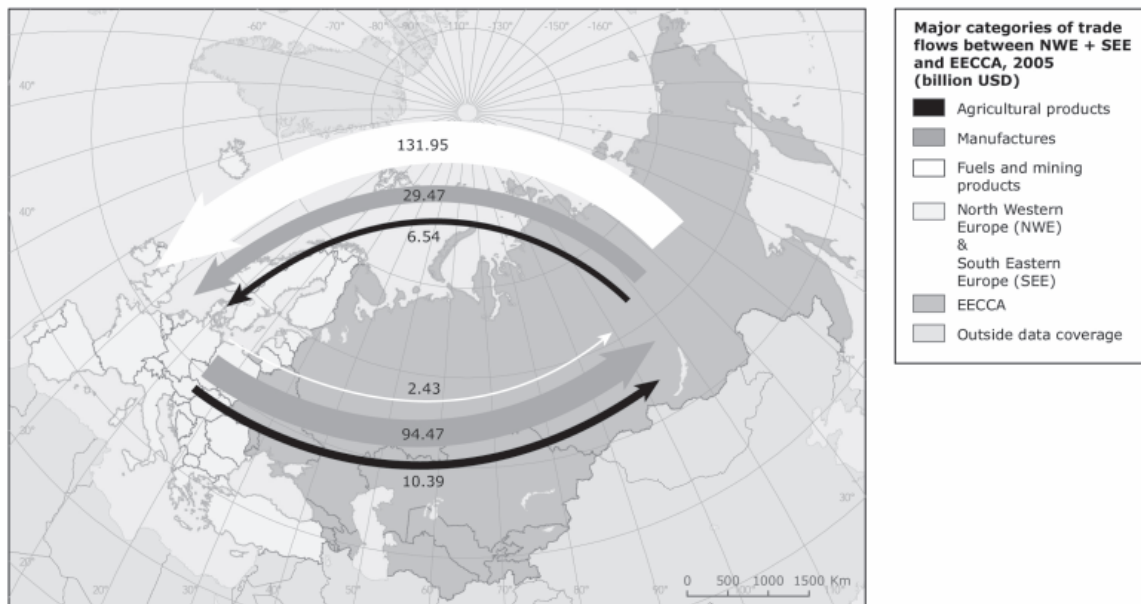
Figure 6.2. Material Use by Consumption Category



Source: European Topic Centre on Resource and Waste Management (ETC/RWM).

One additional factor at play is international trade which leads to a shift of environmental pressures from the European Union to other parts of the world. The import of resource-intensive goods leads to significant material extraction in regions outside the EU in order to supply European consumption. The quantity of these materials, meanwhile, is much greater than materials extracted in the EU to produce goods and services for export.

Figure 6.3. Trade Flows between North Western Europe and South Eastern Europe (NWE+SEE) on the One Side and Eastern Europe, Caucasus and Central Asia (EECCA) on the Other, 2005.

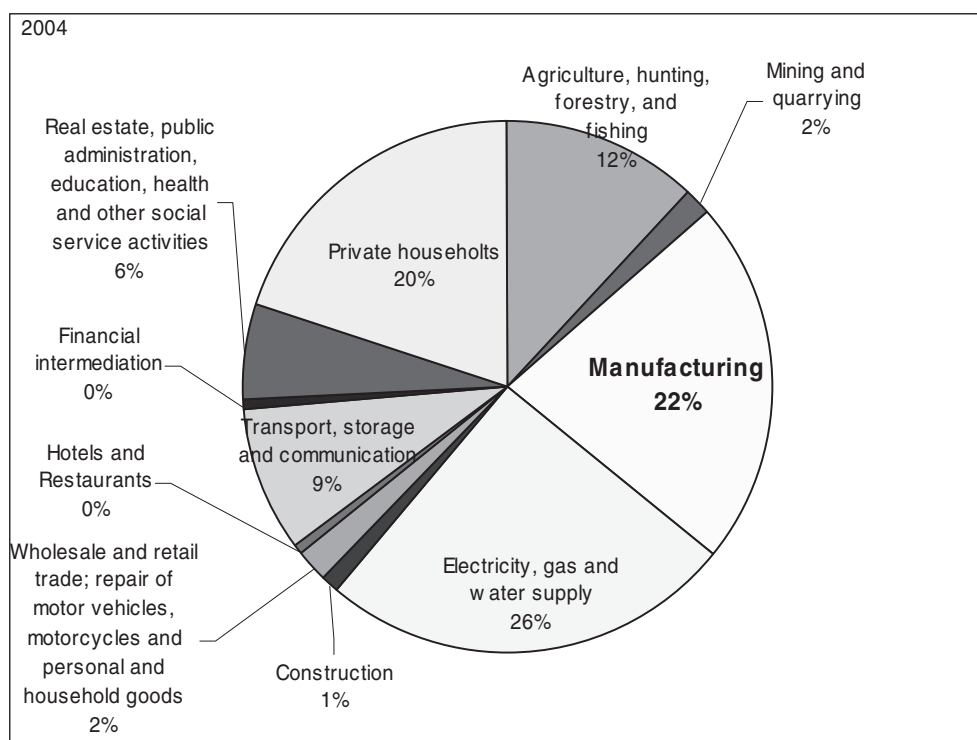
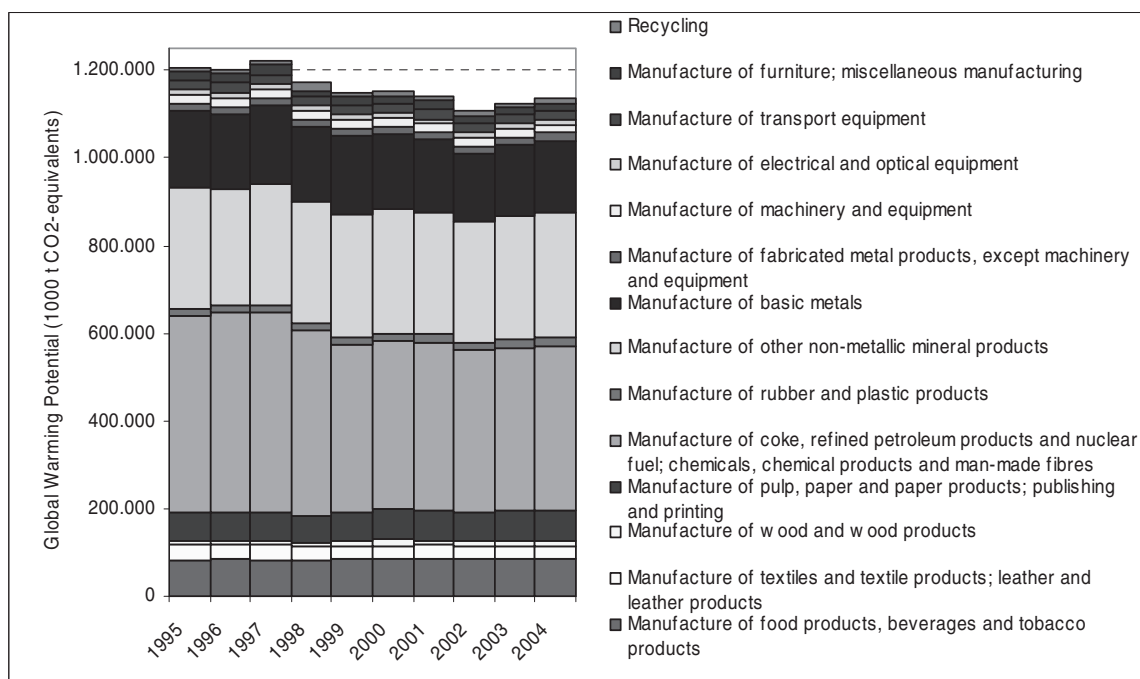


Furthermore, it is important to note that eco-efficiency improvements in key production sectors are typically more than offset by growth in consumption. In other words, consumption growth is outweighing the gains from technological improvements. Meanwhile, consumers show little sign of shifting spending to less pressure-intensive types of goods and services.

Production perspectives

The study shows that agriculture, electricity generation, transport services and mining are those economic sectors which contribute most to the environmental pressures in Europe. Moreover, while these industries emit over half of an economy's total environmentally harmful emissions, they typically contribute a little over 10% to GDP.

NAMEA enables comparisons of the environmental pressures from manufacturing to that of other sectors. Manufacturing contributes 22% of European global warming potential (Figure 6.4) as well as 14% of acidification potential, and 21% of tropospheric ozone potential. The major contributors to global warming within manufacturing are: basic metals; coke, refined petroleum products and fuel and chemicals; and other non-metallic mineral products such as cement (Figure 6.5).

Figure 6.4. Global Warming Potential by Sector (EU25, 2004)**Figure 6.5. Manufacturing Contribution to Global Warming Potential (EU25)**

Source: Eurostat

Conclusion

Using the tool known as NAMEA (National Accounting Matrix including Environmental Accounts), the European Environment Agency (EEA) and its European Topic Centre on Resource and Waste Management (ETC/RWM) have compiled and analysed environmental accounts for eight European countries for which comprehensive data was available (Denmark, Germany, Hungary, Italy, the Netherlands, Spain, Sweden and the United Kingdom). The environmental pressures analysed are global warming potentials, acidification potentials, tropospheric ozone forming potentials and resource use.

From a production perspective, the study shows that in those countries, the sectors contributing the most to environmental pressures are agriculture, electricity generation, transport services and mining. Moreover, while these sectors emit over half the emissions analysed, they typically contribute little over 10% of GDP. Manufacturing contributes about 20% to those pressures. Manufacturing contributes about the same share of employment and value-added to the European economy.

From a consumption perspective, the study shows that the production-consumption chain of activities related to the consumption of housing, food & drink and mobility causes the majority of environmental pressures. The findings of this paper are consistent with findings of other research projects undertaken in recent years by other organizations. Hence there are good reasons to focus future sustainable consumption and production policy action on the consumption clusters of food and drinks, housing and mobility.

Chapter 7. Surveying Firm Environmental Practices

Nick Johnstone, OECD Environment Directorate

Introduction

It is well understood that in the absence of public policy interventions, firms will face inadequate incentives to take into account the environmental impacts of their production choices. It is also known that market-based instruments and flexible performance standards are a more efficient means for public authorities to provide such incentives than more direct forms of regulation. However, a detailed analysis of the effects of public environmental policy on the inner workings of the firm has been largely absent from the vast body of literature which has been marshalled in support of these insights.

In order to fill this gap, the OECD undertook a set of empirical studies, drawing upon a database which includes observations from approximately 4,200 facilities with more than 50 employees in all manufacturing sectors in seven OECD countries (Canada, France, Germany, Hungary, Japan, Norway, and United States). The data was collected by means of a postal survey conducted in 2003. Respondents were generally chief executive officers (CEOs) and environmental managers (OECD, 2007).

Data was collected on facility-level environmental practices, including physical investment in abatement, research and development expenditures, and implementation of environmental management systems (EMS) and tools. In addition, the database provides information on the characteristics of the environmental policy framework to which facilities are subject. And finally, data was collected on other factors such as whether the facility manufactured final goods or intermediate inputs, whether it targeted local or international markets, whether it is listed on the stock exchange, whether it was profitable, and a host of other factors.

In this paper, some of the main results with respect to environmental management (EM), research and development, and environmental performance are reviewed. In addition, the main results of an assessment of the links between environmental and commercial performance.

Quality of environmental management

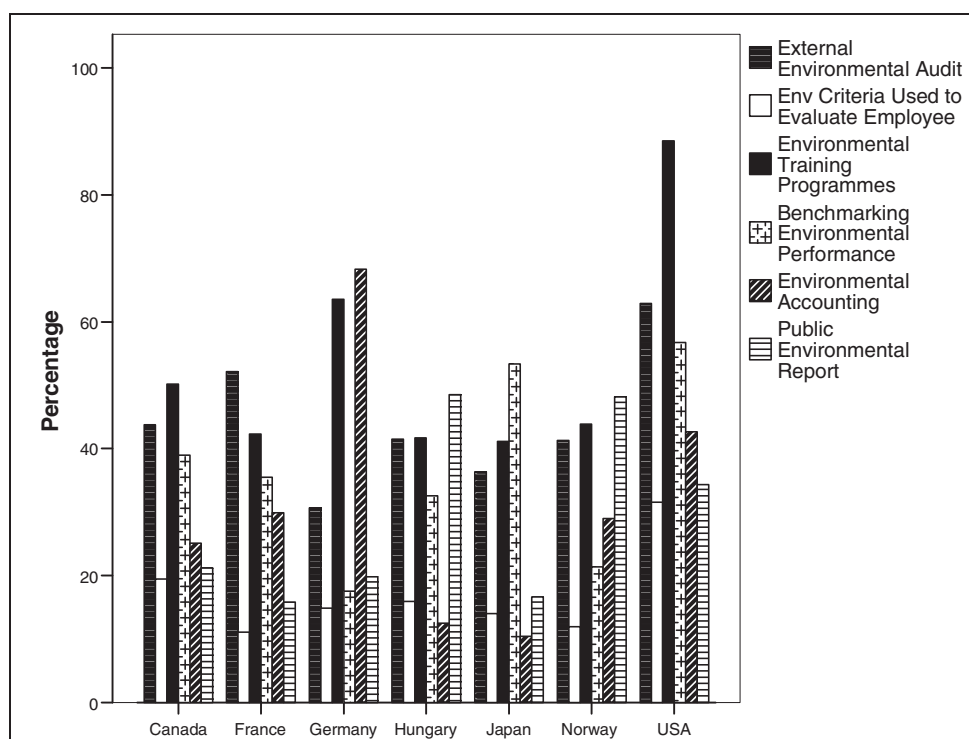
One of the primary objectives of the OECD project was to collect information on the nature and extent of environmental management in different facilities. This relates not only to the presence of EMSs *per se* (certified and uncertified), but also more specific EM tools, the institutional location of the person responsible for environmental matters, and general management practices which may have environmental implications. In addition to

understanding the prevalence and comprehensiveness of a facility's EM strategy, it is important to have an understanding of the motivations for its introduction.

Overall, 39% of respondents to the OECD survey reported having an EMS. However, the number of facilities reporting that they had environmental management systems in place varies across countries, with figures ranging from just under 30% (Germany and Hungary) to almost 45% (United States). There are large numbers of facilities reporting that they were in the process of implementing environmental management systems.

Data on the number of facilities which have "certified" environmental management systems was also collected, but this is not strictly comparable across countries, since different schemes are relevant for different regions. Nonetheless, over 1,000 facilities (25% of the sample) indicated that they had ISO 14001 certification. In addition, data was collected for the year in which it was first certified. As expected, smaller facilities are less likely than larger ones to have environmental management systems in place. For the smallest class (50-99 employees), less than 20% had an EMS, while for the largest class (>500 employees) the figure is over 60%. The differences between the groups are statistically significant (even for the two higher classes), as indicated by the 95% confidence intervals.

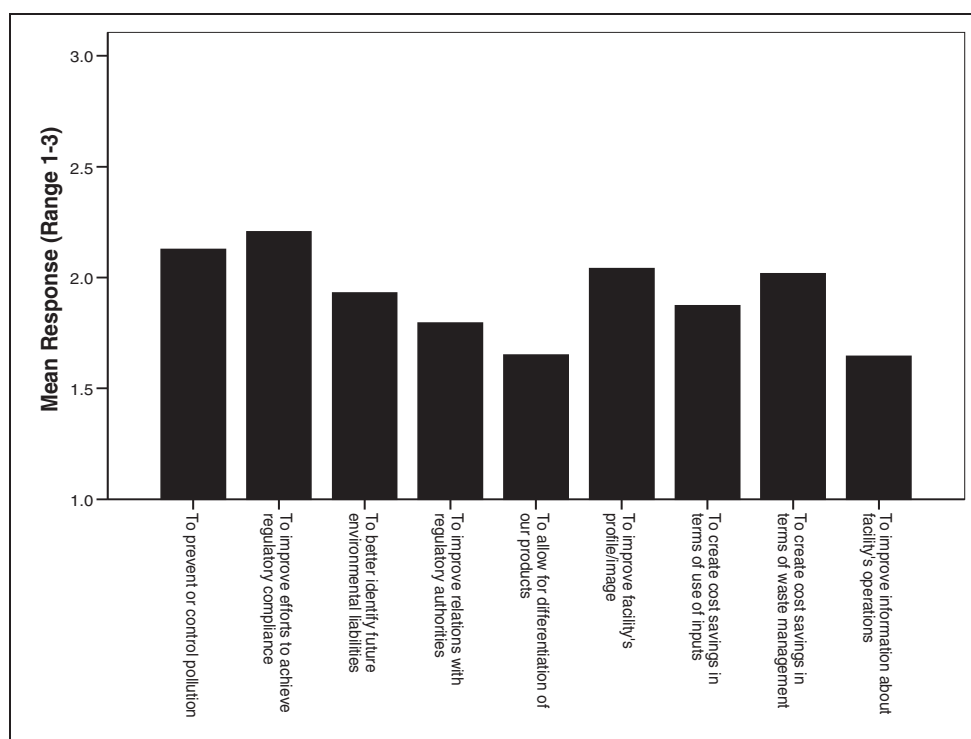
Since an EMS can mean very different things to different facilities in different countries, it is perhaps more interesting to examine facilities' use of more specific environmental management tools (Figure 7.1). The most commonly reported tools are "written environmental policies" and "environmental training programmes". There is, however, significant variation across countries. In Germany, environmental accounting is much more important than elsewhere, and much more important than other tools. In the United States, there is much greater tendency to use environmental training programmes. There are few facilities which evaluate or compensate employees on the basis of environmental criteria, except in the United States. It must be assured that this would only affect a small minority of employees. Hungary and Norway have the greatest proportion of facilities with public environmental reports.

