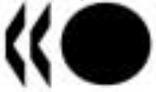


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Working Party on Global and Structural Policies

CLIMATE CHANGE AND ENERGY: TRENDS, DRIVERS, OUTLOOK AND POLICY OPTIONS

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FOREWORD

The *OECD Environmental Outlook to 2020* was published in 2001. That *Outlook* presents an economy-based assessment of environmental pressures and conditions in OECD countries, an indication of practical policy options to change those conditions in a more environmentally friendly direction, and analyses the potential economic and environmental consequences of implementing such policies. It also covers several sectors, one of which focused on climate change and energy. This document contains the primary background material used to prepare that (climate/energy) chapter of the *Outlook*.

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EXECUTIVE SUMMARY

Primary energy use in OECD countries grew by 36% from 1973 to 1998. By 2020 it is expected to grow by a further 30-50%, and by more than 60% worldwide. Commercial and residential energy uses, as well as transport, represent the most rapidly growing demands for energy use worldwide. Energy use is the main contributor to GHG (greenhouse gas) emissions, air pollution and nuclear waste production, and also leads to noise, water pollution, and ecosystem degradation. Energy-related air pollution has significant negative effects on human health.

In the 2020 timeframe, there is a potential for significant improvements in the efficiency and environmental performance of fossil fuel combustion, and for a growing market share for renewable energy and new technologies such as fuel cells. These trends have the potential to lower the air pollution intensity of energy use. However, expected total increases in energy use, combined with an increasing share of electricity in the fuel mix (with its low conversion efficiency) and a projected declining use of nuclear energy, are likely to lead to increased total primary energy use and energy-related greenhouse gas and other emissions.

To achieve significant reductions in energy-related GHG emissions and to meet existing international and national targets in OECD countries, even greater use of renewables and increased substitution to gas, especially in high-efficiency applications, including co-generation, is likely to be required. Improvements in fossil-fuel combustion technologies, including advanced gas turbines and coal gasification, offer considerable emission abatement potential. Falling costs of renewable energy have made wind and biomass cost-competitive in a widening range of applications, and improved power storage technologies, such as flywheel and combined conversion systems, could further assist in the penetration of renewable energy.

Even with these technological improvements, greater attention to demand management will be required to keep energy sector emissions from growing rapidly. Policies aimed at consumer demand management can improve energy efficiency in the residential, commercial, agricultural and transport sectors, as well as promote “green power”. Policies targeting energy-using consumer products will also be essential.

Emissions of greenhouse gases, of which energy use is the largest individual source, are likely to increase substantially in the period to 2020. OECD projections estimate an increase of approximately 33% in CO₂ emissions from energy use in OECD countries from 1995 to 2020, although CH₄ and N₂O emissions are expected to increase more slowly, and in some cases even decline slightly. These projected increases in GHG emissions indicate the state of the challenge of achieving emission reductions compared to 1990 levels, as specified under the Kyoto Protocol.

Policy options to address greenhouse gas emissions vary across three important dimensions - geography, sectors, and measures. Countries with quantitative commitments as envisaged under the Kyoto Protocol should balance the use of domestic action and international flexibility mechanisms. They should also address the full range of potential economic sectors and policy measures (e.g., greenhouse gas taxes; subsidy reform; promotion of alternative transport fuels and renewable energy technologies; and domestic and international emission trading systems). Policy action would also benefit from linking GHG emission reductions to initiatives to combat air pollution, biodiversity loss and land degradation.

1. INTRODUCTION

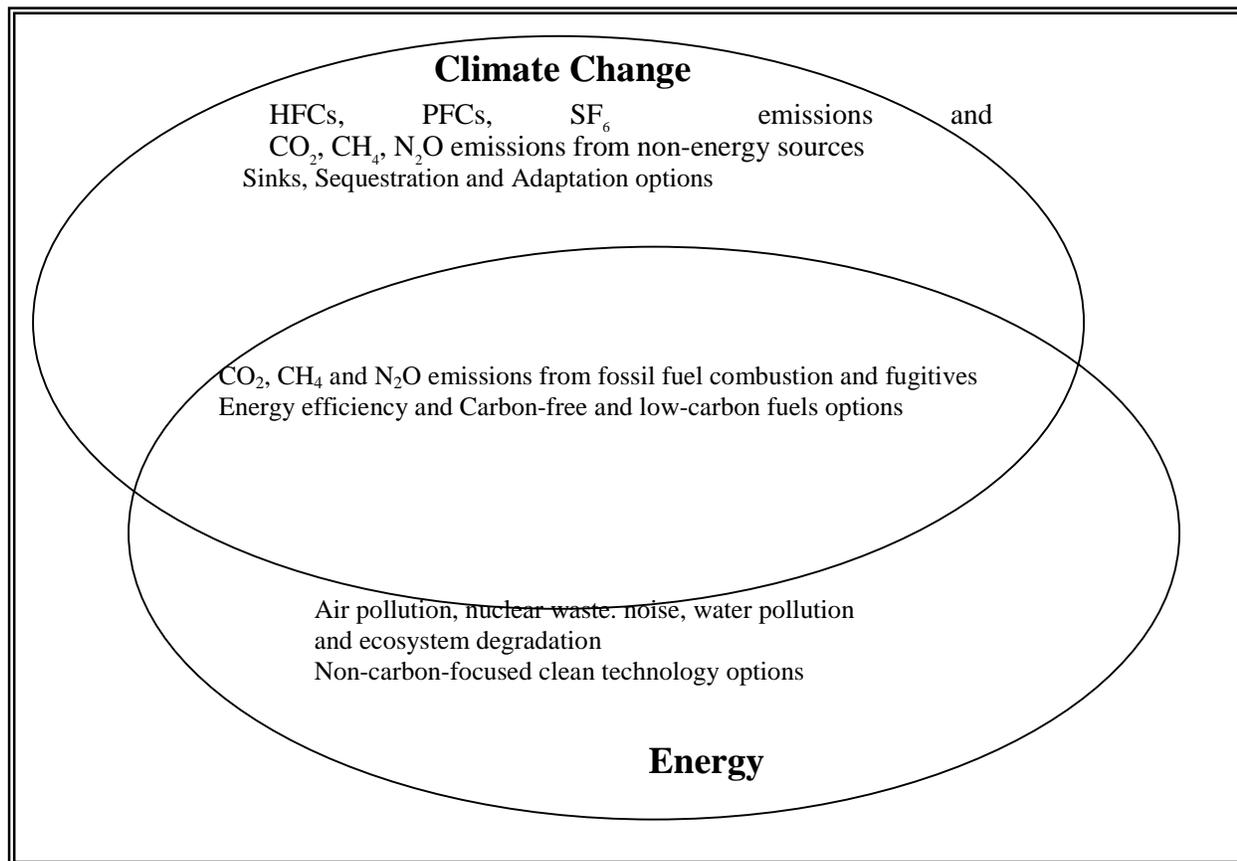
Recent scientific evidence indicates that global warming is underway. Observed changes show that despite large variations from year to year, the global mean temperature has risen significantly in the last century. Expected future increases in global average temperatures may have adverse, possibly irreversible effects on the climate, including changes in regional temperature patterns, more frequent extreme weather events and a rise in sea level. Climate change will affect human life and the ecology of the planet in a variety of ways, including changes in agriculture, water supply and quality, human settlements, and human health, in addition to affecting biodiversity and migratory patterns and causing other eco-system disturbances.