Figure 7.1. Proportion of Facilities with Selected Environmental Management Tools

Different factors encourage or discourage a facility from introducing an EMS. Multivariate analysis confirms many of the findings from this past research. For instance, facility size has a positive effect on the probability of having implemented an EMS, perhaps reflecting economies of scale in their introduction. In addition, facilities whose markets are more international in nature are more likely to have an EMS, even when other factors are controlled for (*e.g.* size, sector, profitability, etc.) The presence of a “quality management system” has a positive influence, reflecting perhaps economies of scope between the introductions of the two management systems.

At a more subjective level, respondents were requested to assess the importance (1=not important; 2=moderately important; 3=very important) of different factors when considering whether or not to introduce an environmental management system (Figure 7.2). While there is some overlap, these can be broadly distinguished between factors which are related to the role of EMSs as supply-side efficiency-improving measures (cost savings in terms of resources and waste management, information about operations), demand-side market factors (firm image and product differentiation), and those which relate to regulatory concerns (ensuring regulatory compliance, improving relations with regulators, and preventing or controlling pollution).

Figure 7.2. Motivation for Introduction of EMS



Effective environmental management can be seen as an indicator of environmental performance more generally. However, the quality of environmental management can be difficult for outsiders to discern. An EMS is often also used by firms in an effort to signal good environmental practices. However, the intended target of such signalling varies by facility size. While large facilities target public authorities, perhaps seeking to reduce inspection frequency, small facilities target supply chain partners. In the latter case, the result is stronger the more “distant” the facility is from its supply chain partners, reflecting the need to provide a tangible sign of good management practices when it is difficult to document by other means.

The role of the environmental policy framework may also be important in determining the facility’s assessment of the costs and benefits of introducing environmental management systems and tools. More prescriptive technology-based standards may be thought to result in fewer benefits from environmental management than more flexible policy measures, since the value of the information generated (*i.e.* via environmental accounting) and the mechanisms by which such information can be acted upon (*i.e.* training policies) is correspondingly lower. Thus, the adoption of an EMS is not likely to generate as significant benefits for the firm under direct regulations (which are more prescriptive in nature, and thus give firms much less flexibility in their abatement strategy). There is little benefit in identifying cost-effective abatement opportunities if the regulatory regime restricts your options.

However, if EMSs are seen by managers as being primarily measures to ensure that a firm is in compliance, the difference in incentives for their adoption provided by flexible and prescriptive policy instruments may be less apparent. For instance, by providing information on the regulatory environment and on the status of the firm’s degree of

compliance, there may be little difference in the effects that flexible and prescriptive measures have on the actual benefits of introducing an EMS. At a descriptive level, the data collected from the OECD project does not provide strong evidence with respect to the relative importance of these two different potential relationships; and nor is any strong relationship found in the empirical work that was undertaken.

Environmental research and development

Environmental regulations create a demand for new processes which allow firms to comply with the regulations in a less costly way than currently available processes. This encourages investment in research and development (R&D) and may affect the rate and direction of technological change. Investment in R&D in general is influenced by a variety of factors such as market structure, firm size, capital availability, technological opportunities, etc. (OECD, 2006).

Defining that part of R&D which is “environmental” is problematic. In most cases, respondents to surveys are requested to classify R&D as “environmental”, if improved environmental performance is the primary objective of the investment. However, this has two problems. Firstly, if investment in R&D is a form of “search” strategy, the objective may not be the same as the outcome. Secondly, as the discussion on change in production process has made clear, it can be difficult to distinguish between environmental and other impacts of production decisions.

Assuming it can be classified as such investment in specifically “environmental” R&D is likely to be driven by all of the same factors which drive more “general” R&D. In addition to these factors, the facility’s decision to devote resources specifically to environmental R&D is influenced by two additional factors: the stringency of the environmental regulatory regime; and the type of instrument used.

Policy stringency

When introducing a new environmental regulation, the regulator explicitly (in the case of a market-based instrument) or implicitly (in the case of a technology-based standard) increases the price of emissions faced by facilities. Following from theories of induced innovation, this may have an impact on the type of R&D performed (Ahmad, 1966).

Therefore, environmental policy is expected to create incentives for a certain type of innovation (*i.e.* environmentally-friendly innovation). The bigger the price change (*i.e.* the more stringent the environmental policy), the more important are the incentives to engage in environmental R&D. Thus, the relative stringency of the environmental policy regime is expected to have a positive impact on the likelihood to engage in environmental R&D.

Instrument choice

The size of the market for environment-related innovations also depends upon the choice of environmental policy instrument, and a distinction can be drawn between “more prescriptive” instruments and “more flexible” instruments. First, the risk associated with investment in R&D is likely to be greater under prescriptive technology-based standard than with more flexible instruments. Under a flexible instrument if a facility identifies a

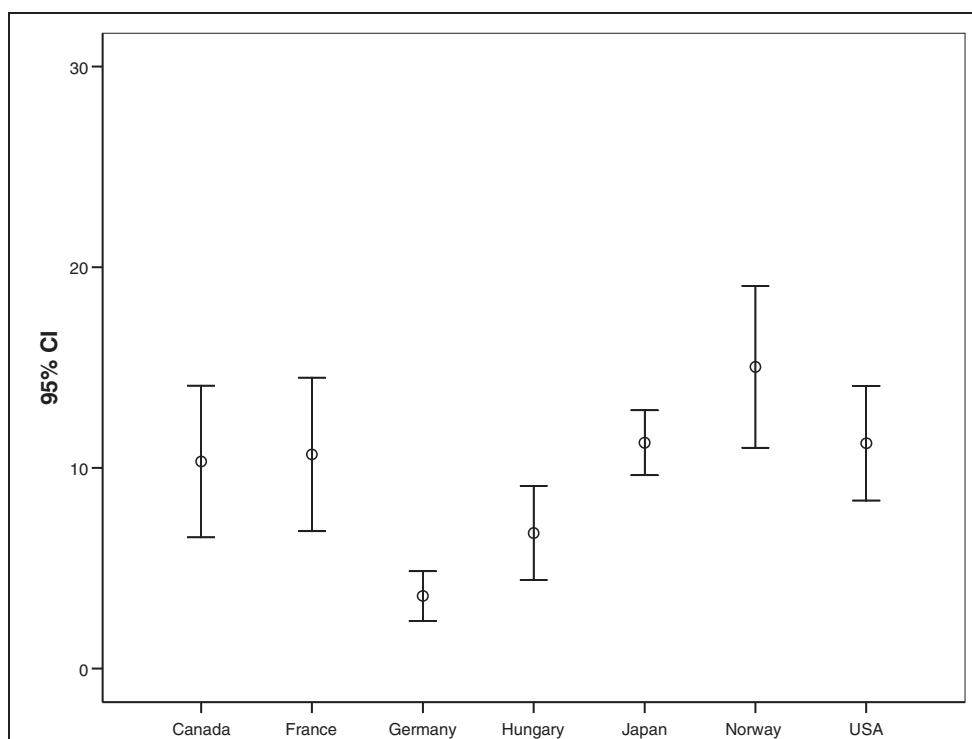
new process which reduces environmental impacts, there is potentially a market for whatever process is identified. This is not the case for more prescriptive technology-based standards, unless the standard is changed.

Second, among flexible instruments, market-based instruments provide stronger incentives to innovate than performance-based standards. Once a facility reaches the prescribed standard, it faces no incentives to identify means to reduce its emissions further. The very fact that market-based instruments provide incentives to go toward zero emissions increases the space for relevant innovations, and therefore the potential size of the market for those innovations. Therefore, MBIs are expected to have a greater impact on the likelihood to engage in environmental R&D than performance-based standards, which in turn are expected to have a greater impact on the likelihood to engage in environmental R&D than technology-based standards.

Empirical studies

There have been a small number of empirical studies on the links between environmental policy and R&D expenditures (Arimura, 2004), but the OECD project is one of the few studies which has gathered data on environmental R&D across countries. Respondents were asked if their facility had a separate budget for research and development (Figure 7.3). This indicates that on average somewhat less than 10% of all respondents report having such a budget, with the highest percentage in Norway.

Figure 7.3. Reported Percentage of Facilities with R&D Budgets for Environmental Matters



Facilities and firms were also requested to report on the percentage of total R&D budgets were devoted to environmental matters. Of the approximately 400 facilities

reporting that they had a budget, there were 275 responses to the quantitative question, and these were used in empirical analyses in conjunction with the binary question reported on above. Larger facilities are more likely to undertake environment-related research and development (Johnstone and Labonne, 2006). Comparing across countries, Japanese facilities are much more likely to report having invested in environment-related R&D, even when the effects of other factors (sector, size, etc...) are controlled for in the models.

However, it is the policy framework which is of particular interest. There is direct evidence of the positive role played by flexible instruments on investment in environmental R&D. While environment-related input taxes have a positive role, technology-based standards have a negative influence (Johnstone and Labonne, 2006). A different model finds that perceived policy stringency is the over-riding determinant of specifically “environmental” R&D, but that policy instrument choice does not have a direct influence on the decision to invest in environmental R&D (OECD, 2007).

However, the latter approach does find that there is an indirect influence through the role of environmental accounting – “flexible” policy instruments encourage the use of environmental accounting, and this in turn encourages greater investment in environment-related R&D. The role of accounting seems to be key, and the decision to invest in R&D appears to be closely bound up with the decision to implement an environmental accounting scheme, highlighting the importance of the links between management and technological initiatives.

Reported environmental performance

Respondents were requested to indicate the change (if any) in their environmental impacts in nine specific areas in the previous three years (*i.e.* solid waste, local air pollution, wastewater, global air pollutants, environmental accidents, soil contamination, etc...), and whether they had undertaken significant environment-related investments in these areas. Comparison of responses to the relevant questions with other data sources reveals reasonable degree of correlation.

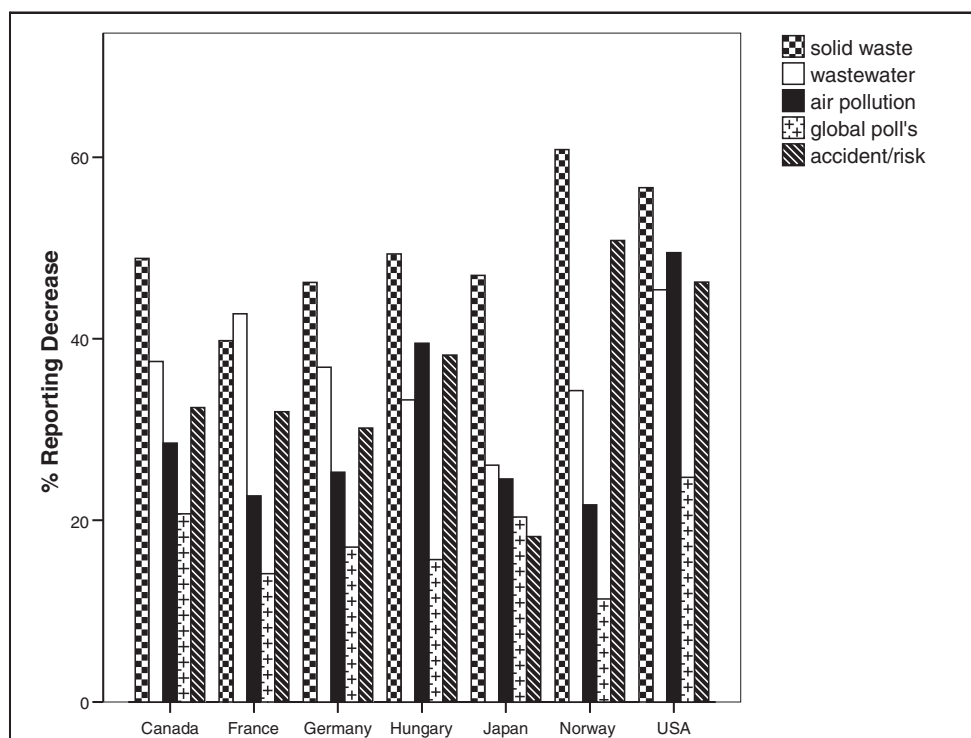
There is surprising congruence across the responses from different countries – with solid waste always the highest reported impact (approximately 80%) for which significant investments have been undertaken, with over 85% of Norwegian and US facilities reporting that significant efforts had been made. Wastewater is often second in importance, and global pollutants are the lowest (between 20% and 40%). Investments undertaken to reduce the risk of severe accidents exhibits the greatest variance, with less than 50% of Japanese facilities undertaking significant investments and almost 90% in the US sample. Reassuringly, there is a high degree of correlation between facilities which report having undertaken investments in those areas for which they feel that the potential negative environmental impacts from their production processes are likely to be significant. There are statistically significant positive correlations in all environmental impact areas.

However, having undertaken significant investments does not necessarily result in improved performance. Facilities were, therefore, also requested to report on the change in environmental impacts from their activities in the previous three years, ranging from a significant decrease (1) to a significant increase (5). For the same impact areas, it is interesting to see that in all cases (except solid waste in Norway), less than 60% of facilities reported a significant or moderate decrease. Respondents most frequently cited

solid waste as the area where the largest improvements had been made, followed by wastewater and air pollution, with global pollutants lagging far behind (Figure 7.4).

Previous empirical work has indicated that exogenous firm characteristics (firm size, fuel type, product diversification, etc.) explain a great deal of the reported variation in environmental performance within a sector. Identifying the links between such characteristics and environmental performance is key to successful environmental policy design. Firstly, this will help public authorities target scarce resources toward areas where it can be of the greatest use. Secondly, it will help public authorities enforce regulations more efficiently. Thirdly, it may help policy-makers design policies differently for different “segments” of the economy. And finally, in methodological terms, omission of relevant firm and market characteristics from the empirical studies would bias results related to the variables of primary interest - *i.e.* public policy.

Figure 7.4. Reported Environmental Performance in Last Three Years by Type of Environmental Impact



The empirical literature which does exist hypothesises a number of relationships between various firm characteristics and environmental performance. A number of issues are thought to be particularly important here:

- *Firm size* – presumed to be positive due to visibility (and thus, the probability of enforcement and the strength of community pressures), as well as economies of scale in environmental investments;
- *Capital stock turnover* – presumed to be positive due to “cleaner” nature of many newer technologies relative to older ones;

- *Exposure to international markets* – presumed to be positive due to economies of standardisation and the need to meet standards of the most stringent market;
- *Geographical origins of capital* – dependent upon relative stringency of domestic regulations relative to other countries;
- *Source of equity* – presumed to be positive for firms with stock exchange listings, due to higher environmental demands of equity markets relative to other sources of capital;
- *Capital availability* – presumed to be positive for firms with internal sources of funds, due to capital costs of investments in environmental improvements;
- *Public firms vs. private firms* – presumed to be negative for public firms due to lower probability of enforcement and existence of “soft” budget constraints which discourages resource and material efficiency;
- *Diversity of product lines* – presumed to be negative due to diseconomies of scope in investment in environmental improvements; and,
- *Proximity to final consumers* – presumed to be positive, due to the importance of environmental demands of final consumers.

Table 7.1 provides a summary of the general results, drawing upon results from a large number of empirical studies.

Table 7.1. Firm Characteristics and Environmental Performance

Characteristic	Hypothesised Relationship	Evidence
Firm Size	Larger -> improvement	Generally supported
Capital Vintage	Newer -> improvement	Not supported
Trade Ratio	Highly traded -> improvement	Weakly supported
Investment Source	Foreign -> improvement	Not supported
Source of Equity	Public shareholdings -> improvement	Generally supported
Capital Availability	Internal -> improvement	Generally supported
Institutional Characteristics	Private firm -> improvement	Generally supported
Proximity to Final Consumers	Closer -> improvement	Weakly supported
Diversity of Product Lines	Specialisation -> improvement	Generally supported

The findings with respect to some of these relationships are supported by the results of the OECD project. Facility size has a positive relationship with respect to both the environmental performance and action variables in most of the models estimated. In addition, the profitability of facilities has a positive and significant influence in many cases. While results for other factors such as whether the facility manufactures final goods or capital vintage are more mixed, support for these hypotheses is mixed, weak or non-existent in previous work.

As in other areas, there is a particular interest in the role of public policy on environmental performance. The determinants of undertaking significant environment-related investments and self-reported reductions in environmental impacts were assessed with respect to air and water pollution, as well as solid waste. Perceived policy stringency consistently appears to be significant in a wide variety of models estimated for these three

areas. Reported frequency of inspections is also a significant determinant of environmental performance and actions.

As with previous work, the role of instrument choice is less evident. Performance standards – perhaps the most common policy instrument actually applied in the countries sampled – have a positive influence in a large number of the models estimated. Reliance on input taxes occasionally has a negative influence and there is no obvious reason why this may be the case. One possible explanation is that they are often set too low for political reasons. However, this effect would be reflected by a statistically insignificant result (*i.e.* not a significant and negative result), unless the introduction of a tax makes it less likely that other measures will also be introduced.

As noted above, there are a variety of channels through which other stakeholders and groups can influence the environmental performance of manufacturing facilities, and there is a growing body of evidence in this area. In particular, much research has been undertaken on the role of financial markets, with some support for the role that financial markets can play in providing incentives for improved environmental performance. In many cases such studies examine the effects of environmental “news” (good or bad) on stock market valuations. Longer term impacts such as the implications of environmental performance on “return on assets” are also sometimes assessed.

Given the widespread belief that environmental management systems and tools support improved environmental performance, it is not surprising to find that policy-makers are providing a wide array of incentives for their introduction. However, what does the empirical evidence tell us about the role of environmental management on environmental performance?

Assessing the precise role of public policy in shaping the management-performance relationship is inherently problematic. On the one hand, it is possible that good environmental management and good environmental performance are reflections of the same underlying phenomenon, with the former not playing a distinct causal role in bringing about the latter. As such, attributing good environmental performance to good environmental management may be inappropriate. Both may be attributable to some other factor - *i.e.* corporate ethics or policy requirements. In such circumstances, the introduction of an EMS or other environmental management tools in a given facility may not cause improved environmental performance.