Scientists believe that the observed global warming is mainly due to changes in human activities and related increases in concentrations of greenhouse gases - chiefly carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆). These changes are driven by worldwide population and economic growth, and the underlying production and consumption of fossil fuels, as well as by the intensification of agricultural activity and land use changes. Energy production and use, the largest sole source of CO₂ emissions and a large contributor of CH₄ and N₂O emissions, accounted for 81.7% of emissions in industrialised countries in 1998 (UNFCCC 2000). Energy systems also have other adverse environmental effects including air pollution, nuclear waste, noise, water pollution, and ecosystem degradation.

As illustrated in Figure 1.1, the environmental and policy issues associated with energy and climate change are closely related but not completely identical. The close relationship between energy and climate change means that common analysis of trends and policies is warranted. Emissions of CO₂, CH₄ and N₂O are at the nexus of the two topics, but there exist other issues specific to one or the other fields. This document focuses primarily on the issues of energy-induced CO₂, CH₄ and N₂O emissions. It also discusses the other two broad categories of issues - those specific to energy and those concerning only climate change - because policy actions taken there will also influence the options for actions on the central issue of CO₂, CH₄ and N₂O emissions.

Although OECD countries are the main historical contributors to human-induced climate change and have a special responsibility in implementing policies to reduce emissions of greenhouse gases and enhance sinks, they will not be able to effectively combat climate change on their own. Long term stabilisation of greenhouse gas concentrations will also require broadening the effort to include emission reduction from at least the world's major developing economies.

Figure 1.1 Schematic of environmental issues of energy and climate change



1.1 Climate change: A real problem

In recent years, climate change science has made it clearer than ever before that human-induced global warming is underway. Climate change scenarios prepared by the Intergovernmental Panel on Climate Change (IPCC) show a wide range of possible impacts from global warming in the next century. In 2100, scenarios estimate CO₂ concentrations to range from 550 ppm to 800 ppm, corresponding to an increase in global mean temperatures of 1.4 – 5.8 °C relative to 1990 (IPCC 2001a). Precipitation is likely to increase though projections vary by region (e.g. decreases in precipitation levels in subtropical areas). Changes in precipitation and temperature levels are expected to increase the risk of more extreme weather events, such as flooding. In mid-continental regions, the frequency and severity of droughts could increase with drier summers and lower precipitation overall as the result. A continued decline in glacier mass is foreseen, as well as a decline in snow cover and sea-ice, especially in the Northern Hemisphere. For the next 100 years, the scenarios also show a wide range of possible sea level rise, from 0.09 to 0.88 m. Expected future rises in global average temperatures may have a variety of adverse, possibly irreversible effects on the climate, including changes in regional temperature patterns, more frequent severe storms and a rise in sea level. The ensuing climate change will affect human life and the ecology of the planet in a variety of ways, including changes in agriculture, water supply and quality, human settlements, human health, as well as biodiversity, migratory patterns and other eco-system characteristics.

The observed global warming is largely due to increases in the emissions of greenhouse gases (CO₂, CH₄, N₂O, HFCs, PFCs and SF₆) from various human activities. Ice core data show that changes in

the atmosphere since pre-industrial times far exceed changes from the preceding 10,000 years¹. These changes are driven by worldwide population and economic growth, and underlying production and consumption of fossil energy, agricultural activity and land use change.

In February 2001 the IPCC accepted the Third Assessment Report of Working Group II, entitled *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. That report makes the strongest statement yet by the IPCC on the extent of climate change impacts, predicting that “projected climate changes during the 21st century have the potential to lead to future large-scale and possibly irreversible changes in Earth systems, resulting in impacts on continental and global scales” (IPCC 2001b). The report also states that developing countries, and the lower income groups in developed countries, would suffer the most for all magnitudes of warming. In the developed countries, an increase of global mean temperature of up to a few degrees would produce a mixture of economic gains and losses -- but an increase of global mean temperature of more than a few degrees Centigrade would produce economic losses for all countries.

The IPCC report concludes that Northern Hemisphere countries would probably become hotter, bringing a rise in deaths from heat stroke in cities (especially for children and the elderly) and an advent of diseases until now restricted to tropical areas, including malaria and mortal viral infections.

Africa will be highly vulnerable, partially due to its low resilience to shock and lack of adaptive capacity. Disease levels could increase significantly, especially in crowded cities along the continent's coasts - which could also face inundation as sea levels rise. In Asia, mangrove forests that protect river and sea banks could be swamped, especially in Bangladesh. Forest fires could become more frequent and warmer conditions could increase the spread of vector-borne disease. The melting of glaciers in the Himalayas, which feed river systems providing water to around 500 million people, could cause huge flooding and then massive water shortages. Much of Latin America, from Mexico to Argentina, could see a decline in crop yields, deciduous tropical forests could shrink and new diseases spread, while there could be significant species loss. (There is also significant species loss predicted for ice-edge animals, such as polar bears and penguins.)

In Europe, southern countries are more likely to be negatively affected, with an increased risk of water shortage and a deterioration in soil quality that would affect agriculture. (At higher temperature increases, even northern countries will be adversely affected). Australia could face a major threat to agriculture in the event of frequent droughts. In the Middle East, decreased water availability could heighten existing political tensions.

There is a need for even more detailed knowledge about regional impacts of climate change in order to agree a long term sharing of the responsibility to mitigate and adapt to climate change at the international level. Regional impacts will also drive the level and the mix of national policy responses to mitigate and adapt to climate change. The evolving science of climate change underscores the need for policy makers to make decisions in the context of uncertainty as well as the need to recognise and respond to the risk posed by climate change to future generations.

Climate change impacts are inter-linked with other global environmental problems including loss of biodiversity, deforestation, stratospheric ozone loss, and desertification. A recent report by UNEP, the United States National Aeronautical and Space Agency and the World Bank calls for institutional changes in the way governments approach policy responses to global environmental problems (UNEP *et. al.* 1998). The close geo-physical linkages among different global and regional environmental problems requires careful design of policies to take into account multiple objectives.

1 Ice cores trap air bubbles from the atmosphere over time. This allows scientists to measure directly levels of greenhouse gases associated with different times in history, dating back 10,000 years.

1.2 The international policy context

The objective of the UN Framework Convention on Climate Change (UNFCCC), or "the Convention", is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. So far the Convention has been signed by 186 countries. Ratification of the Convention, which occurred in 1994, indicates that OECD countries agree to lead the way towards a low emission future based on the notion of common but differentiated responsibilities. Achieving this objective clearly requires extensive international co-operation, contributions across different levels and areas of government, as well as stakeholder engagement to change business-as-usual production and consumption patterns.

The Convention has advanced in its definition and implementation of specific emission reduction targets, beginning with the targets established for industrialised countries (Annex I countries) under the 1997 Kyoto Protocol. The Protocol establishes legally binding greenhouse gas emission targets for individual Annex I countries, with a view to achieving at least a 5 per cent aggregate reduction from 1990 emissions levels in the period 2008 to 2012. The Bonn Agreement of July 2001 clarified some of the main definitional uncertainties included in the Protocol, and laid the foundation for its ratification by a vast majority of OECD countries.

1.3 Drivers of greenhouse gas emissions

Climate change emissions derive from virtually all economic activities. The most pervasive and largest source of greenhouse gas emissions is the energy sector, including transport, but agriculture, forestry, industrial processes and waste management have implications for greenhouse gas emissions as well. Climate change policy therefore needs to be comprehensive in addressing emissions and potential emission reductions across all economic activities, although the energy sector must be a key focus of policy action. This comprehensiveness of greenhouse gas emissions means that there are many important interactions with other policy concerns, environmental and otherwise.

Effective policy-making must pay attention to the underlying drivers of emission trends. For example, growth in energy sector CO₂ emissions is a function of some key underlying factors. The general picture is one of increasing scale (population and GDP/capita) offset to some degree by reduced intensity of environmental emissions per unit of production. In the case of energy-related CO₂, scale effects have outweighed intensity improvements, so that the overall level of emissions has been increasing. In other sectors, this may not be the case. For example recent improvements in some industrial process emissions have been rapid enough that these industrial process greenhouse gas emissions have fallen, despite increases in the scale of activity. Analyses similar to this are theoretically possible in all sectors, but outside the energy sector, data is often not available.

Understanding trends in underlying factors helps to understand the environmental impacts of energy use. But for policy-making purposes, it is generally necessary to look at underlying drivers in even more detail to determine those effects which are most important and subject to policy influence. This process often shows that the factors are not independent. For example, certain types of energy end uses lend themselves to certain fuel choices, which in turn have implications for the combustion technologies (and efficiencies) available. And all of these factors combine to influence prices, which affect choices throughout the production chain.

1.4 Environmental effects of energy production and use

Energy production and use is a fundamental element of modern, industrialised economies, and supports all economic activity. Energy is used to move vehicles, heat homes, and power industry. However, producing and using energy also leads to a multitude of adverse environmental effects, including:²

- Greenhouse gas emissions.
- Ambient air pollutants (indoor and outdoor).
- Hazardous air pollutants.
- Acid deposition.
- Water pollution.
- Maritime pollution.
- Land degradation and soil contamination.
- Natural resource depletion.
- Radiation hazards.
- Solid waste disposal accumulation.
- Environmental accidents.

In general, the impact of energy use on the environment is a result of several factors: the mix of fuels used to produce energy; the efficiency of conversion of primary energy into useful energy (including distribution); the technology in use; and the total level of energy used. The use of fossil fuels in the fuel mix for energy with today's technologies continues to pollute the air and emit greenhouse gases, though emissions as a percentage of output are declining. Nuclear energy production entails the risk of nuclear accidents and the need to dispose of radioactive waste. Even renewable energy sources have some negative environmental impacts: hydropower degrades the ecosystem by altering the ecological balance of river basins, with resulting effects on flora and fauna; and other renewable energy systems, such as wind, have visual and noise impacts.

In the OECD countries, the expected increases in total energy production will increase the environmental effects, while shifts in the fuel mix will change the character of these effects. Reduced reliance on coal will lead to lower emissions intensities for SO_x, particulate matter and CO₂, while reduced reliance on nuclear may counterbalance these effects and lead to increased NO_x emissions depending on the fuel that is used to replace the declining share of nuclear. The decline in the share of nuclear energy in the fuel mix will, however, lower the risk of nuclear accidents and reduce the generation of radioactive waste.