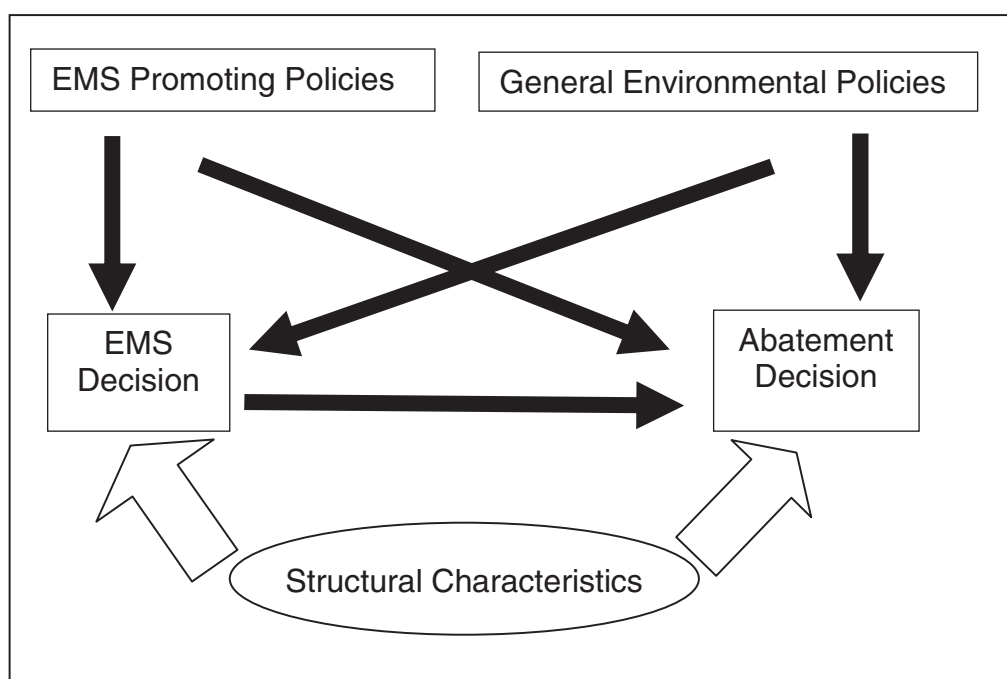
On the other hand, the motivation for introducing an EMS or environmental management tools may also have an important influence on the strength and direction of the management-performance relationship. In particular, the provision of different targeted policy incentives for the introduction of an EMS may affect the role it plays in terms of environmental performance. For instance, the perception that the introduction of an EMS will reduce inspection frequency or provide some other regulatory relief of different forms may “break” the apparently positive management-performance relationship. Moreover, they may be particularly attractive incentives to the “worst” performers. Given the robust evidence of the statistical significance of the first of these factors (inspection frequency) on the decision to introduce an EMS, this is potentially important in policy terms.

Therefore, it is necessary to examine not only how EMS-promoting policies affect the decision to introduce an environmental management system, but also the consequent effect that this has on actual environmental performance. Given that general environmental policies such as regulatory standards and environmental taxes may also

affect the EMS decision differentially (and not only environmental performance), it is necessary to examine all of these relationships simultaneously.

Figure 7.5 illustrates the possible influences on the facility's environmental practices and performance, with EMS-promoting policies affecting both the EMS decision and environmental performance directly (*e.g.* if the incentive relates to inspection frequency or regulatory stringency) and indirectly via the influence of EMSs on environmental performance. In addition, more general environmental policies may influence not only environmental performance (as intended), but also the EMS decision. For instance, if EMSs provide valuable information on potential hazardous waste generation, small changes in liability regimes can influence the EMS decision significantly.

Figure 7.5. Direct and Indirect Influences of Policy Measures on Environmental Performance



In the empirical work undertaken for the OECD project, the presence of an EMS is consistently shown to have a significant positive impact on performance. However, the results are somewhat less significant when possible endogeneity is addressed - *i.e.* when the decision to implement an EMS and to undertake concrete environmental initiatives are modelled as inter-related decisions. This is significant if one wishes to evaluate whether EMSs actually bring about improved environmental performance, rather than just being a reflection of such an improvement. For those facilities with EMSs in place, certification and (less frequently) the length of time since it had been implemented appear to be significant influences on the likelihood of reporting improved environmental performance.

On the other hand, no firm evidence was found in the OECD project that facilities which introduce EMSs in order to signal their good intentions to regulators (*i.e.* to reduce inspections, to expedite permits, or to reduce stringency) are less effective than those who introduce EMSs for other reasons (*i.e.* to manage environmental impacts more effectively). Even if the introduction of an EMS results in lower inspection frequency for

a particular facility, the role that EMSs play in encouraging good environmental practices dominate any possible negative consequences. Nonetheless, the significant role that such incentives appear to play in the EMS decision for some facilities warrants further analysis of this question.

Environmental and commercial synergies

The links between environmental and commercial performance have become an area of increased interest to both private firms and regulatory authorities. It has been argued that environmental policy can lead to “win-wins”, with improved environmental performance co-existing with improved commercial performance (Porter and van der Linde, 1995). However, others question the extent to which this is likely to be the case, and the implications that it may have for public policy (Palmer *et al.*, 1995).

At the level of the individual facility or firm, there is little question that opportunities to improve both environmental and commercial performance may arise in cases where there is a close link between the use of commercial resource inputs and a given environmental impact, and the firm has not previously been using the resource input efficiently. Examples include increased efficiency in the use of fossil fuels (potentially reducing greenhouse gas emissions and associated air pollutants), process water (potentially protecting aquatic ecosystems and fish stocks), and wood fibre (potentially conserving natural forest habitats).

By using the resource more efficiently, the firm will drive down its costs of production and incidentally both conserve scarce natural resources and protect environmental quality. Analogously, where there are significant potential financial liabilities associated with any negative environmental impacts arising out of a firm’s production practices, measures taken to reduce such liabilities will yield both commercial and environmental benefits. The costs of raising capital on stock markets or from banks, as well as the costs of insurance will be lower than would be the case in the absence of having undertaken such measures.

Secondly, such opportunities may arise in cases where the firm is able to sell its products on the basis of the customers’ use of marketed inputs (which themselves have close links to environmental impacts). Most obviously, this relates to energy-saving and water-saving consumer durables and capital equipment, with similar environmental benefits to those discussed above. Increasingly, liability for the costs of end-of-life disposal may also be a factor in the consumer’s purchase decision.

In this case, the firm is able to capture market share, and thus to realise commercial benefits, by selling its products on the basis of the lifetime financial costs of the good for the customer. The widespread use of energy-efficiency labelling for appliances and fuel efficiency labelling for motor vehicles is evidence of the potential importance of such opportunities. In many cases, firms are explicitly seeking to capture market share by emphasising both the private financial benefits to the consumer and the public environmental benefits. In such cases, the complementarity between demand for the private good and the public good is exploited.

Thirdly, environmental-commercial opportunities may arise in cases where the firm is able to exploit the value which the customer attaches to the public environmental good, even though the product itself remains essentially the same. In this case, it is only the benefits in terms of public environmental benefits which are used to capture market share

or rents. This may be done directly in the means by which the product is marketed (“product differentiation”), or more indirectly based upon the reputation for the firm as a whole (“firm branding”). Unlike the previous case, such a strategy can be pursued even in sectors where the commodity marketed is homogeneous (*i.e.* electricity service providers), reflecting the fact that the consumer’s decision is based entirely on demand for public environmental goods and not any associated private benefits. And since, the intention is often to distinguish oneself or one’s product from principal competitors in relative terms, it can even be successful in so-called “dirty” industries.

Fourthly, environmental-commercial opportunities may arise in cases where there is a close link between the effects of the production process on public environmental goods and non-financial attributes of the product which are valued by customers. The example of organic agriculture is illustrative. On the one hand, through reduced chemical pesticide and fertiliser use organic agriculture practices may reduce runoff of water pollution, protecting public environmental goods. On the other hand, there is widespread perception that consumption of organic foods may be beneficial for personal health reasons. As such, there may be private demand for organic agriculture, irrespective of concerns about the public environmental benefits.

Anecdotal evidence suggests that financial benefits do exist for “green” firms. In many cases, good environmental practices do appear to result in reduced resource inputs, resulting in very significant direct cost savings. It is not surprising to find that the incentives for firms to improve their operational efficiencies by reducing their production inputs, waste treatment costs, and long-term liabilities can result in significant environmental benefits. In addition, even if there are no cost-savings, demand-side factors may result in increased market share or rent capture.

In the OECD project, the link between facilities’ environmental and financial performance was examined. The assessment of the links is complicated by the fact that many of the factors which result in good environmental performance also result in good commercial performance. A firm which is active on international markets, is listed on the stock exchange, and which has good management practices is also likely to be a good performer both in environmental and commercial terms. As such, it is important to account for this when assessing the environmental-commercial performance relationship.

The results of the empirical work undertaken indicate that anticipated cost savings appear to play a significant role in encouraging improved environmental performance with respect to natural resource use and solid waste generation, but not for wastewater effluent and air pollution. This is not surprising since in the former two cases there is likely to be a much stronger relationship between private commercial interests (material and resource efficiency) and public environmental goals (reduced environmental externalities). No direct support is provided for the role that environmental performance has on commercial support via firm branding or product differentiation.

Interestingly, the results also show that the perceived stringency of the environmental policy regime is associated with lower commercial performance (profits and sales). There is no evidence that the stringency of public environmental policy can help firms identify opportunities which are in their private commercial interest. Indeed, since the effect is negative and significant this runs counter to the argument often forwarded that public environmental policy is “costless” for the individual facility.

Moreover, there is no significant difference in these results depending upon the types of policy measures introduced. This is not surprising. At the aggregate level it is clear that

more efficient instruments will result in lower aggregate costs due to improved allocation of resources across facilities. However, for individual facilities there is no reason to expect that more “efficient” instruments will always be less costly, for a given level of environmental performance.

These results are in many senses very reassuring. The result that improved commercial and environmental performance go hand-in-hand highlights the potential for significant “win-wins”, and that many facilities are exploiting these opportunities. However, these opportunities are not induced through policy stringency. This could be considered as evidence that policy-makers are (rightly) focusing their regulatory efforts on areas which would not be otherwise addressed by private firms in their decision-making.

Conclusions

Assessing the effectiveness of public environmental policy measures necessitates a good understanding of environmental management, investment, and performance within firms and facilities. Some of the main OECD findings include:

- 1) Those facilities which see the environmental policy framework as “stringent” are more likely to have undertaken significant investments with respect to a variety of environmental impacts, as well as to have reduced the effects of their production practices on these environmental impacts.
- 2) Investment in environment-related research and development is encouraged by policy stringency. By changing the relative prices (or by introducing production constraints), policy stringency provides incentives to search out alternative means of improving environmental performance. Conversely, the argument that environmental policy stringency “uses up” financial resources that could otherwise been used to generate environmentally-beneficial innovation is *not* supported in the OECD results.
- 3) Good environmental performers are more likely to report being profitable and to experience sales growth. However, the role of perceived public environmental policy stringency on commercial performance (profitability, value of shipments) is consistently negative. This suggests that those “win-wins” that do arise are not induced through public policy – they emerge as a consequence of incentives internal to the firm and the market in which it operates.
- 4) There is no strong evidence that using either “direct” regulations or market-based instruments affects environmental performance (either positively or negatively) at the level of the facility.
- 5) The choice of policy instrument does affect the means by which an individual facility will achieve its reported environmental performance. Policy flexibility directly induces environmental R&D. Introducing more flexible instruments can also have a positive indirect influence, by encouraging introduction of environmental accounting – which in turn encourages investment in environment-related research and development.
- 6) Implementation of environmental management systems and tools has a positive effect on environmental performance. Moreover, for facilities that have already implemented environmental management systems, there is some evidence of a positive role being played by third-party certification, as well as by the length of time in which the EMS has been in place.

- 7) EMS and related tools (such as environmental accounting and reporting) provide information which is helpful to managers in their efforts to ensure compliance with environmental policies and improve their environmental performance more generally. However, the role of public policy seems to be less significant in this decision than that of other influences (especially downstream buyers).

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Chapter 8. Measuring Minimal Manufacturing

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Introduction

A great deal of natural resources is used to make products and substantial amounts of materials and energy are wasted at the end of the flow. Looking at market flows, suppliers produce products to meet the specific demands of users. Because the market itself is governed by economic principles, cost and performance are the most crucial factors, with less attention paid to the effects of using resources and wasting materials and energy. The environment or ecological system may collapse if we continue to leave things solely to economic principles.

This leads to a very simple but essential policy: “we have to produce high performance products which meet market demand while using the minimum amount of resources and wasting the minimum amount of materials and energy. “*Minimal Manufacturing*” is defined as “the manufacture of the highest performance products through minimal resource input and minimal energy use (in terms of manufacturing cost and environmental load), while maintaining minimal environmental load in the disposal stage”.

This will help establish the technological base which leads to industry innovation for a sustainable society. Here, a question arises; “what is the standard or criterion of “minimum” for a sustainable society?” The less the amounts of used resources, wasted materials and energy, the smaller the environmental burden. However, this frequently suppresses sound developments in industry and economy. For this reason, the Minimal Manufacturing Index considers competitiveness in economic activities and the specific AIST technologies which would meet those conditions.

Minimal Manufacturing Index

The use of exergy

When we take a look at the lifecycle of a product from the beginning to the end, namely, from design to waste, we can find that there are different space-time ranges with which that product is involved during the life. The product is designed and made within the production range. In this stage, the consumed raw materials and energy should be minimized without sacrificing performance or function. After the product is supplied to users, its performance and function should satisfy their requirements, while the energy (power, fuel, etc.) needed during usage should be minimized. Also, the higher reliability

and durability make the usage-time longer, giving more value to it. When the product runs out, it comes to the stage of disposal. It should be recycled or reused as much as possible so as to minimize the waste and reduce the environmental burden.

The aims and items of the “minimum” depend on the stages such as production, usage and disposal. With expanding the space-time range, it takes different aims and items. As already stated, the environmental impacts in the different stages are affected and interact with each other in very complicated ways.

To minimize the environmental impacts in total, we need to have an index which can commonly describe “quantities of state” for energy, resources, and products in those stages. One of the most potential indices will be “*Exergy*.” There are a variety of inputs and outputs of resources, products, energies, and wastes in different stages. The number of inputs and outputs increases with the size of the stage, say, from specific process to society. This makes comprehensive evaluation difficult and complicated. Exergy is the “quantity of state” which can commonly deal with these inputs and outputs as well as fixed values in each stage.

The concept of exergy

Assume that there are two artificial products, A and B, whose exergies in the production stage are different from each other like these. Then after the usage and disposal, A’s exergy in waste state is still high while B’s is nearly equal to the environment standard. This difference can be regarded as degree of environmental impact (Figure 8.1).

In thermodynamics, exergy has been defined as a measure of the actual potential of a system to do work. Exergy is also considered as entropy-free energy in energetic, biological and other systems. It is generally expressed by the following equation¹⁾.

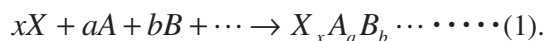
$$E_x = (H - H_0) - T_0 (S - S_0)$$

E_x , H , S , and T are the exergy, enthalpy, entropy and the absolute temperature, respectively. And the subscript, “0” stands for the environment standard. Here, the environment standard is taken as earth resources. Exergy is consumed and then instantly entropy is generated.

Exergy calculations

1) Chemical Exergy Calculations for Metal and Inorganic Compounds

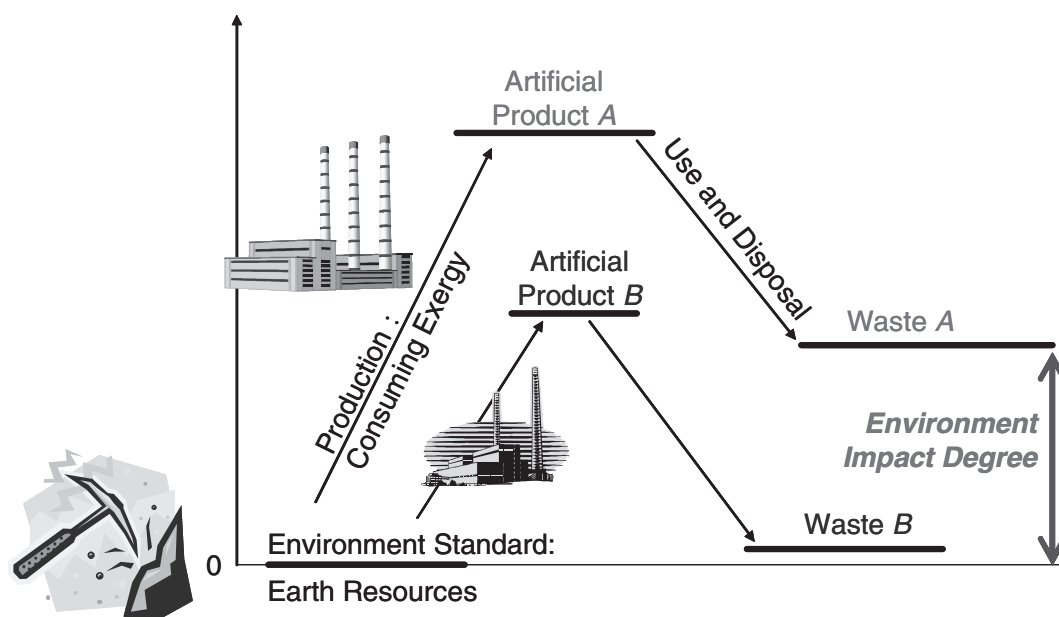
Referential species of inorganic compounds are denoted X_x , A_a , B_b , $\dots$. They are formed according to the following reaction formula.