Numerous new technologies are also under development which could significantly transform the links between energy production and use and the environment. In addition to electricity systems based on renewable energy, these include the use of cellulose ethanol fuel in motor vehicles, and the development and use of hybrid vehicles, hydrogen fuel cells and CO₂ capture technologies. A key challenge in the development of a sustainable future is the transition to cleaner technologies and energy sources which

² Short descriptions of other environmental effects appear in the Appendix.

improve the balance between security and reliability of supply, costs of production and use of energy, and environmental externalities.

1.5 Structure of the report

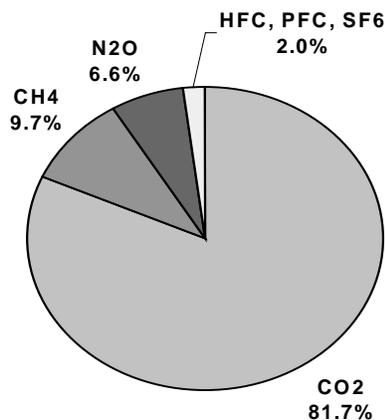
The next chapter examines at the trends in greenhouse emissions, with a focus on OECD countries since 1990 (the base year for most Parties with commitments under the Kyoto Protocol). Chapter 3 then examines the trends in energy use and the key drivers of these trends, with particular focus on energy use at an aggregate level and in major sub-sectors. Chapter 4 considers possible future greenhouse gas emissions scenarios, including a discussion of what factors may influence the development of indicators. Chapter 5 explores the potential costs of climate change and the costs of its mitigation. Chapter 6 then identifies a framework for considering policies to support environmentally-sound futures. A few conclusions are presented in Chapter 7.

2. GREENHOUSE GAS EMISSIONS: TRENDS AND DRIVERS

2.1 OECD greenhouse gas emissions (1990-1998)

Three greenhouse gases account for the majority of human induced global warming effects; namely carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) (Figure 2.1)³. CO₂ is the dominant greenhouse gas, accounting for 75% of global emissions, and 82% of emissions from OECD countries (excluding land use and forestry uptake). This is followed by methane (19% globally, about 10% in OECD countries) and nitrous oxide (roughly 7% both globally and in the OECD countries). Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆) account for a small share (about 2 %) of total emissions in the OECD regions, but they are growing quickly, and thus are managed under the UNFCCC's Kyoto Protocol (Burniaux 2000; UNFCCC 2000).

Figure 2.1 OECD Greenhouse gas emissions by gas, 1998



Source: UNFCCC (2000).

Note: Gases are in CO₂ equivalents.

3 Unless otherwise noted, the figures used in this chapter are based on UNFCCC "official" national data, and refer to emissions of the 3 main gases CO₂, CH₄, and N₂O. They do not include emissions from the land use change and forestry sector. Data may not be completely consistent across time or countries.

CO₂ emissions from fossil fuel combustion can be broken into emissions related to energy production and transformation (34%), and emissions related to energy end-use sectors (industry 17%, transport 27%, residential and commercial 13%), with other sectors contributing 9% in 1998. Presently, coal is responsible for 34% of total CO₂ energy-related emissions, while oil is responsible for 45% (IEA 2000a). Due to market reform policies and changes in technology, recent shifts away from coal towards natural gas have led to a drop in carbon intensity from electricity production and other industry sectors. However, this decline may not continue if, or when, nuclear power is phased out.

The largest CH₄ emission sources in OECD countries are the natural gas and oil industry (leaks and deliberate releases), livestock enteric fermentation (the normal digestive process of livestock), and landfilling of solid waste (the decomposition of organic matter in landfills) – accounting for 75% of total methane emissions. The largest source of N₂O emissions in OECD regions is from agricultural soil (over 60%), with industrial processes accounting for 15%. N₂O emissions from transport grew rapidly (over 20%) during the last decade. These emissions are closely linked to air-fuel mixes and combustion (EPA 2001, forthcoming).

2.1.1 Emission trends by region

Recent trends in greenhouse gas emissions for OECD and other Annex I countries⁴ are carefully monitored under the Convention. Total OECD country emissions (excluding Mexico and Korea) of all greenhouse gases increased by about 4% over the 1990-1998 period reaching 13,902 Mt CO₂. All but five OECD countries have reported emission growth during this period, partly due to robust economic growth. Emissions are rising, although the pace of emission growth has tapered off in the last few years. OECD country emissions in 1996 alone grew more than the first five years of the decade combined, but this rapid growth appears to have levelled off in 1997 and 1998. The five largest emitters in the OECD (US, Japan, Germany, Canada and UK) account for around 75% of OECD country greenhouse gas emissions, which means that OECD trends are dominated by changes in these countries.

OECD countries currently account for about 50% of global CO₂ emissions from energy use, but the share of emissions from OECD countries is gradually falling as other parts of the world show higher economic growth. For the other greenhouse gases, the OECD area share is smaller and is likely to decline in the period to 2020.

Total emissions of CO₂ in OECD countries increased by about 6% in the 1990-1998 period reaching 11,026 Mt CO₂. In the OECD regions, the highest rates of growth in CO₂ emissions have occurred in North America (11% from 1990 to 1998)⁵ and Asia Pacific (12%), while emissions in Europe actually decreased by 5%⁶ (UNFCCC 2000). From 1990-1998, Annex I emissions as a whole declined by 7%, due to the economic slowdowns in countries with economies in transition.

4 Under the UNFCCC, Annex I (industrialised) countries agreed to an aim of limiting their greenhouse gas emissions. Annex B of the Kyoto Protocol established legally-binding greenhouse gas limitation commitments for almost all Annex I countries.

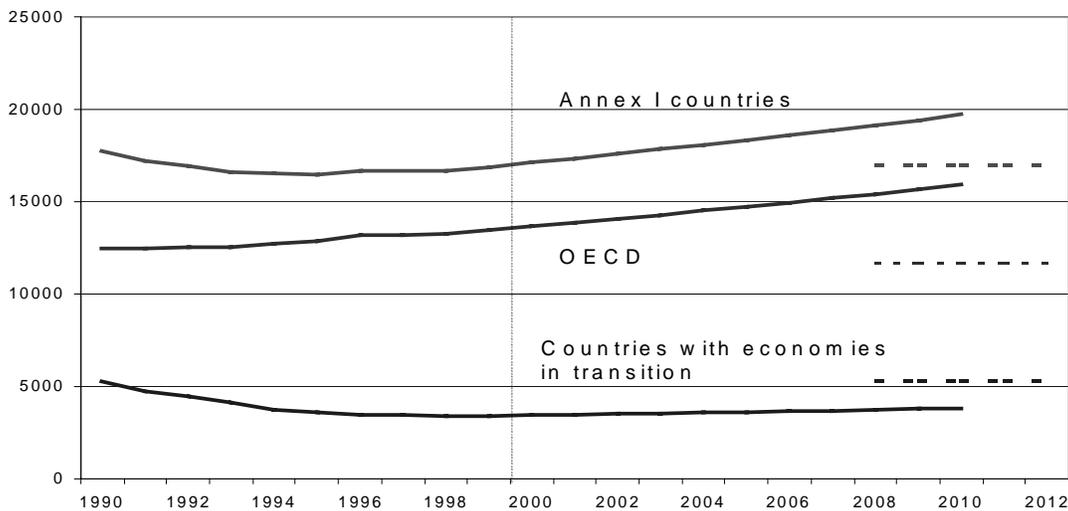
5 From 1996 to 1998, the emissions growth rate from fuel combustion has slowed considerably in the US, from 3.5% to 0.5%.

6 The number for Europe includes some non-OECD eastern European countries with economies in transition. Economic slowdown in these countries, and a drop in coal-powered generation in the UK, accounts for the drop in emissions.

CH₄ emissions⁷ in the OECD decreased by 6.5% from 1990 –1998, with fugitive fuel emissions down 15%, and waste emissions down 9.8%. N₂O emissions for OECD decreased over this period by 0.4%- while industrial process emissions decreased by 33%, fuel production emissions were up by 5.5%, and emissions from agriculture were up 6.4%.

Emissions in OECD countries have continued to rise (Table 2.1), despite efforts to implement policies and measures to mitigate climate change. Compared with business-as-usual, targets contained in the Kyoto Protocol imply emission reductions of 20-30% for most OECD countries, should countries tackle the targets unilaterally (Figure 2.2). Slower growth or even declining emissions for countries with in economies in transition, suggest that overall emission reductions required across Annex I countries may be more modest (18%). However, the size of the gap will vary with the pace of economic development which is very uncertain in these transition economy countries. Emission abatement of such magnitude is likely to require significant structural adjustments and this has led to concern over costs.

**Figure 2.2 Annex I country GHG emission trends compared to Kyoto targets
CO₂, CH₄ and NO₂ emissions (million tonnes CO₂ equivalent): 1990-2010**



Source: UNFCCC 2000 inventory data for historical figures, Burniaux 2000 and OECD GREEN estimates for projections.

Notes: historical data up to 1998; projections to 2010.

7 Figures for both CH₄ and N₂O are estimates, and exclude Turkey and Mexico. Source: UNFCCC 2000.

Table 2.1 Overview of national emission trends, Kyoto objectives and EU burden-sharing

Country	1990 GHG Emissions (1000 Gg CO ₂ equiv.)	Percentage change in 1998* from 1990	Kyoto Target for 2008-2012 (as a percentage of 1990)
Non-EU OECD			
Australia	423	14.6%	8.0%
Canada	612	13.1%	-6.0%
Czech Republic	190	-22.1%	-8.0%
Hungary**	102	-17.9%	-6.0%
Iceland	3	4.7%	10.0%
Japan	1213	10.0%	-6.0%
New Zealand	73	2.7%	0.0%
Norway	52	7.7%	1.0%
Poland***	564	-28.7%	-6.0%
Switzerland	53	1.9%	-8.0%
United States	6049	11.2%	-7.0%
EU OECD			
			EU -8.0% (Burden-sharing targets below)
Austria	75	6.7%	-13.0%
Belgium	136	6.6%	-7.5%
Denmark	70	8.6%	-21.0%
Finland	75	1.3%	0.0%
France	554	0.9%	0.0%
Germany	1209	-15.6%	-21.0%
Greece	105	18.1%	25.0%
Ireland	53	20.8%	13.0%
Italy	519	4.4%	-6.5%
Luxembourg	13	-23.0%	-28.0%
Netherlands	218	8.3%	-6.0%
Portugal	64	17.2%	27.0%
Spain	306	20.9%	15.0%
Sweden	69	7.3%	4.0%
United Kingdom	741	-8.2%	-12.5%

Source: UNFCCC (2000). Data for Iceland and Luxembourg are from 1995, and for Japan from 1997. Data for 1998 or latest year as noted above.

** Hungary's base year is an average annual figure over 1985-1988.

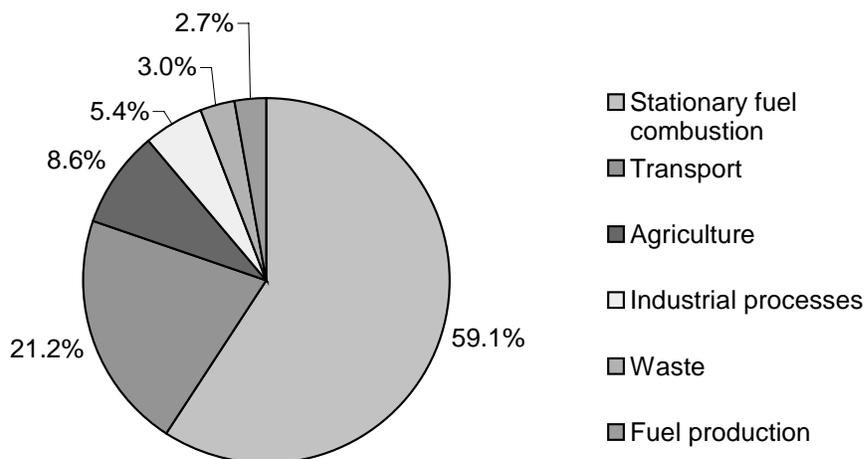
***Poland's base year is 1988.