Using G^0 for the Gibbs free energy change, the chemical exergy of the inorganic compound can be calculated using the equation below.

$$E_x^0 = \frac{1}{x} \left[-\Delta G^0 - aE_x^0(A) - bE_x^0(B) - \dots \right] \dots \dots (2)$$

Figure 8.1. Concept of Exergy



As a reference, the exergy value of a substance is defined as zero if it does not react in a temperature environment of 25°C (298.15 K). Referential species for some artificial materials are published in Japanese Industrial Standards (JIS), but for those not mentioned in JIS, the reference is the smallest free energy value.

2) Chemical Exergy Calculation for Organic Compounds

The chemical exergy equation for organic compounds is derived based on chemical exergy values for the individual hydrocarbon compounds that act as the building blocks of petroleum. Although the formulas of Rant¹⁾ and Szargut are known to be statistically dependent on elemental composition, in this report we revised the Rant formula for solid fuels, and the Nobusawa equation was used for practical application.

$$Ex = m \cdot H_l \cdot \left(1.0064 + 0.1519 \frac{\phi_H}{\phi_C} + 0.0616 \frac{\phi_O}{\phi_C} + 0.0429 \frac{\phi_N}{\phi_C} \right) \dots (3)$$

Here, Ex is exergy. m and H_l are weight (kg) and lower calorific value, respectively (J/kg).

And ϕ_C , ϕ_H , ϕ_O , ϕ_N are weight average of carbon, hydrogen, oxygen and nitrogen, contained in organic compounds.

3) Exergy Calculation for Input Energy (Electric Power, Gaseous Fuels)

The input energy used in this study was from electric power and LPG. The exergy value for electrical power was the same as the electrical energy value, because electrical power has extremely low entropy. The calculation for LPG exergy was based on the Nobusawa equation, as used in the previous section. The distribution was obtained for a mixed mole rate of the exergy values of C_3H_8 and C_4H_{10} (0.2 and 0.8, respectively), and

the mixed entropy was calculated based on the difference between LPG exergy and the lower heating value.

Example: Efficiency of Process in Ceramic Parts and Estimation of Exergy Consumption Rate

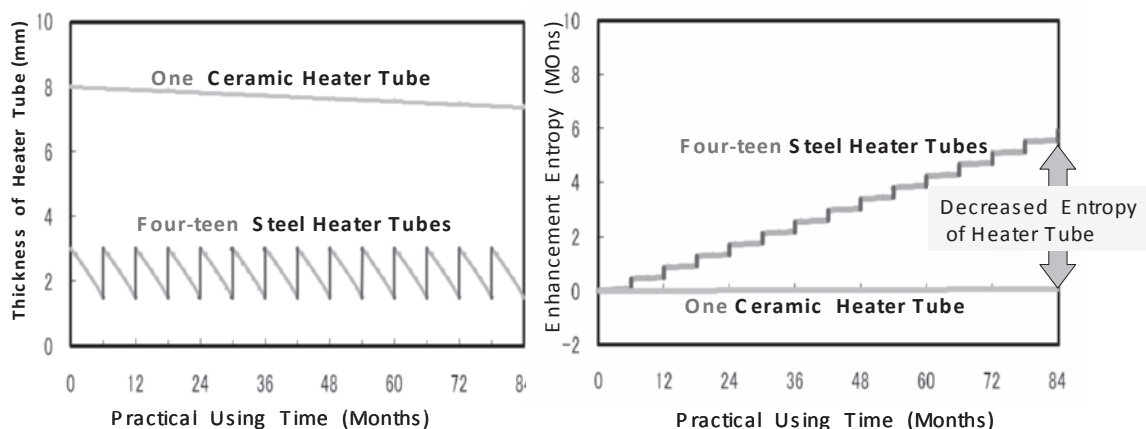
In the melting and casting production of aluminium, silicon nitride ceramics are now being applied as many component materials exposed into the molten aluminium due to their superior corrosion and thermal-shock resistances. One of these applications is ceramic heat-tubes, which contains heat-sources such as gas-burners inside to keep the molten aluminium constant. It is said that use of highly durable silicon nitride heat-tube leads to great improvement of thermal efficiency¹⁾. We made exergy analyses on production of silicon nitride heat-tubes.

Calculation on input and consumed exergies was conducted for individual processes of the production. In each process, raw materials, fossil fuels, water, etc. are put in, and products come out while wasting some amounts of materials, heats, etc. Specific exergy can be obtained from the data on materials, energy, and entropy. In this figure input exergy is negative in Y-axis, and wasted and fixed exergies are positive. In the sum, input exergy is 70 MJ or so for raw materials, 400 MJ for electric power, and 600 MJ for LPG. Some 70 MJ is fixed while 1000 MJ or so is wasted. Efficiency of process, which is the ratio of fixed energy to input, can be calculated as about 7 % in total.

Because exergy is enthalpy difference minus a product of environmental temperature and entropy difference as shown earlier; exergy consumption rate is almost identical with entropy generation rate. Here we compare exergy consumption rates in the melting and casting production of aluminium in the two cases; one is using a silicon nitride ceramic tube which I already introduced before, and the other is a steel heater (Figure 8.2).

A steel heater, which is soaked into molten aluminium, is recessed due to chemical reaction, and is diffused into the aluminium. Therefore, replacement is generally made with intervals of 6 months. The chemical reaction can be considered to occur in generation of entropy. Assume that the reaction proceeds as an exponential function of time. In this case, 6 MOns (Mega Onnes) of entropy is generated for a steel heater.

Figure 8.2. Decreased Entropy by Use of Ceramic Heater Tube



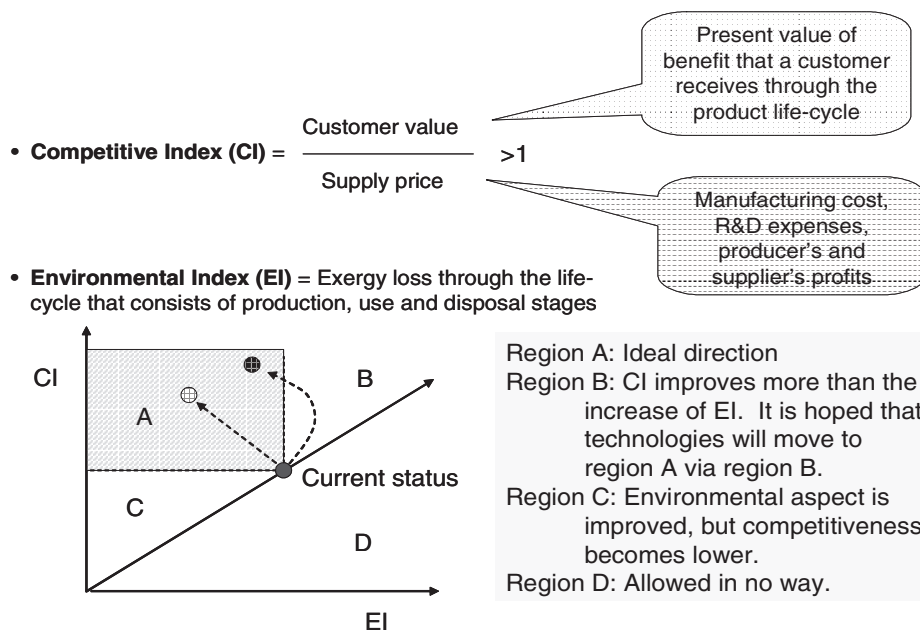
In 7 years, 5287 MOns entropy was generated for steel heaters are used while 4089 MOns for ceramic heater. As mentioned above, a silicon nitride heater does neither react with aluminium even in molten state nor diffuse due to its high stability. This indicates that very little entropy is generated during service. Another advantage of using a ceramic heater is replacement-free operation. Compared to the steel heater, the frequency of replacements is substantially reduced.

Competitiveness implications

In order for a product to be accepted and used in society, the competitiveness of that product is, of course, important besides the environmental impact the product causes. A competitive index of the product, CI, expressed by this equation, is needed beside an environmental index, EI (Figure 8.3). This is given as “customer value” divided by “supply price”. The customer value is the present value of benefit that the customers or buyers receive through the product life-cycle. The supply value includes the manufacturing cost, R&D expenses invested for it, plus profit. The higher the CI is, the more competitive the product is. The EI is defined as exergy loss through the life-cycle that consists of production, use and disposal stages. We have to consider both the two indices in minimal manufacturing.

We here consider the direction to be taken in this EI-CI chart, when developing a new product, assuming the current status is the red point. The most idealistic direction is toward Region A; CI improves while EI decreases. Region B is the case where both CI and EI increase but the former increase is larger than the latter. It is hoped that technology will move to region A via region B. This case is very often seen in actual product developments. When it is toward Region C, environmental aspect is improved, but competitiveness becomes weak. The movement toward Region D is allowed in no way.

Figure 8.3. Minimal Manufacturing Index



Considering customer value, it can be found that it consists of so many factors. These, however, can be roughly divided into three groups; economical, environmental, and emotional values. In the case of automobile, for example, the economical value is how little it costs a user to purchase and maintain a car when the performance is equivalent, or how high performance a car gives a user when the prices and maintenance costs are the same. In most cases this is the most important value. The environmental value is how benign a car is, or how little a car burdens to environment. For example, when we take an energy-saving car, or so called hybrid car run by fuel and battery, we are less burdening environment than driving a conventional one.

The emotional value is the value determined by personal emotion, favour, style, thought, sensitivity, etc., and is generally difficult to be quantified. If one's favourite colour is, say, blue, she or he will choose a car whose body is blue. In this case, this blue colour has some value to that person, though a colour itself has nothing to do with car's performance. Difference between these values is sometimes ambiguous. In the case of driving a hybrid car, one may feel happy, being conscious of less environment impact. In this sense it can be counted as an emotional value as well. There are various types of automobiles. In case of a commercial vehicle, the economical value is the most crucial to owners, who usually are not drivers.

On the other hand, in case of a passenger car, the owners are usually the drivers. While the economical value is still important for popular cars, the emotional value comes to be influential in luxury cars. Automobile users also can be classified into several groups, depending on wealth, age and other factors (family members, region, and character). The purpose of having cars is different from users to users, and therefore, their value also depends on types of users.

Customer values and effects

We here show some examples of products with their economical, environmental, and emotional values. Their effects on supply prices, customer values, EI and CI are also shown together with the corresponding region (Table 8.1).

In case of a hybrid car, its gas mileage will be very good. The company data show that the fuel efficiency becomes almost two-fold. This gives us lower fuel cost as the economical value. I have already stated the environmental value of a hybrid car. Also as above stated, if one feels environmentally benign in driving, she or he may count it as emotional value. Then, in this case, the supply price increases compared to a conventional car, but the customer value increases more, and the resultant CI is improved. Since the environmental impact is small, of course, and the EI decreases (or becomes better), the corresponding region in an EI-CI chart is A, that is an idealistic direction. On the other hand, a diesel car equipped with a PM filtering unit has a worse gas mileage and a lower customer value than that without the unit. Then, the supply price increases but the customer value might be unchanged, lowering both the CI and EI and leading to the region C.

Many people want to have a multi-functional mobile phone rather than a mono-functional one, despite of the higher supply price. Then, the CI is higher but, the EI is also higher due to a lot of exergy loss through the life-cycle, and the corresponding region is B in this case. Efforts should be made so as to shift it towards region A.

Table 8.1. Classification of Customer Values and Effects on the Index

Examples	Customer value			Supply price	Customer value	CI	EI	Region
	Economic value	Environmental value	Emotional value					
Hybrid car	Lower fuel cost	Contributing to energy saving	Feeling envi. benign	+	++	up	OK	A
Lead-free product		Preventing soil and water pollution	Feeling secure	+	+	depends	OK	A or C
Plant-derived plastics		Contributing to oil saving		+	even	down	OK	C
Diesel car with PM filter	Higher fuel cost	Preventing air pollution		+	even	down	OK	C
Multi-functional mobile phone	More functions			+	++	up	bad	B
Healthy tea			Feeling healthy	+	+	up	n/a	
Easy assembly/disassembly product	Lower recycle cost	Enhancing recycle		-	+	up	OK	A
Water-saving lavatory	Lower water cost	Contributing to water saving	Feeling spacious	+	++	up	OK	A

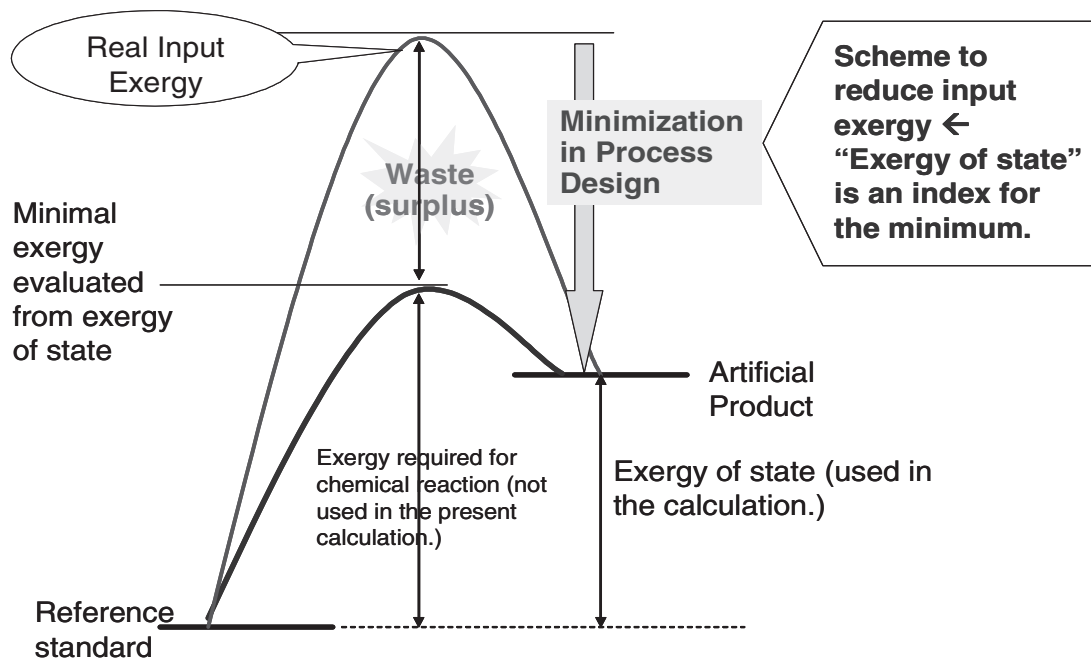
Exergy in process design

Exergy analysis can be very beneficial in process design (Figure 8.4). The exergy of state of the target artificial product is here and that of reference standard is here. Assume that the real process, or process employed currently, is the red line while the minimal exergy evaluated from exergy of state, or the idealistic process. This indicates that there is a great deal of waste or surplus between these two lines. “Exergy of state” is an index for the minimization in the process design and we can know how much we can reduce input exergy. Also we can use exergy as a tool for better material and structure design.

By reducing the exergy of the target artificial product, it is possible to decrease the input exergy in production. For this purpose we have to minimize the material and structure, in other words, to design the material and structure with the same function but lower weight and exergy. As potential approaches, we can give the following examples:

- 1) 1) Integrating functions by nanotechnology. This makes devices and others smaller and lighter substantially, without sacrificing functions.
- 2) 2) Using abundant, natural raw materials. This leads to products close to the reference standard.
- 3) 3) Light weight products by optimizing internal structure and materials microstructure.
- 4) 4) Re-use design, by which newly fabricated parts become fewer.

Figure 8.4. Using Exergy in Process Design



Conclusions

The problems of current industrial technologies can be divided into three categories: inflexibility, complexity and local minimization. Current industrial technologies derived from mass production cannot deal with the various demands of users and rapid changes in markets. In order to solve this problem of inflexibility, a flexible manufacturing system is proposed.

One example is “cell production” which is now frequently employed for final assembly in Japan. Vast numbers of high technology processes currently employed in production lines tend to excessively raise product costs for manufacturing. To address this complexity, we need simplification. Omission of photo-masks in semiconductor IC productions is one of these approaches. Another example is a super ink-jet process being developed in AIST. This process enables us to use a required amount of a material making even the lithography process unnecessary.

Minimization is now carried out locally in individual processes by companies. This local minimization does not lead to “total minimization” in many cases. Unification is a scheme to combine, integrate or unite these individual efforts so that manufacturing is minimized in the entire industry. This can be attained, for example, by utilizing systematically heats and materials wasted in a factory for different production processes in a neighbouring one.

Chapter 9. Auditing Industry Performance

Johanne Gelinas, Deloitte-Touche

Introduction

There is an increasing trend towards requests for auditing the economic, environmental and social performance of companies and their corporate reports as a means for reducing risks and increasing shareholder value, performance and competitiveness. There are a number of drivers for this, including for example:

- 1) increased director liability and board accountability for risk management
- 2) adoption of formal control and certification frameworks (Fairtrade)
- 3) legal requirements for transparency and full disclosure (2002 Sarbanes-Oxley Act, Asset Retirement Obligations)

There is also increasing interest by the investment and financial communities in the environmental and social dimensions of company performance. An example is the Carbon Disclosure Project. In 2003, institutional investors issued greenhouse gas emissions disclosure requests to the Financial Times 500 largest companies. The aim was to facilitate integration of this information into investment analysis. The fourth Carbon Disclosure Project report was released in September 2006 and included responses from 91% of the largest 500 companies. The fifth CDP request on behalf of 280 institutional investors was sent to 2400 global companies in February 2007. Similarly, financial institutions in Canada modelled the impact of the monetization of carbon on selected corporations in a number of different sectors using publicly available information. JP Morgan Chase has announced it will add “carbon disclosure and mitigation to our client review process beginning by year end 2005.”