2.1.2 Emission trends by sector

Stationary fuel combustion - mostly for power generation - is the largest single source of greenhouse gas emissions (59% in 1998; Figure 2.3). In many countries, increasing demand for electricity production is a main driver for CO₂ emission trends. The IEA estimates that CO₂ emissions from the power sector in OECD countries will rise to 21% above their 1997 level in 2010 and 33% in 2020. Growth

in CO₂ emissions is projected to remain slightly below the growth in electricity demand because of improvements in fossil-fuel power generation efficiency (IEA 2000a).

Figure 2.3 OECD greenhouse gas emissions by sector, 1998



Source: UNFCCC (2000).

Note: Gases are expressed in CO₂ equivalents.

In most OECD countries, emissions from transport have risen faster than those from all other energy-related sources since 1990 (Schipper *et al.* 2000). Emissions from transport rose from 19% of total GHG emissions in 1990 to about 21% in 1998, the absolute increase for the sector being 15% (UNFCCC 2000). Within the transport sector, emissions from aviation are the most rapidly growing, although they still account for a relatively small share of total transport emissions⁸. CO₂ accounts for the overwhelming majority of increasing emissions from transport, but N₂O emitted by that sector is increasing even more rapidly. It is projected that the contribution of the transport sector to total CO₂ emissions in OECD regions will increase from approximately 20% in 1995 to 31% in 2020. Other main sectoral sources of greenhouse gas emissions are agriculture (9% in 1998); industrial processes (5% in 1998); waste (3% in 1998), and fuel production (3%).

Land use and forestry activities are accounted for separately from other greenhouse gas sink categories. The establishment and harvest of plantations, commercial forest management, and fuel-wood gathering lead to changes in forests and other woody biomass stocks. Converting forests for agricultural use and abandoning managed lands affects not only the amount of carbon stored in above-ground biomass, but also the amount of carbon stored in the soil. Depending on the overall change in forest coverage and density, and change in agricultural land use, these activities may result in either net emission of greenhouse

8 International aviation emissions are not covered under national mitigation obligations in the Climate Convention or the Kyoto Protocol, as these emissions are considered to be “international” rather than “national” in origin. Countries report the emissions, but they are not included in national inventory totals.

gases to the atmosphere, or net removal. As of 1998, land use changes and forestry are estimated to be a net CO₂ sink for most OECD countries (UNFCCC 2000; see Table 2.2).⁹

Terrestrial carbon sinks are a critical dimension of the natural system regulating climate. Although much of the total flow of carbon to and from sinks is natural, human-induced flows are large.¹⁰ The Kyoto Protocol covers a portion of these flows. The Bonn Agreement, reached in July 2001, clarifies which activities are eligible as “domestic sinks” under the Protocol (in industrialised countries); and that afforestation and reforestation are eligible activities under the Clean Development Mechanism.¹¹ Some studies indicate that the costs of achieving emissions reductions through sinks could be lower than energy sector mitigation (Reilly 2000; Alcamo *et. al.* 1998).

Though the relative contribution of sinks to emission reductions required in the longer term is likely to be less important, in the 2010 time-frame sinks could contribute to achieving Kyoto targets and significantly lower the costs of doing so. Use of sinks as a means to mitigate GHG also affects the achievement of other social or environmental policy objectives: depending upon how such mitigation is undertaken these could be positive or negative (IPCC 2001c). Environmental linkages include biodiversity and habitat protection, whereas social considerations often have to do with competition for land. Decisions on how to account for sinks must take into potential synergies to ensure positive overall results.

9 With all OECD countries reporting except Greece, Iceland, and Luxembourg.

10 Anthropogenic sink activities are estimated to absorb 0.5 to 0.7 billion tonnes of C a year in industrialised countries, equivalent to roughly 15% of emissions from burning fossil fuels from these countries (IPCC 2000c and UNFCCC 2000). This figure does not include agricultural lands, which the IPCC estimates to contribute to the total terrestrial sink; this could increase the figures another 50 to 75 per cent.

11 Estimates of the total mitigation potential through sinks in developing countries is estimated to be nearly two times that of the potential in Annex I countries (IPCC 2000b).

Table 2.2 1990 - 1998 Removals of GHG from land-use change and forestry (LUCF)

Country	Emissions (+) or Removals (-) through LUCF in 1990 (1000 Gg CO ₂ – equivalent)	Emissions (+) or Removals (-) through LUCF in 1998 (1000 Gg CO ₂ –equivalent)	Change in carbon sequestration from LUCF 1990-1998
Australia	70	35	50%*
Austria	-9	-7	-22%
Belgium	-2	-1	-50%
Canada	-40	-20	-50%
Czech Republic	-2	-4	+100%
Denmark	-1	-1	0
Finland	-24	-10	-58%
France	-60	-70	+17%
Germany	-34	-33	-3%
Greece	N/A	N/A	-
Hungary	-3	-4	+33%
Iceland	N/A	N/A	-
Ireland	-5	-6	+20%
Italy	-26	-24	-8%
Japan	-84	NA	-
Luxembourg	0	NA	-
Netherlands	-2	-2	0
New Zealand	-22	-21	-5%
Norway	-10	-18	+80%
Poland	-35	-30	-14%
Portugal	-4	-5	+25%
Spain	-29	-29	0
Sweden	-34	-28	-18%
Switzerland	-4	-6	+50%
United Kingdom	21	15	29%*
United States	-1160	-773	-33%
OECD Total	-1,414	-1041	-26%

Source: UNFCCC 2000.

Note: * Based on reduction in total GHG emissions from LUCF, as opposed to increase in sinks.