It is now widely recognised that financial indicators alone do not adequately capture a company’s underlying strengths or vulnerabilities, particularly in areas such as contributions to climate change and also human rights, employment conditions, etc. And it is becoming the responsibility of company boards to monitor both non-financial and financial measures of performance.

Barriers to sustainability reporting

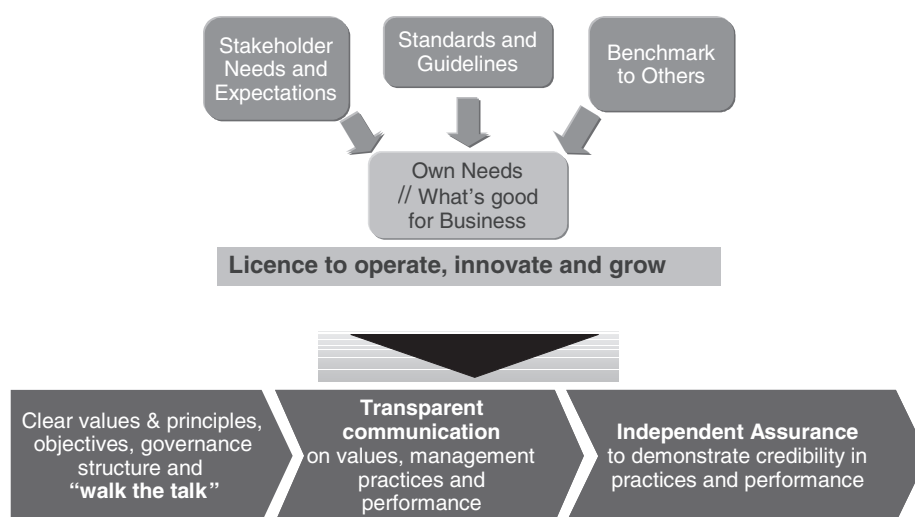
Surveys show that there are two main barriers to the effective usage of non-financial performance measures in the private sector: 1) scepticism that these measures are directly related to the bottom line; and 2) underdeveloped tools for analysing such information.

Another factor is a lack of time among board members and senior management to focus on a new set of metrics.

There is also a crisis of trust in business which cannot be ignored. A 2002 Gallup International Survey showed that private companies are only just ahead of parliaments in terms of public trust and well behind other societal groups. Forward-thinking businesses recognize the need to be accountable to shareholders and others for the impact of their operations on society and are working to re-establish lost ground on the “trust-front”. They are realising that it is their actions in a number of sustainability areas which count, but that they also need to be more transparent.

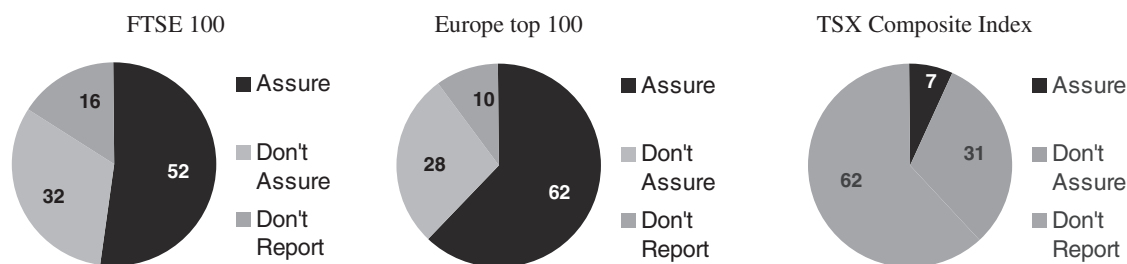
Enhanced corporate responsibility can help rebuild this trust (Figure 9.1). Public trust is achieved through behaviour, transparency and non-biased verification. It is a key success factor for businesses to operate, innovate and grow.

Figure 9.1. Corporate Responsibility as Trust Builder



Trends in corporate responsibility

More companies are issuing corporate responsibility reports in the effort to increase transparency about all aspects of their operations and products, to fulfill the expectations of shareholders, and to bridge gaps with non-governmental organisations (NGOs) (Figure 9.2). Effective assurance or certification of these reports is driven by the demands of stakeholders for reliable information on which to make decisions. According to the Global Stakeholder Report, stakeholders overwhelmingly think that corporate responsibility reports should be verified by a professional assurance or verification body by the following percentages: employees (46%), academics (58%), NGOs (59%) and the financial community (71%).

Figure 9.2. Trends in Corporate Reporting

With regard to the external value of independent certification of corporate reports, it helps a company:

- demonstrate commitment and seriousness in managing the corporate responsibility agenda
- improve overall trustworthiness to stakeholders
- gain higher credibility to assured processes and information
- obtain third party confirmation of compliance to stated standards/ guidelines

There are also internal advantages for firms:

- increasing confidence in the reliability and quality of assessed management systems, data collection, report preparation process and ultimately disclosed information
- gaining professional third party recommendations for improvement of reporting systems
- supporting discipline and professionalism in internal management and reporting
- assisting decision-making in the implementation of future strategy

External certification

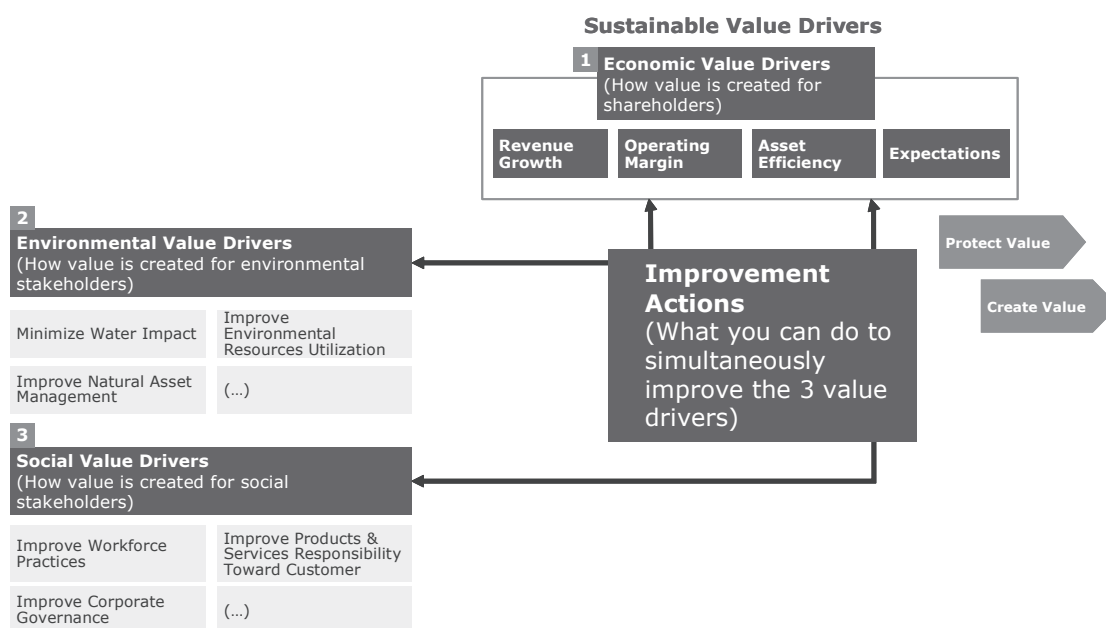
External certification is an evaluation method that uses a specified set of principles and standards to assess the quality of an organization's or company's subject matter and the underlying systems, processes and competencies that define its performance. It is best summed up as: *steps taken to increase confidence in a corporate report*. Assurance and auditing of non-financial data has been conducted by a variety of organizations such as NGOs, engineering firms, accounting firms, etc. All have a different interpretation or approach to assurance and certification. This is evident in the variety of opinions being provided. But the beneficiaries are many: external stakeholders such as investors, regulators interested in assurance and risk, customers, and the media, as well as internal stakeholders such as management and corporate boards and employees.

The key drivers for companies seeking external certification and auditing of their corporate and sustainability reports are:

- transparency: building trust & credibility
- decision making: ensuring credible information to facilitate decision making by stakeholders
- learning: improving management systems through use of processes of continuous improvement
- meeting legal compliance requirements: *e.g.* for financial and environmental reporting.

Companies seeking external certification or auditing of sustainability performance should be clear on their purposes in obtaining assurance, set and communicate realistic expectations both internally and externally, and engage and leverage their resources (people, knowledge, processes, and peers). A road map may be necessary for full success (Figure 9.3).

Figure 9.3. Convergence of Environmental Performance, Social Accountability and Shareholder Value



Chapter 10. Developing a Composite Sustainability Index

Rajesh Kumar Singh, Bhilai Steel, India

Introduction

The concept of sustainable development (SD) has become an important objective of industry leaders. The Brundtland Report defines sustainable development as “*development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs*” (WCED, 1987). There are a number of frameworks for sustainability assessments that evaluate the performance of companies. The World Business Council for Sustainable Development (WBCSD, 1997), the Global Reporting Initiative (GRI 2002a, 2002b) and development of standards (OECD, 2002) have been the foundation for sustainability reporting. There is also a special framework for sustainability indicators for the mining and minerals industry, which is also compatible with GRI (Azapagic, 2004).

Corporate sustainability is a business approach to create long-term shareholder value by embracing opportunities and managing risks deriving from economic, environmental and social developments. Corporate sustainability leaders harness the market’s potential for sustainable products and services while at the same time successfully reducing and avoiding costs and risks. A growing number of investors perceive sustainability as a catalyst for enlightened and disciplined management, and, thus, a crucial success factor.

The steel industry has been an important source of employment and has played an important role in building nations. The steel industry also recognizes that it has a key role to play in sustainable development by raising the living standards of people in both developed and developing countries while not damaging the environment. On the other hand, steel making leads to various environmental impacts like depletion of non-renewable resources, global warming, depletion of land resources, acidification, and depletion of water resources as well as social impacts such as potential threats to the health and safety of employees and effects on communities.

Steel is valued as a major foundation of a sustainable world and this is achieved by a financially sound industry, taking leadership in environmental, social and economic sustainability and seeking continuous development (IISI, 2004). The major challenge to industry is to demonstrate its contribution to the welfare and wellbeing of the current generation without compromising the potential of future generations for a better quality of life. The “triple bottom line” approach is a concept, which addresses the three issues, *i.e.* environmental performance, economic performance and societal performance of the company. Nowadays, many companies recognize and monitor these three aspects using sustainability indicators, which provide information on how the company contributes to sustainable development (Azapagic and Perdan, 2000).

A standardized set of sustainability indicators for companies covering all main aspects of sustainable development has been developed as well as models for integrated assessment of sustainable development (Krajnc and Glavic, 2005b). Comparisons of countries on economic, environment and social issues have also been performed quantitatively. There are more than 600 initiatives working on indicators and frameworks for sustainable development of societies. Despite these sustainability assessment tools, there is still no comprehensive framework for assessing sustainability performance at company level.

Indicators have been applied in various fields such as:

- *Environment*: pilot Environment Performance Index (WEF, 2002), Index of Environment Friendliness (Statistics Finland, 2003), Eco-indicator 99 (Pre Consultants, 2001), Life Cycle Index (Khan, 2004), Korean Complex Environment Index, Environment Sustainability Index (ESI).
- *Economy*: combined consumption level index, human resources development index, composite basic needs indices, OECD composite leading indicators, internal market index (JRC, 2002), Index of Economic Freedom, Index of Sustainable Economic Welfare (ISEW).
- *Society*: physical quality of life, Index of Social Progress, Human Suffering Index, quality of life rankings, Human Development Index (UNDP), overall health system attainment.
- *Sustainability*: Dow Jones Sustainability Index, Index of Balanced Sustainable Development (Seljak, 2001), The Dashboard of Sustainable Development.

Some corporate sustainability indices are:

- Composite Sustainable Development Index (ICSD)
- Dow Jones Sustainability Index (DJSI)
- FTSE4GOOD Sustainability Index
- Ethibel Sustainability Index (ESI)
- Global Responsibility Rating
- Folksam Environmental Index
- Sustainable Value Added

Sustainability policy

Bhilai Steel Plant in India has a sustainability policy (Box 10.1) and faces the key sustainability challenges of a typical steel plant (Table 10.1).

Box 10.1. Sustainability Policy of Bhilai Steel Plant

Bhilai Steel Plant (BSP) is the flagship integrated steel plant of the Steel Authority of India Limited, specializing in production of rails, structurals, plates, wire rods and merchant products. BSP is committed to improving its performance in accordance with the three pillars of sustainability: economic, environment & social areas of operations and undertakes to:

- 1) operate business in an efficient and financially sustainable way in order to satisfy its customers and add value to stakeholders
- 2) optimise the eco-efficiency of its manufacturing processes through conservation of natural resources and increased energy efficiency.
- 3) demonstrate social responsibility by promoting values and initiatives that show respect for people and communities associated with its business.
- 4) engage stakeholders in constructive dialogue to help implement sustainable development.
- 5) foster health and safety of employees and provide healthy, safe and environmentally sound operations and products.
- 6) conduct business with high ethical standards.
- 7) achieve performance improvements through continuous monitoring and review of sustainability indicators.

Table 10.1. Sustainability Challenges for a Typical Steel Industry

Sustainability categories	Sustainability Challenges
Economic	Financial robustness, Cost competitiveness, Cost of product, stock price, Exports, Value added (% of revenue), Operating cost, Return on capital employed, Revenue growth, cost of capital, Turnover, Profitability, Investment on new products and processes, Return on capital employed
Environment	Energy use and efficiency, Resource efficiency, Waste management and recycling, Land requirements, Biodiversity, Air pollution, Eco-design, Effluent quality, Use of ozone depleting substances, Hazardous waste management
Social	Stakeholder engagement and accountability, Quality of life, Expenditure on community development, Health and safety aspects of employees, Public perceptions, Code of conduct and ethics, Education, Health and infrastructure, Value creating partnership, Human rights issues, Job opportunities, Labour practices and management relations, Freedom of association, Customer health and safety,
Technical aspects	Equipment availability, Quality control and defects, Customer satisfaction, Labour productivity, Delivery compliance, Supplier satisfaction, New product development
Organizational governance	Investment and strategic planning, Process management and technological parameters, Raw material availability and cost, Professional growth and good remuneration, Leadership, Corporate governance, Technology, Expenditure on Research & Development, Outsourcing, Consumer education, Future business

Stakeholder engagement process

Stakeholder engagement is central to a company intending to adopt sustainability management. In order to incorporate sustainability management, companies need to work in partnership with other organizations and groups, which have an interest in the company's activities and their economic, social and environmental impacts.

Engagement is an essential element of the business. The aim of engagement is to ensure benefit to both stakeholders and the company. It helps organisations to learn from stakeholders to identify and manage risks, to build trust and strong relationships, and to identify ways to improve our performance. The management's perception towards the stakeholders are *“those groups or individuals, that can reasonably be expected to be significantly affected by the organisation's activities, products and/or services and whose actions can reasonably be expected to affect the ability of the organisation to successfully implement its strategies and achieve its objectives”*.

The benefits of good stakeholder engagement include: (i) access to a greater range of skills and experience, (ii) better understanding of the concerns of groups that can have an impact on the business, (iii) better able to anticipate change, (iv) increased acceptance of company's negative impacts, (v) improved image, (vi) better understanding of stakeholders' expectations of the company and (vii) improved relationships with stakeholder

Information related to sustainability is gathered from stakeholders by concerned departments of the organization. Key sustainability issues are prioritized by management. Objectives and targets are set for the corresponding sustainability indicators and budgets are allocated for its implementation (Figure 10.1). The various stakeholders and their key sustainability challenges related to steel plant are shown in Table 10.2.

Figure 10.1. Stakeholder Engagement Process

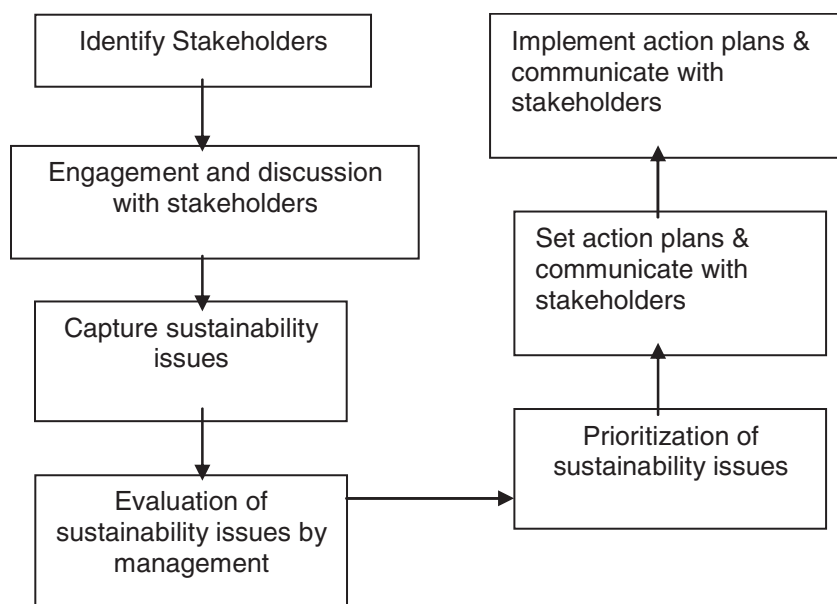


Table 10.2. Stakeholders and Sustainability Challenges in the Steel Industry

Stakeholders	Stakeholder Concerns
Shareholder	Profitability of the company
	Creation of wealth
	Stock price
	Grievances & complaints
Employees	Safe and healthy working condition
	Good remuneration packages & professional growth
	Quality of life & welfare measures
	Training & career development
Suppliers	Partnership with value creation
	Timely payment
	% of local suppliers
	Supplier satisfaction
Customers	Partnership with value creation
	Product Quality
	Delivery compliance & customer satisfaction
	Complaints
Community	Quality of life
	Job opportunities
	Education
	Welfare measures
	Medical facilities
Government	Revenue and tax distribution
	Profitability
	Employment & contribution to GDP
	Safe working & environment compliance
Banks & Insurers	Financial risk
	Debts and borrowings
	Potential liabilities
	Compliance to statutory requirements
NGOs	Environment quality
	Human rights issues
	Freedom of association
	Compliance to Child & forced labour
Regulators	Environmental compliance
	Human rights issues
	Number of accidents
	Compliance to ILO conventions
Professional organizations	Partnership with value creation
	Employment & contribution to GDP
	Training & development
	Ethics violations
Competitors	Knowledge sharing
	Partnership with value creation
	Anti competitive behaviour
	Consumer privacy

Sustainability model

In order to address the integration challenge of the three pillars of sustainability, the sustainability model adopted by Bhilai Steel Plant is shown in Figure 10.2. Leadership of the organization at various levels gives emphasis to a balanced approach towards economic, natural and social capital. The utilization of this capital has been done in such a manner that the impact of the operations is minimized and the value creation is maximized.