2.1.3 *Longer-term emission trends*

Although CO₂ emissions from OECD countries grew by about 9% between 1990 and 1998, they were only 7% above 1973 emission levels in 1990 (IEA, 2000b). This slower rate of increase in the 1970s and 1980s was due to decarbonisation of the energy supply in OECD countries and to a decline in the energy intensity (TFC/GDP) of the economy. The latter is due to both improvements in technology and to a change in the structure of OECD economies. The shift away from heavy industry towards the service sector in the OECD during this period led to a drop in energy intensity¹². Relatively high energy prices over the last two decades also stimulated technical change and increases in technical energy efficiency of the economy.

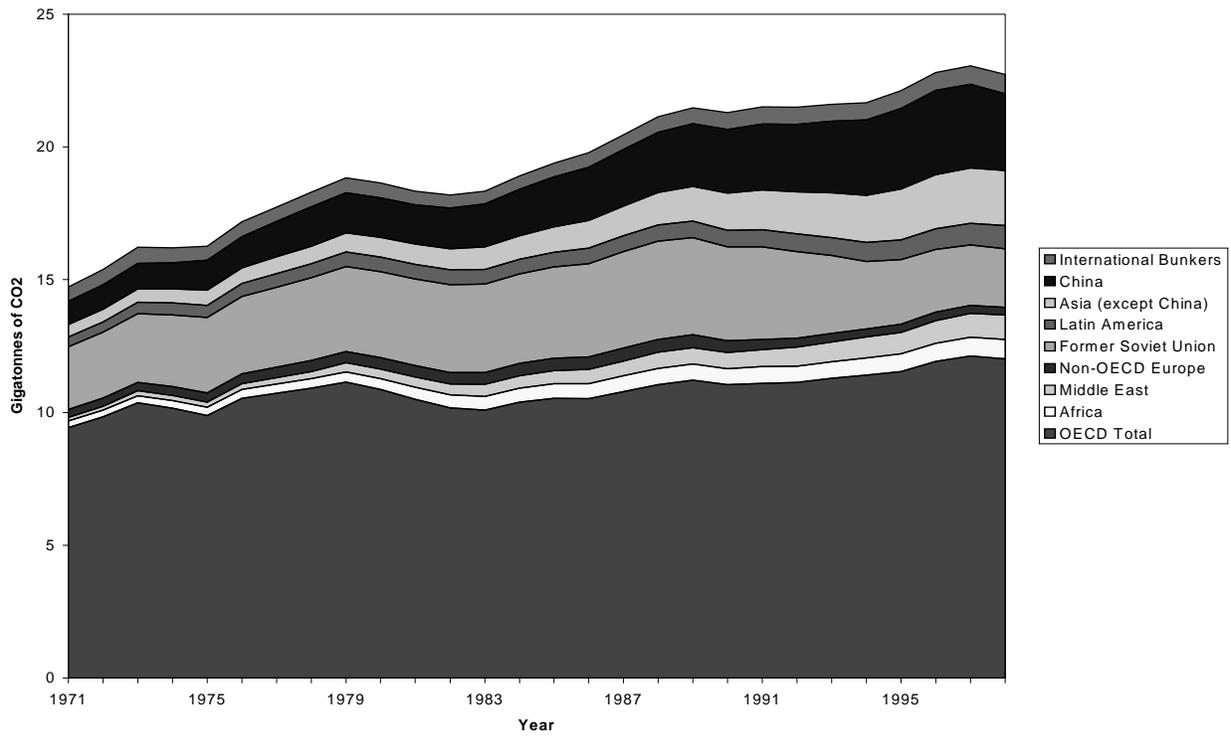
Reducing energy intensity (or inversely, improving energy efficiency) is a key part of national strategies to reduce greenhouse gas emissions. Yet global and OECD trends indicate that even with relatively rapid improvements in energy efficiency, growth in energy demand is likely to continue to drive emissions higher in the OECD and world-wide under current policy scenarios. This is in contrast with IPCC analysis (IPCC 1996a) which suggests that, in order to stabilise greenhouse gas concentrations at safe levels, reductions of global emissions on the order of 50-60% will be required by around the middle of the 21st Century. To achieve this while also continuing to develop economically will require massive changes in technology and behaviour.

2.1.4 *Global trends*

Figure 2.4 shows trends in energy CO₂ emissions from world regions. This shows that the OECD is the dominant emitter of CO₂ and accounts for a large portion of current atmospheric concentrations. However, the OECD's share declined steadily until the 1990s, when economic turmoil in eastern Europe led to reductions in GDP and energy use in that region. Most other world regions continue to grow more quickly than the OECD, so the OECD's share of global emissions has fallen, and will likely fall more quickly as eastern European economies recover (or at least stop declining). This demonstrates the growing need for global solutions to greenhouse gas emissions, not limited to OECD countries, which account for the bulk of Annex 1 country emissions.

12. Some of this shift is related to a general trend where manufacturing and other industry capacity is shifting out of the OECD into non-OECD regions.

Figure 2.4 World CO₂ emissions from fossil fuel combustion by region



Source: IEA Statistics.

3. ENERGY TRENDS AND DRIVERS

This chapter examines the past trends and underlying drivers of the energy system- encompassing fossil fuels and renewables extraction and processing, electricity generation, and energy use in the transport, industrial and residential and commercial sectors. It presents energy projections developed for the *OECD Environmental Outlook*, using the JOBS and PoleStar models.¹³ These "Reference Scenario" projections are based on current activities and recent trends. They do not include the adoption or implementation of new policies. The section also reviews current policies, as a basis for considering likely future environmental impacts.