Assessment of impacts on these capitals provides direction towards formulation of the company's vision, goals, policies and strategies. These strategies are subsequently implemented across the various business processes of the organization. Key performance results are monitored by the management at various levels through systematic identification of sustainability performance indicators. Indicators provide fuel to the employees for innovation and learning, which is again used as feedback for re-envisioning and updating of strategies.

Stakeholders of the company play a predominant role in identification of key sustainability issues. Inputs of stakeholders are used for the preparation of sustainability objectives and targets. After implementation of objectives and targets, the value creation is evaluated and communicated to the stakeholders. The various management tools adopted by Bhilai Steel Plant for addressing sustainability issues are given in Table 10.3.

Figure 10.2. Sustainability Model of Bhilai Steel Plant

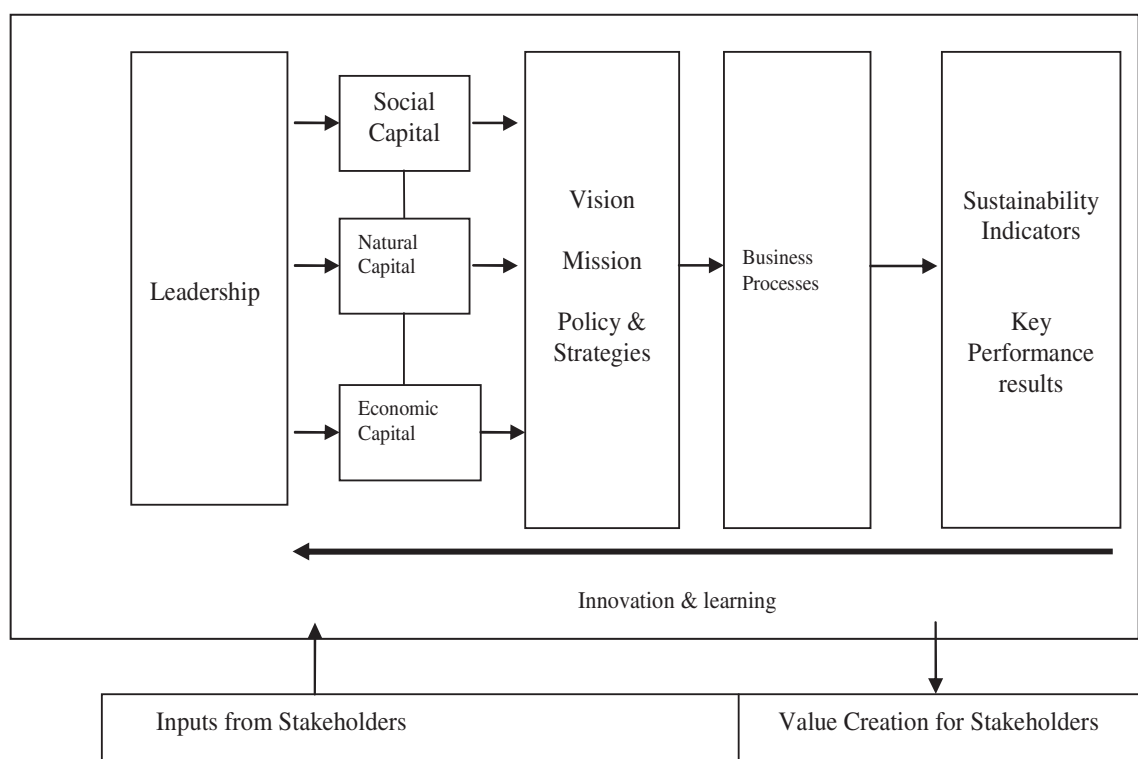


Table 10.3. Management Tools Adopted by Bhilai Steel Plant

Environment Management Systems as per ISO 14001	Clean Technology/ Pollution Prevention	Quality Management Systems (ISO 9001:2000)	Occupational health & Safety (OHSAS 18001)
Environment Performance Evaluation	Environment consideration at design stage	Quality Circles	Social Accountability (SA 8000)
Life Cycle Assessment	Environment Impact Assessment	Knowledge Management	
Environment Management Information System	Green Supply Chain	Six Sigma	
Sustainability Management System	Clean Development Mechanism	Benchmarking	
Sustainability Reporting	Environmental Accounting	ERP/MES	

Sustainability indicators

Defining sustainability criteria in operational terms is a primary requirement towards addressing sustainability challenges. It is imperative that the criteria selected should mimic as closely as possible the essence of the sustainable development concept. Owing to the large scale operations of the steel industry, a number of sustainability performance indicators are being measured, monitored and recorded on a regular basis. However, every indicator is not relevant to the industry. Therefore, it is essential to identify key sustainability indicators. To accomplish this, we interacted with various functional managers of the steel industry.

For evaluating the sustainable performance of steel plants, all the three pillars of sustainability relating to economic, environmental and societal performance are selected. Organizational Governance and Technical Aspects have also been considered as the fourth and fifth dimensions of sustainability. The sustainability indicators for the corresponding sustainability issues have been identified. A survey was conducted involving experts from different functional areas of the steel company who are directly involved in the sustainability management of the company. The purpose of the survey was to identify the relevant stakeholders and key sustainability attributes/themes/issues of the industry. In order to identify key issues, the experts were asked to rate on a 5-point Likert scale, the level of importance of each item *i.e.* 1 = not important, 5 = very important. The results of the survey were compiled, where the mean value of each factor is determined. The sustainability issues are arranged in descending order of their mean values.

Quantitative indicators were selected for environmental, economic and social performance. However, most of the attributes from organizational governance and some from societal performance are based on qualitative sustainability themes or issues instead of quantitative sustainability indicators. The various themes of organizational governance are the enablers for achieving continual growth in the business. The identified key sustainability indicators along with prioritized weights for organizational governance, technical aspects, economic, environmental performance and societal performance are summarized in Table 10.4.

These key SPIs are prioritized based on the Analytical Hierarchy Process (AHP). The categorization of sustainability indicators for economic, environmental and societal

performance as per sustainability reporting guidelines based on the Global Reporting Initiative (GRI) G3 guidelines, have been suggested for a typical steel industry. These data are collected and compiled on a regular basis. IISI member companies worldwide reported voluntarily on the eleven sustainability indicators which are demonstrated as appropriate measures of sustainability for the steel industry (IISI, 2004).

Table 10.4. Key Sustainability Indicators

SI No	Organisational Governance	Technical Aspects	Economic	Environmental	Society
1	Leadership	Coke rate (Kg/thm)	Gross margin/turnover ratio	Particulate Matter stack emission load (Kg/tcs)	Nos of fatal Accidents
2	Strategic planning & resource mgmt	BF productivity	Net profit/ average capital employed	Percent utilisation of total solid wastes (%)	Accident Frequency rate
3	Cost competitiveness	Labour productivity	Net profit/ total income or revenue	Specific energy consumption (Gcal/tcs)	Absenteeism rate (% of total mandays available)
4	Management tools	Export tonnage ratio	Investment in new processes and products (% of revenues)	Specific Raw material Consumption (tonnes/tcs)	Nos of employees trained (mandays /employee/yr)
5	Innovation & Knowledge mgmt	Defects (%)	Turnover/ Inventory ratio	Specific water consumption (m3/tcs)	Expenditure on peripheral development
6	Technology & Investment	Special grades production (%) of saleable steel		Specific carbon dioxide emissions (kg/tcs)	Employee satisfaction
7	Human resource management	New product development (% of saleable steel)		Specific effluent load (kg/tcs)	Quality of life
8	Order generation market dev. & customer satisfaction	Market performance (% increase in domestic share with prev. year)		Specific refrigerant consumption (kg/tcs)	Employment generation
9	Materials Mgmt	Customer satisfaction Index		Specific power consumption (Kwh/tcs)	Non-discrimination, diversity & opportunity
10	Research & Development	Savings through suggestions & QC projects (Rs/tcs)		Specific refractory consumption (kg/tcs)	Freedom of association
11	Process mgmt	Cost reduction (Rs/tcs)		Percentage green cover of total plant area (%)	Child & forced labour and human rights compliance
12	Information technology	Equipment availability (%)		Specific Hazardous waste generation (kg/tcs)	Suppliers & contractors practices
13		Order compliance (%)		Specific Heavy metals discharge load (kg/tcs)	Concern for local communities
14		No. of complaints		Average Noise level in the periphery of plant (dB)	Customer health & safety
15				Overall average Opacity (%)	

Composite Sustainability Performance Index

Composite indicators are an innovative approach to evaluating sustainable development. Computing aggregate values is a common method used for constructing indices. An index can be either simple or weighted depending on its purpose. Indices are very useful in focusing attention and, often simplify the problem (Atkinson *et al.*, 1997). Such an approach allows for the evaluation of a multitude of aspects, which can then be deciphered into a single comparable index. The detailed methodology for development of composite sustainability performance index is discussed. (Singh *et al.*, 2007)

It is frequently argued that composite indicators are too subjective, due to the assumptions in estimating the measurement error in data, mechanism for including or excluding indicators in the index, transformation and/or trimming of indicators, normalization scheme, choice of imputation algorithm, choice of weights and choice of aggregation system. A combination of uncertainty and sensitivity analysis can help to gauge the robustness of the composite indicator, to increase its transparency and to frame policy discussions. Sensitivity analysis is the study of how output variation in models such as a composite indicator can be apportioned, qualitatively or quantitatively, to different sources of variation in the assumptions. In addition, it measures how the given composite indicator depends upon the information that composes it. A synergistic use of uncertainty and sensitivity analysis is proven to be more powerful (Saisana *et al.*, 2005; Tarantola *et al.*, 2000).

The weights of indicators in each pillar of sustainability are ascertained using Analytical Hierarchy Process (AHP) model. The research in this paper has focused on formulating an AHP-based model to evaluate the sustainability performance of the company. However, the concepts of the development and the structure of the model will be easily adapted to any type of industry. This model enables industry to identify the key sustainability performance indicators and provides framework for aggregating the various indicators into the Composite Sustainability Performance Index (CSPI). The calculation of CSPI is a step-by-step procedure of grouping various basic indicators into the sustainability sub-index for each group of sustainability indicators. Sub-indices then subsequently derived in the form of aggregated index. Liberatore scoring and Z score method were employed for aggregation of indicators (Singh *et al.*, 2007).

The Analytical Hierarchy Process (Saaty, 2000) is a decision approach designed to aid in the solution of complex multiple criteria problems in a number of application domains. The method is a multiple step analytical process of judgment, which synthesizes a complex arrangement into a systematic hierarchical structure. It allows a set of complex issues that have an impact on an overall objective to be compared with the importance of each issue relative to its impact on the solution of the problem. The AHP modeling process involves four phases, namely, structuring the decision problem, measurement and data collection, and determination of normalized weights and synthesis-finding solution to the problem. The decision-maker judges the importance of each criterion in pair-wise comparisons.

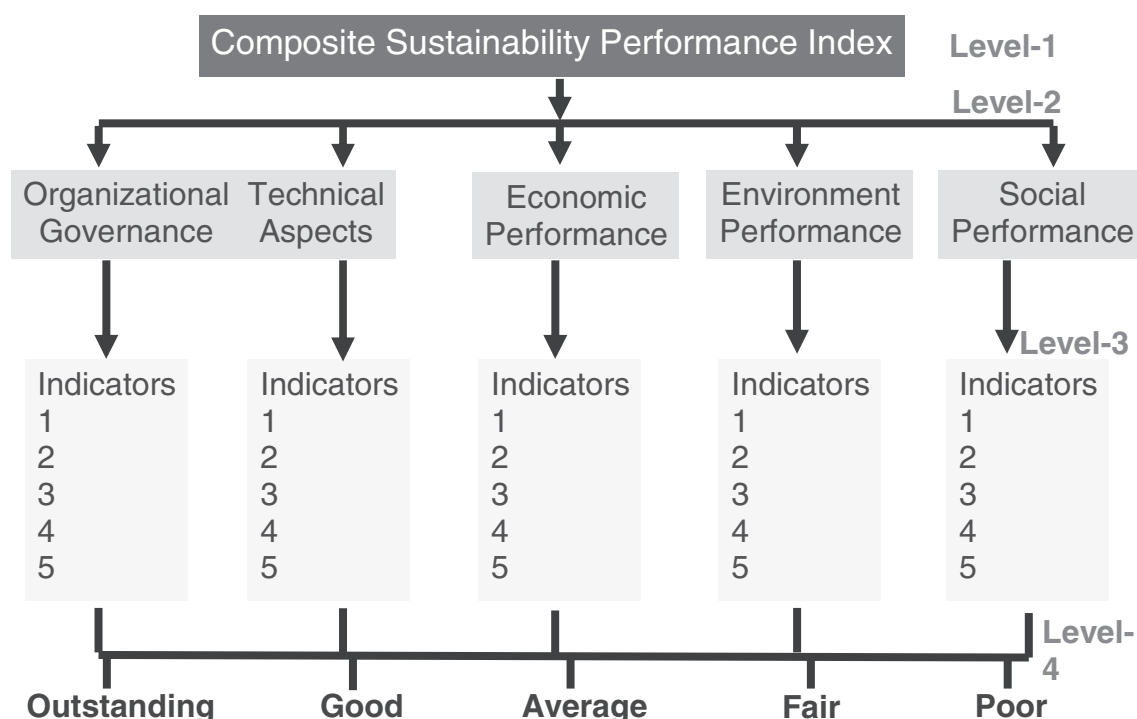
The objective or the overall goal of the decision is represented at the top level of the hierarchy. The criteria and sub-criteria contributing to the decision are represented at the intermediate levels. The second step requires pair-wise comparisons to be made between each pair of indicators (of the given level of the hierarchy). The AHP compares decision

factors by pairs and assigns weights to reflect their relative importance. The next step is the synthesis of the pair-wise comparison matrix to obtain the relative weights of the selected indicators. Saaty (1980) has shown that solving the right eigen vector of the matrix will provide an excellent estimate of the relative weights of the indicators indicating their priority level. The intensity of preference is expressed on a factor scale from 1 to 9. A scale of 1 to 9 is used to reflect the perceived relative importance of a pair of criteria, the larger the number, the greater the importance:

The AHP also provides a measure called the Consistency Ratio (*CR*) to check the consistency of each judgment. Each of the matrices is translated into the corresponding largest eigen-value problem and is solved to find the normalized and unique priority weights for each criterion. The normalized weight for the pair wise comparison judgment (PCJM) matrix has been evaluated for each evaluator ratings. Subsequently, the mean of each evaluator's normalized weights are ascertained at each hierarchy level, to obtain the final relative weights. The excel tool was devised to determine the normalized priority weights

After computing the normalized priority weights for each PCJM of the AHP hierarchy, the next phase is to synthesize the rating for each indicator. The normalized local priority weights of dimensions of sustainability and various SPIs are obtained and are combined together in order to obtain the global composite priority weights of all SPIs used in the third level of the AHP model. The Excel worksheet is used to determine these global priority weights. The various levels of the hierarchy are shown in Figure 10.3.

The goal of our problem is to develop composite sustainability performance index that can be used to evaluate the sustainable performance of the steel industry. The last level of the hierarchy contains the rating scale. This level is different from the usual AHP approach in that a rating scale will be assigned to each SPIs with respect to previous performance, best national and international levels. The use of a rating scale can be found in Liberatore's studies (Liberatore, 1987). The main reason for adopting this method is that evaluation of criteria *i.e.* sustainability indicators involves large number of technical details consisting of several sub-criteria. It may be practically too difficult to make pair-wise comparisons with respect to sub-criteria. Also, it is a time-consuming process. The use of rating scale can eliminate these difficulties as each evaluator can assign a rating to the system without making direct comparisons. As suggested by Liberatore, a five-point rating scale of Outstanding (O), Good (G), Average (A), Fair (F) and Poor (P) is adopted and the priority weights of these five scales can be determined using pair-wise comparisons.

Figure 10.3. General Hierarchy of Composite Sustainability Index

The model has been evaluated based on the real-time application for a steel industry. Wherever, data was not available, synthetic data input were used. To assess the sustainability performance, the proposed model has been applied at Bhilai Steel Plant. Composite sustainability performance index (CSPI) with its sub-indices for each dimensions of sustainability was evaluated for the time period of four years.

By employing the AHP model, framework of CSPI is established. CSPI have been grouped under five categories covering: organizational governance (12 indicators), technical aspects (14 indicators), economic performance (5 indicators), environmental performance (15 indicators) and societal performance (14 indicators) as dimensions of sustainability. A group of experts was formed in order to determine the relative weights of dimensions of sustainability. The relative weights assessed from the AHP matrix for each member have been compiled and mean value is calculated.

Similarly, pair-wise comparisons of indicators for each category of sustainability were performed in order to determine the relative weights of the indicators selected. The first level is defined as goal *i.e.* determination of composite sustainability performance index. The typical pair-wise comparison for second level *i.e.* sections of sustainability, third level *i.e.* for indicators of organizational governance, technical aspects, environmental performance, societal performance and economic performance. A typical example of pair-wise comparison matrix and relative weight evaluation for dimensions of sustainability are shown in Table 10.5.

The evaluated global weights for each level are used in evaluation for the data generated for the period of four years. Expert opinion was taken to give rating to various indicators based on Liberatore's rating system. The overall score and sub-indices of various sections of sustainability are evaluated by multiplying the global weights to Liberatore's rating value and adding the values of respective sections. These scores are

normalized to 10 point rating system, which will yield Rating Score and sub-indices as per Liberatore method. The rating of environmental performance is shown in Table 10.6.

Table 10.5. Pair-Wise Comparison Matrix

	OG	TA	ECO	ENV	SOC
Organisational governance (OG)	1.00	1.00	0.33	3.00	2.00
Technical aspects(TA)	1.00	1.00	0.50	2.00	2.00
Economic (ECO)	3.00	2.00	1.00	3.00	3.00
Environment(ENV)	0.33	0.50	0.33	1.00	1.00
Society(SOC)	0.50	0.50	0.33	1.00	1.00
	5.83	5.00	2.50	10.00	9.00

	OG	TA	ECO	ENV	SOC	Relative Weights
Organisational governance (OG)	0.17	0.20	0.13	0.30	0.22	0.205
Technical aspects(TA)	0.17	0.20	0.20	0.20	0.22	0.199
Economic (ECO)	0.51	0.40	0.40	0.30	0.33	0.390
Environment(ENV)	0.06	0.10	0.13	0.10	0.11	0.100
Society(SOC)	0.09	0.10	0.13	0.10	0.11	0.106

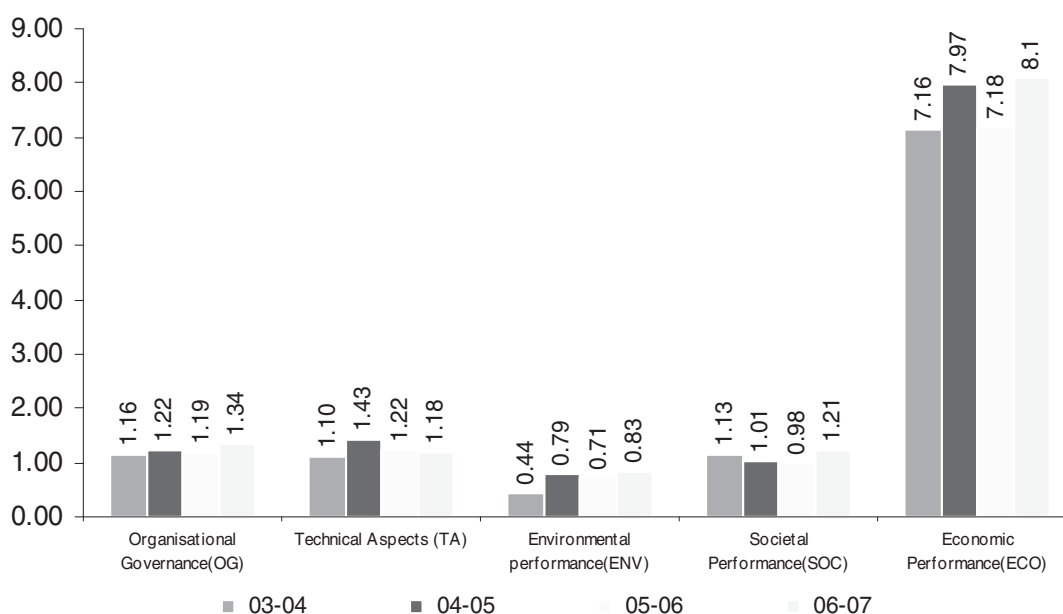
Table 10.6. Liberatore Rating for Environmental Performance Indicators

Sub-factors	Local Weights	Global Weights	Overall Rating	Liberatore score	Rating Score	Max.Weight
Environmental performance (ENV) - Weight: 0.140						
Particulate Matter stack emission load (Kg/tcs)	0.137	0.019	O	0.513	0.010	0.0099
Percent utilisation of total solid wastes (%)	0.111	0.016	A	0.129	0.002	0.0080
Specific energy consumption (Gcal/tcs)	0.111	0.016	G	0.261	0.004	0.0080
Specific Raw material Consumption (tonnes/tcs)	0.119	0.017	G	0.261	0.004	0.0086
Specific water consumption (m3/tcs)	0.079	0.011	O	0.513	0.006	0.0057
Specific carbon dioxide emissions (t/tcs)	0.069	0.010	A	0.129	0.001	0.0050
Specific effluent load (kg/tcs)	0.059	0.008	G	0.261	0.002	0.0043
Specific refrigerant consumption (kg/tcs)	0.022	0.003	G	0.261	0.001	0.0016
Specific power consumption(Kwh/tcs)	0.046	0.006	A	0.129	0.001	0.0033
Specific refractory consumption (kg/tcs)	0.031	0.004	A	0.129	0.001	0.0022
Percentages green cover of total plant area (%)	0.037	0.005	O	0.513	0.003	0.0026
Specific Hazardous waste generation (kg/tcs)	0.044	0.006	A	0.129	0.001	0.0032
Specific Heavy metals discharge load (gm/tcs)	0.040	0.006	G	0.261	0.001	0.0029
Average Noise level in the periphery of plant (dB)	0.032	0.005	G	0.261	0.001	0.0023
Overall average Opacity around the plant (%)	0.062	0.009	A	0.129	0.001	0.0044
					0.039	0.0721
				SILR _{ENV}	5.395	

Similarly, based on the data collected for the company, the mean value of data has been evaluated for each indicator. These mean values are to be given sign + or – based on type of indicator (Negative or Positive). These average values along with the indicator value for the evaluation year, are to be normalized through transformation into Z score. The normalized Z score is multiplied to global weights and weighted normalized score for each indicator is evaluated. The sub-indices are assessed by taking average of all the Z score components for each indicator and multiplying by 100. Adding the sub-indices of

all five dimensions will give scoring based on Z score method. The sub-index for sustainability using Liberatore rating method is shown in Figure 10.4.

Figure 10.4. Sub-Index for Sustainability Using Liberatore Rating Method



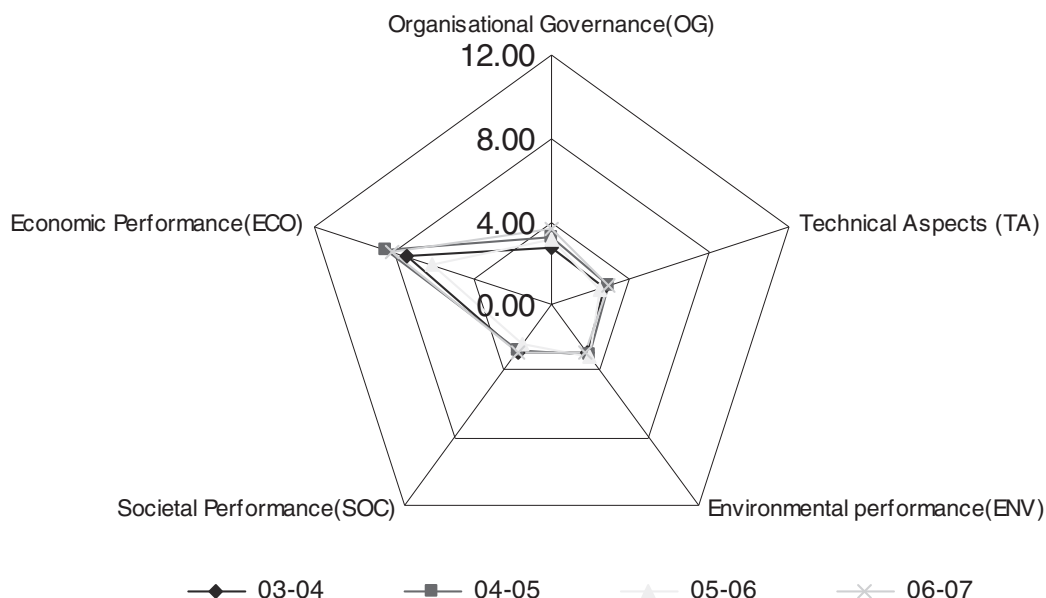
The final Composite Sustainability Performance Index and sustainability sub-indices for organizational governance, technical aspects, economic performance, environmental performance and societal performance for the steel industry based are summarized in Table 10.7. One can also use either Liberatore method or Z score method separately for evaluation of CSPI.

Table 10.7. Composite Sustainability Performance Index

Dimensions of Sustainability	03-04	04-05	05-06	06-07
Organisational Governance (OG)	2.68	3.27	3.11	3.66
Technical Aspects (TA)	2.63	2.83	2.39	2.81
Environmental Performance (ENV)	2.92	3.05	3.09	2.87
Societal Performance (SOC)	2.86	2.69	2.37	2.79
Economic Performance (ECO)	7.41	8.39	6.03	8.09
Composite Sustainability Performance Index	18.51	20.21	16.98	20.22

Visual representation

The visualization of CSPI and sub-indices can also be done through the presentation technique of amoeba indicator (Ten Brink *et al*, 1991) and LCA polygon (Georgakellos, 1997). Georgakellos (1997) proposed LCA polygon technique, which describes impact categories in a radial system of axis. In a hypothetical system of n impact categories, a regular n – sided polygon is formed, the edges of which are inscribed in a circle. Each radius ending on an edge of the circle is a measuring axis for each impact category. The geometry of the shape suggests that the successive axes form equal angles. The actual values of different sub-indices of the company for the evaluation year are to be plotted on the corresponding axes. Joining of point forms a new 5-sided polygon. The larger the area, better sustainability performance of the company. For the graphical representation of the sustainability performance of the company, values of each dimension of sustainability are shown in Figure 10.5.

Figure 10.5. Graphical Representation of Sub-Indices

Conclusion

Steel companies are exploring opportunities to integrate the concept of sustainable development into their business operations in order to achieve economic growth with the assurance of environmental protection and social values. The objective is to achieve a better quality of life for present and future generations. A methodology for sustainable assessment and quantified evaluation of the steel industry has thus been developed. It aims to formulate a uniform methodology for assessment using a composite index for comparison and decision making.

Composite indices are subject to subjectivity despite the relative objectivity of the methods employed in formulating the composite. Composite indices are of a cardinal nature, but remain ordinal in so far as the difference in index values cannot be interpreted meaningfully. Care has been taken to adopt a simplified process so that replication to other industries can be done easily. Attempts have been made to aggregate the indicators in a more scientific manner. The Analytical Hierarchy Process (AHP) is used for identification of key indicators so that sustainability objectives and targets are set to address these issues. The process enables one to assess the sustainability performance for each category and their trends. The model also allows industry to identify opportunities for improvement. The model can also be used in benchmarking exercises and can be adopted for sustainability reporting in accordance with the guidelines of the Global Reporting Initiative (GRI). Investors may evaluate the company's role towards sustainable development or alternatively assess the long term liabilities.

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Chapter 11. Developing a Product Sustainability Index

Wulf-Peter Schmidt, Ford Europe

Introduction

The automotive industry is facing a multitude of challenges in moving towards sustainability that can be partly addressed by product design. All of these challenges present both risks and business opportunities. They include:

- Climate change and oil dependency. The growing weight of evidence holds that man-made greenhouse gas emissions are starting to influence the world's climate in ways that affect all parts of the globe (IPCC, 2007). There are also growing concerns over the use and availability of fossil carbon. There is a need for timely action including in vehicle design.
- Air quality and noise emissions. Summer smog situations frequently lead to traffic restrictions for vehicles which not compliant with emission standards. Other emissions such as noise affect up to 80 million citizens, much of it caused by the transport sector including roads, railways, aircraft, etc. (ERF, 2007).
- Mobility capability. Fulfilling societal demands for mobility is a key factor enabling (sustainable) development. This is challenged where infrastructure is not aligned to mobility demands and where the mobility capability of individual transport modes (cars, trains, etc.) are not fulfilling these needs, leading to unnecessary travel time and emissions (traffic jams, non-direct connections, lack of parking opportunities, etc.). In such areas, insufficient infrastructure is the reason for 38% of CO₂ vehicle emissions (SINTEF, 2007). Industry has also to consider changing mobility needs in aging societies.
- Safety. Road accidents (including all related transport modes as well as pedestrians) result in an estimated 1.2 million fatalities globally.
- Affordability. As mobility is an important precondition for economic development, it is important that mobility solutions are affordable for targeted regions and markets.

The need for integrated approaches

Sustainable product design is only one answer to the challenge of sustainable mobility. Looking at the first item listed above, John Fleming, President and CEO of Ford of Europe, stressed in 2007:

“We, the auto industry, need to take the initiative, accept that consumers are not ready to compromise price or performance for green objectives, accelerate low-carbon technologies, communicate our achievements more constructively and pro-actively, co-operate with the oil companies, and work with governments for support through taxation, incentives and infrastructure”.

A lot of efforts have been devoted to accelerating low-carbon technologies, although their efficiency and costs vary. For example, bio-ethanol vehicles have a very high efficiency ratio in Europe if the whole life cycle and the well-to-wheel performance are taken into account. For full hybrids, efficiency is dependent on the individual share of driving outside cities, *i.e.* the more motorways, the lower the efficiency of current full hybrids. This demonstrates the importance of actions by all stakeholders, *e.g.* fuel providers should establish the necessary station infrastructure offering sustainable bioethanol.

This integrated approach leads to additional, efficient opportunities to reduce CO₂ emissions of vehicles. Examples are eco-driving and gear shift indicators as well as infrastructure measures. For example, the Japanese government includes 28Mt CO₂ reductions through infrastructure measures in its Kyoto Protocol planning. ERF concluded recently that “measures must now be completed by initiatives in the field of road infrastructure which currently represent an underexploited opportunity for energy efficiency gains”, for example by removing bottlenecks and completing missing links “which together cost billions every year in lost fuel” (ERF, 2007). These additional measures affect not only new vehicles but also the existing vehicle fleet. This is one of the reasons for the high efficiency of these measures.

This integrated approach – covering both engine/car technology actions as well as eco-driving, infrastructure, biofuels, tax frameworks and other actions – will deliver the necessary CO₂ reductions from current levels in an efficient and effective way. This is reflected in CARS 21, the stakeholder discussion of the European Commission about a competitive automotive regulative framework for the 21st Century (EC, 2007).

Design for sustainability

The introduction of environmental aspects into automotive design beyond emission and fuel consumption reductions was initially based on the idea that the mechanical recycling of plastics would be key for improving the overall environmental performance of vehicles. Dismantling of plastics had been the only known solution in the early 1990s. In 1993, Ford Motor Company was the first automotive company issuing design for recycling guidelines at the global level. These were focused on parts accessibility, type and number of fasteners as well as parts marking in a design for disassembly approach. Another aspect was reducing the material complexity of vehicles. Later, recycled content targets completed the DfD guidelines for a comprehensive *Design for Recycling* approach.

However, in the late 1990s and the beginning of the 21st century, new scientific evidence challenged this traditional approach.

- Life cycle assessment studies could not confirm that the mechanical recycling of non-metals was significantly improving vehicle impacts from a holistic environmental point of view (Schmidt et al, 2004), etc. In addition, other end-of-life approaches beyond mechanical recycling (feedstock recycling, energy

recovery etc.) were identified as delivering a similar environmental benefit at much lower cost (Nürrenbach et al, 2003).

- Real world tests of dismantling times for parts with different accessibility, fastener types etc. could not verify the theoretical link between Design for Disassembly actions and dismantling time (SEES, 2005).
- Post-shredder treatment technologies replaced the traditional dismantling approach in several European countries, allowing the recycling and recovery of all material mixes in line with European recycling targets in a more economic way while delivering at least the same environmental benefit as the traditional dismantling based mechanical recycling of non-metals (Krinke, 2005).

Therefore, the previous *Design for Recycling* approach was replaced by a more comprehensive *Design-for-Environment* approach (Gottselig, Schmidt, 2001; Schmidt, 2001; Quella, Schmidt, 2003). But this approach did not fit into the challenges of sustainability summarized above. Therefore, first the economic elements were introduced. Then all important aspects of sustainability were tackled with the target to establish a sustainability management tool for the product development of passenger cars (Schmidt, Taylor, 2006).

This process resulted in Ford of Europe's Product Sustainability Index (PSI), which is the first time in automotive industry that various dimensions of sustainability have been combined in a comprehensive set of metrics for steering vehicle development. Sustainable development is defined by meeting "the needs of the present without compromising the ability of future generations to meet their needs" (United Nations, 1987). Normally, this approach refers to three dimensions – environmental, social/societal and economic. Other definitions mention eight or more dimensions of sustainability – physical, properties, environmental, economic, social, equity, cultural, psychological, ethical (Bossel, 1998). However, organisational aspects are also of importance.

Sustainable product design is a subset of a broader approach towards sustainable product development that looks beyond product design aspects to other strategies to improve the sustainability of meeting needs – by products, services and/or organisational aspects, e.g. Sustainable Life Cycle Management (Schmidt, 2006).

Sustainable vehicle design

Besides the general positioning of sustainable vehicle design within sustainable life cycle management, the organisational context has to be clarified. It is of utmost importance in complex, big corporations to make the individual departments directly responsible for that specific aspect of sustainability that can be impacted by their area of responsibility.

The main affected departments include product development, manufacturing but also human resources and external affairs. Each main functional group translates the meaning of sustainability to their own area. This is the best way to allocate understanding, ownership and responsibilities in a complex organization. In the case of automotive products, product development needs very long lead times, longer than any other of the above mentioned functions. Changes in methods take several years to trickle through buy-in, cycle planning, kick-off, development and launch. Product development also has a greater impact on automotive products compared to other organisations of automotive manufacturers.

Sustainable vehicle design is a challenge looking at the complexity of passenger vehicles where engineering management as well as design engineers need to cope with a global supply chain, as well as thousands of technically challenging components linked with severe quality, technical, process and infrastructure constraints. This requires a company-specific solution rather than a one-size-fits-all approach.

Product Sustainability Index

One of Ford of Europe's solutions for managing sustainable product development is the Product Sustainability Index (PSI). While there is so far no international standard for measuring product sustainability, there is a common understanding that life cycle thinking should be the basis of such an approach (VDI, 2006). Therefore, the chosen PSI indicators are partly based on ISO14040 (Life Cycle Assessment) and the current work of SETAC Europe on Life Cycle Costing (SETAC, 2006). Part of the additional guiding principles, for the inclusion of indicators in the PSI, has been the following management directions (Schmidt and Taylor, 2006):

- 1) Key environmental, social, and economic vehicle attributes;
- 2) Controllable as mainly influenced by the Product Development department, not by other functions;
- 3) No additional data (regular status tracking possible based on readily available product development data);
- 4) Bottom-line issues (overall life cycle impact); and
- 5) Manageable number of indicators.

The Product Sustainability Index is not reduced to a single score as sustainability is by definition not one-dimensional but always measured by different indicators. Further reasons have been shared in a previous paper (Schmidt and Sullivan, 2002). Other sustainable mobility aspects – in particular service aspects – are not covered as deemed not appropriate on the engineering level. Also legal compliance issues such as recyclability are not covered within the PSI as these are baseline requirements. Some recycling requirements may not even add environmental benefits (Schmidt, *et al* 2004).

The resulting PSI indicators are (Schmidt and Taylor, 2006):

- 1) Life cycle global warming potential (greenhouse emissions along the life cycle – part of an LCA according to ISO14040).
- 2) Life cycle air quality potential (Summer Smog Creation Potential (POCP) along the life cycle (VOCs, NOx) – part of an LCA according to ISO14040).
- 3) Sustainable materials (recycled & natural materials. All materials are linked to environmental, social and economic impacts and cannot be inherently sustainable. However, recycled materials and renewably grown, natural fibres represent a kind of role model on how limited resources can be used in a sustainable way. Overruling is the question whether these materials have – in their specific application – a lower environmental impact along the product life cycle compared to potential alternative materials).
- 4) Restricted substances (Vehicle Interior Air Quality / allergy-tested interior, management of substances along the supply chain; 15 point rating).

- 5) Drive-by-exterior noise.
- 6) Safety (pedestrian and occupant).
- 7) Mobility capability (mobility capacity (luggage compartment volume plus weighted number of seats) related to vehicle size. This is an indicator in transition towards an indicator covering also aspects of providing mobility services to the disabled).
- 8) Life cycle ownership costs (vehicle Price + 3 years fuel costs, maintenance costs, taxation, and insurance minus residual value).

The implementation of the Product Sustainability Index has been done in a process-driven, top-down approach. Process-driven, as PSI has been linked to the existing Ford Product Development System from the very beginning. For example, Ford's PSI is included in particular in the companies' "Multi-Panel Chart" where all vehicle attributes (craftsmanship, safety, environment, costs, etc.) are tracked, through all the development milestones, against the approved vehicle program targets.

Vehicle Integration engineers have been made responsible by the specific vehicle program management to track the performance of the vehicle against the targets. The PSI targets are determined from already existing targets as listed in other sections of the "Multi-Panel Chart" (*e.g.* fuel economy) as well as PSI specific targets not covered otherwise (*e.g.* related to the maximal impacts from the selected materials). PSI reflects the overall impact of the different vehicle attributes and makes the trade-offs visible (*e.g.* between life cycle global warming potential and the life cycle cost of ownership).

In a top-down approach, senior management demanded and finally authorized the Product Sustainability Index in autumn 2002. The roles & responsibilities have been agreed in a way that mainly all actions and responsibilities are conducted by Product Development itself without using a central staff organization (exemption: development of methodology). This way, an optimal integration of PSI is ensured – *i.e.* sustainability is not the responsibility of specialists (within or outside Product Development) but is executed by the same people running other aspects of the vehicle development.

A comprehensive but very simple spreadsheet file has been developed by a Ford LCA specialist to enable non-specialists to track PSI. This tool has been verified against detailed ISO 14040 external reviewed LCAs (Schmidt and Butt, 2006). Based on the central input of few and select data, the PSI – including the simplified Life Cycle calculations – are tracked from the very beginning of the vehicle development throughout its end. Almost all data used had been anyway readily available in the above mentioned "Multi-Panel Chart". Few additional data have been needed (for example, any material changes and data about air-conditioning systems). With around one hour of training, the responsible engineers have been in the position to understand the concept, use the above mentioned file and conducting simplified Life Cycle avoid unnecessary bureaucratic burdens or the need for additional resources while ensuring that sustainability is an integral part of the complex product development process.

The described approach is designed to fit perfectly into Ford design processes and culture. It is not suggested that this approach necessarily fits to other company cultures or markets as the methodologies and approaches cannot be generalized. Any mandatory approaches would be counterproductive. Sustainability can only work based on internal understanding, drivers, motivations and commitment rather than law and order. PSI is a voluntary approach aiming at integrating environmental, social and economic aspects in

the product development as part of Ford's commitment towards sustainability and creating dialogue around these issues.

Ford Galaxy and Ford S-MAX

The first design team that used the Product Sustainability Index from the beginning developed the new Ford Galaxy and Ford S-MAX. Four vehicles have been assessed:

- 1) New Ford Galaxy 2.0 l TDCi with DPF (Diesel Particulate Filter) Trend edition,
- 2) New Ford Galaxy 2.0 l, Trend edition,
- 3) New Ford S-MAX 2.0 l TDCi with DPF Trend edition,
- 4) New Ford S-MAX 2.0 l, Trend edition.

The environmental, economic and social performance has been compared to the prior Ford Galaxy (1.9l TDI, 96 kW, manual 6 speed version). Within Vehicle Integration, engineers have been made responsible for tracking the status based on the input collected in the "Multi-Panel Chart" and a few additional key data specific for PSI. The additional PSI data related to the material breakdown of the different vehicles have been derived from complete teardown data of the predecessor models, weight assumptions as well as weight actions and finally International Material Data System (IMDS) data. Towards the end of the development, an additional verification study has been performed by a corporate LCA specialist.

The PSI, as well as the internal verification study, has been successfully reviewed by two external reviewers - Professor Dr David Hunkeler (former Universities Vanderbilt in Nashville/USA and Lausanne/Switzerland) and Prof Dr Walter Klöpffer (University of Mainz/Germany) - according to ISO 14040. One of the important findings has been that the life cycle calculations done by the non-experts based on a simple spreadsheet file are fully in line with the results of a more detailed study performed by the LCA expert based on an expert tool (IKP and PE, 2005) (calculated absolute figures are less than 2% below; the relative results are the same).

The PSI application itself (without expert verification study and external review that are not necessary for the internal usage of PSI as a sustainability management tool) is done efficiently. Due to the focus on available data as well as a simple spreadsheet file, the incremental resources needed for the management tool itself have been rather low (approx. 10–15 hours for the whole product development process). However, the efforts for the verification study and the external review are much more significant. This has been only done in this specific case because Ford Galaxy and S-MAX have piloted the PSI application. The verification study allowed to get a better confidence about the accuracy of the PSI calculations while the external ISO 14040 review allowed the publication of the taken efforts.

The PSI status has been tracked for different Gateways (Kick-off (KO), Program Approval (PA), Program Readiness (PR) and Change Cut-off (CC)). Table 11.1 summarizes the results for diesel powered Ford vehicles.

Table 11.1. PSI Results for Diesel Powered Ford Galaxy and Ford S-MAX

Indicator	Previous Ford Galaxy 1.9 L TDI	Ford Galaxy 2.0L TDCi with DPF	Ford S-MAX 2.0L TDCi with DPF
GWP [t CO ₂ -eq] ⁽¹⁾	41	40	39
POCP [kg Ethene-eq] ⁽¹⁾	39	37	37
Sustainable Materials (figures may change)	Approx 1 kg	Approx 18 kg	Approx 18 kg
Restricted Substances	Substance management, pollen filter	Substance management, TÜV tested pollen filter efficiency and allergy-tested label ⁽²⁾	
Drive-by-exterior Noise dB(A)	73	71	71
Safety	Reference ⁽³⁾	Significant improvement ⁽⁴⁾	Significant improvement ⁽⁴⁾
Mobility Capability	9,9 m ² , 7 seats, 330l	10,4 m ² , 7 seats, 435l	10,25 m ² , 5 seats, 1171l
Theoretical Life Cycle Ownership Costs ⁽⁵⁾	Reference	5 % lower costs	10% lower costs

⁽¹⁾ based on PSI calculation that have been verified by an independently reviewed LCA according to ISO14040. LCA done based on the methodology and data described previously (Schmidt et al 2004), (Schmidt and Butt, 2006). GWP – Global Warming Potential; POCP – Photochemical Oxidant Creation Potential.

⁽²⁾ based on an independent TÜV certification, certification number AZ 137 12, TÜVdotCOMID 0000007407.

⁽³⁾ including Euro NCAP safety rating: 3 stars for adult occupant protection, 2 stars for pedestrian protection.

⁽⁴⁾ including Euro NCAP safety rating: 5 stars for adult occupant protection, 4 stars for child protection and 2 stars for pedestrian protection.

⁽⁵⁾ 3 years Cost of Ownership including residual value, no guarantee.

Sustainability management tool

Managing sustainable product development is a challenge including and beyond managing the design in a sustainable way. Ford of Europe's Product Sustainability Index (PSI) can be seen as an example of a sustainability management tool that efficiently guides the development of passenger vehicles. However, this is only one tool in a set of tools covering the different functional areas of an automotive manufacturer. In addition, an integrated approach is necessary to gain additional improvement potentials. This sustainable life cycle management is a central approach to efficiently improve the environmental and socio-economic performance of products as passenger vehicles.

Of course, continuous improvement is one important target. However, the results of the PSI have not only to be seen in relation to the predecessor. Product development management needs to realize also the relative performance of the new vehicle compared to other vehicles in the own product portfolio as well as competition. Therefore, a relative scaling of PSI had been used for internal purposes (Table 11.2). The scaling of the eight indicators has been chosen according to the following principles:

- The higher the number the better.
- The scaling refers to the passenger vehicle range of Ford of Europe without SUVs - Sub-B (Ford Ka) through V (Ford Galaxy). By doing so, all Ford of Europe vehicles can be compared using the same scaling. Some of the different functionalities (mobility capability, safety) are reflected by the different

indicators. NB – The varying levels of comfort are not considered in this analysis. That means a lower PSI score does not allow the interpretation of preferences since not all relevant aspects could be considered.

- For the life cycle related indicators, the lowest figure (0%) represents the Ford of Europe vehicle with the highest environmental and cost impacts (worse vehicles by other companies are not considered a suitable benchmark).
- 80% is set at the theoretically best in industry vehicle in the Sub-B to V segment.
- 100% is going beyond the current best-in-industry level – leaving room for improvement towards sustainability.

Table 11.2. Scaling of PSI Indicators

Indicator ¹	0 % scaling	80% scaling	Vehicles
Life Cycle Global Warming Potential	65587 kg CO ₂ -eq	17500 kg CO ₂ -eq	Prior Galaxy 2.8l V6 automatic / 2002 vehicle ²
Life Cycle Air Quality Potential	58,3 kg Ethene-eq	22,9 kg Ethene-eq	Prior Galaxy 2.8l V6 automatic / 2002 vehicle ²
Sustainable Materials	0%	14,9%	Worst case / best case assumptions ³
Restricted Substances	6 points	12,5 points	80% Ford C-MAX
Drive-by-exterior Noise	82 dB(a)	65 dB(a)	Best / Worst homologated value by KBA
Safety	See below ⁵	See below ⁵	Several vehicles
Mobility Capability	0,216	0,7	0%: 9,94 m ² , 2 seats, 140 l 80%: 3,75 m ² , 2 seats, 180l
Theoretical Life Cycle Ownership Costs ⁴	€ 35508	€ 10984	Prior Galaxy 2.8l V6 automatic / Ka Student

¹ calculated based on same assumptions, calculation rules and tools for all vehicles. Life Cycle data cannot be compared to other studies due to different assumptions

² “Best” performing vehicle sold in Europe in 2002 when the PSI was piloted (no longer on the market).

³ Worst case assumption: 0 kg natural fibres, 0 kg recycled material

Best case assumption: 15,3 kg natural fibres (best competitor), 25,1 kg actual used non-metallic recycled materials (Ford Mondeo; note: based on narrow definition).

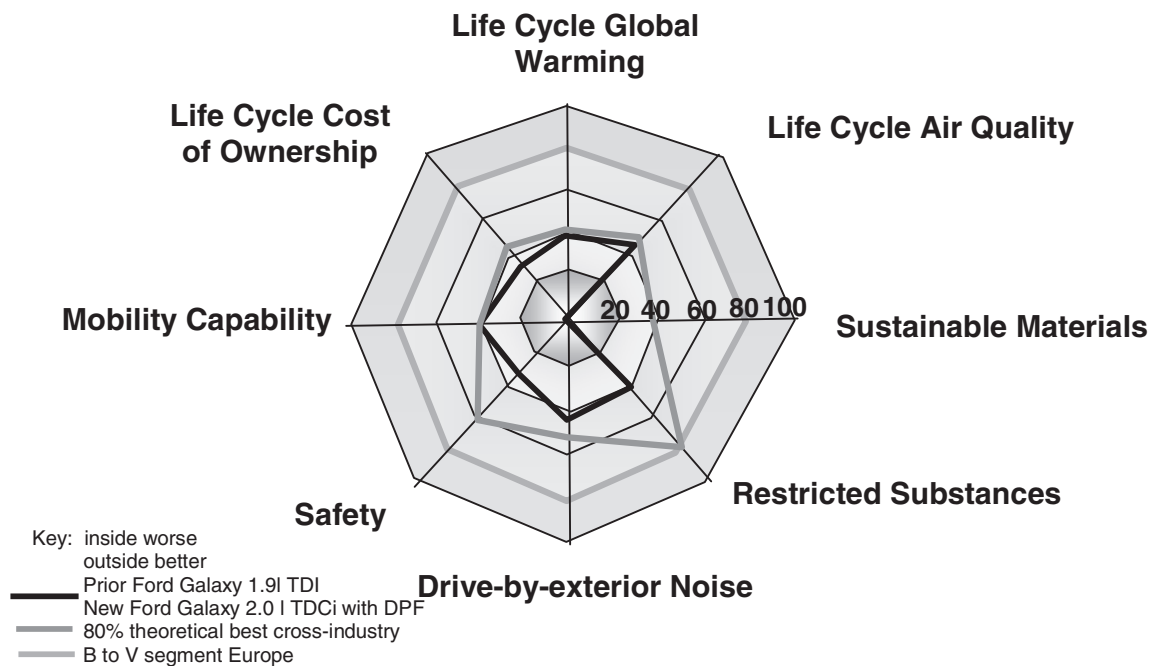
⁴ Referring to 3 years of ownership plus vehicle price (representing the up-stream costs) minus the residual value (representing the down-stream cost aspects). Ford Motor Company does not guarantee that the costs reflect actual market conditions.

⁵ Internal, complex safety indicator including EuroNCAP rating.

Traditionally, sustainability indicators are shown in a radar diagram. The bigger the areas described by the different lines the better. There is no weighting between different indicators of Ford of Europe’s PSI (Schmidt, Sullivan, 2002). Transferring the results in Table 11.1 in relative PSI performance shows that the improvements in most areas are significant (Figure 11.1). The diagram shows in addition which indicator represents an absolute strength or a need for further improvement.

No vehicle can currently perform best in all eight indicators of PSI. Larger vehicles often have a higher mobility capability that results in less favourable life cycle global warming performance (or vice versa). The best global warming performance might be compromised by a not appropriate life cycle cost of ownership. Depending on the market segment, some PSI patterns are typical. Nevertheless, the scaling of PSI always sends the signal to product development management that excellent performance in that segment might be not be best looking at all car segments. Thus further improvements are always encouraged.

Figure 11.1. PSI of New and Prior Ford Galaxy Diesel Variants



Conclusion

Ford of Europe's Product Sustainability Index is one of several different initiatives to address the sustainability challenge for the automotive industry. PSI is a sustainability management tool that can be easily used by vehicle development engineers and their management. Through this approach, product development departments can:

- be made directly accountable for their contribution towards a more sustainable corporation.
- set vehicle targets that lead to improvements in all areas of sustainability.
- visualize trade-offs between conflicting sustainability vehicle attributes.
- track the progress along all gateways of vehicle development.
- relate the vehicle performance relative to the vehicle segment as well as to all passenger vehicles.

This is a good basis for introducing innovative technologies where they are sustainable. However, the basis of the PSI approach is that no additional resources are needed due to the lean and tailored approach. Any mandatory, legal duty in this area would add no value but result in higher resource needs due to bureaucratic rules regarding documentation, auditing, and/or non-tailored methodologies. Instead, the regulatory framework should concentrate on supporting an integrated approach motivating all life cycle stakeholders towards product sustainability.

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OECD PUBLICATIONS, 2, rue André-Pascal, 75775 PARIS CEDEX 16

PRINTED IN FRANCE

(97 2008 02 1 P) ISBN 978-92-64-04412-8 – No. 56117 2008

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