3.1 Macro indicators: an analytical framework

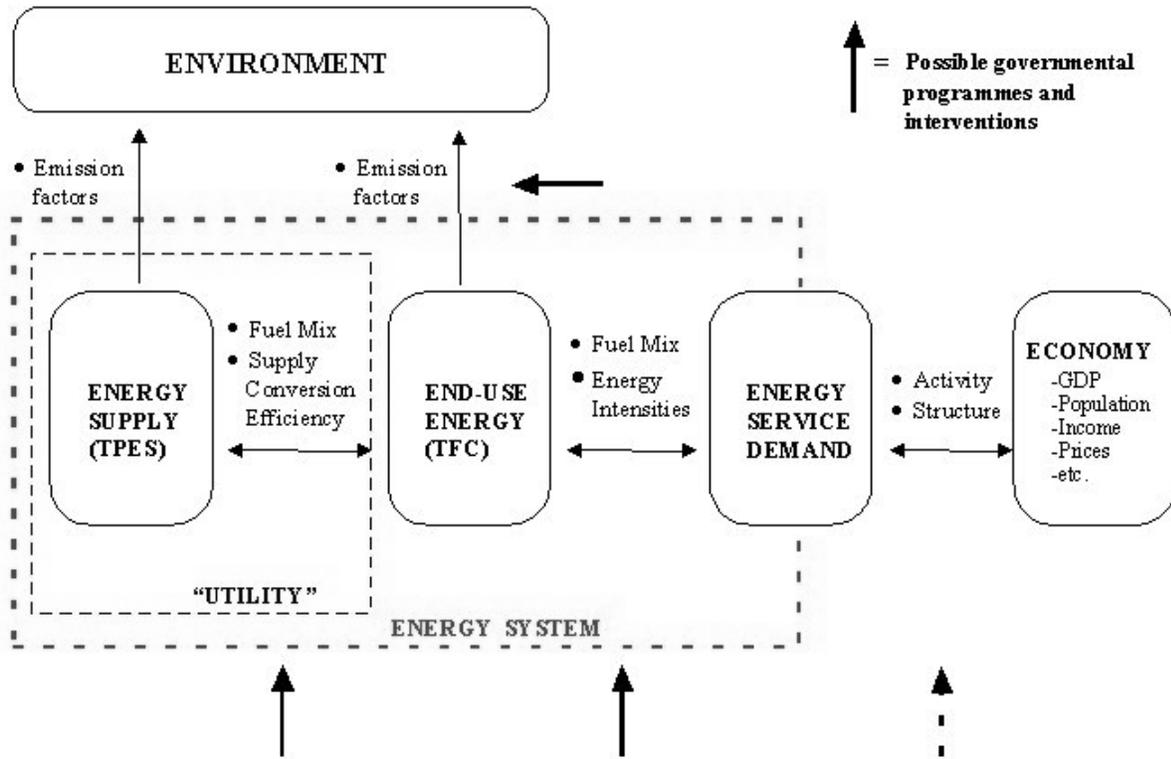
In 1998, OECD countries used about 5100 million tonnes of oil equivalent (Mtoe) of primary energy, accounting for 54% of the world's primary energy use. This represented a growth of 36% (1.2% p.a.) over 1973, when OECD countries accounted for 62% of the world's primary energy use. There are, of course, many trends underlying this overall situation. Macro indicators are often used to explore the underlying trends in order to gain insight into their robustness and consequences.

Figure 3.1 depicts the links within the energy system, between the general economy and its agents' (individuals and companies) demand for energy service, the energy system to supply these services, and the related environmental impacts. Demand for energy services is generated from sectoral activity and the structure within each sector. The driving factors of activity and structure development are inter alia GDP, population, income distribution and prices. Measured at the end-use level, energy intensity represents the final energy needed per unit of activity. Including supply-side losses for each energy carrier indicates the primary energy requirements per unit of activity. In addition, multiplying fuels by emission factors makes possible the estimation of emissions resulting from each activity in the various sectors. By using the indicator approach, changes in energy use and emissions can be decomposed among each of the factors¹⁴ (indicated by bullet points in Figure 3.1). (IEA, 1997a) The relationships illustrated in Figure 3.1 can be expressed in Equation 3.1, known as the Kaya identity.

13 JOBS is OECD's global, dynamic general equilibrium model. PoleStar is the Stockholm Environment Institute's accounting framework for combining economic, resource and environmental information to examine alternative development scenarios.

14 There are interactions and feedback between the factors, e.g. decreasing energy intensities may encourage more activity for a given end-use. For example, most observers find that if fuel use per kilometre driven falls 10%, car use increases 1-2% (Johansson and Schipper, 1997, and Greene, 1996).

Figure 3.1 A model of energy/environmental indicators



Source: IEA, Energy Efficiency Initiative, 1997.

Equation 3.1 The Kaya identity

$$\begin{array}{l}
 \text{CO}_2 \\
 \text{emissions}
 \end{array}
 =
 \begin{array}{l}
 \text{CO}_2/\text{TPES} \\
 \text{CO}_2 \text{ intensity} \\
 \text{of primary} \\
 \text{energy} \\
 \text{supplies} \\
 \text{[dependent} \\
 \text{on emissions} \\
 \text{factors and} \\
 \text{fuel mix]}
 \end{array}
 \times
 \begin{array}{l}
 \text{TPES/TFC} \\
 \text{Energy} \\
 \text{conversion} \\
 \text{ratio} \\
 \text{[dependent} \\
 \text{on conversion} \\
 \text{efficiency and} \\
 \text{fuel mix]}
 \end{array}
 \times
 \begin{array}{l}
 \text{TFC/GDP} \\
 \text{Final energy} \\
 \text{intensity of} \\
 \text{economic} \\
 \text{activity} \\
 \text{[dependent on} \\
 \text{energy} \\
 \text{intensities, fuel} \\
 \text{mix, activity} \\
 \text{and structure]}
 \end{array}
 \times
 \begin{array}{l}
 \text{GDP/POP} \\
 \text{Economic} \\
 \text{activity per} \\
 \text{capita}
 \end{array}
 \times
 \begin{array}{l}
 \text{POP} \\
 \text{Population}
 \end{array}$$

3.2 What the indicators show

Table 3.1 and Figures 3.2 and 3.3 show the trends and relationships of several of the more commonly cited aggregate indicators of energy supply and consumption - energy supply (TPES), consumption (TFC), economic activity (GDP) and population.

Table 3.1 Key energy sector indicators, 1973 - 1997 (average annual growth rates)

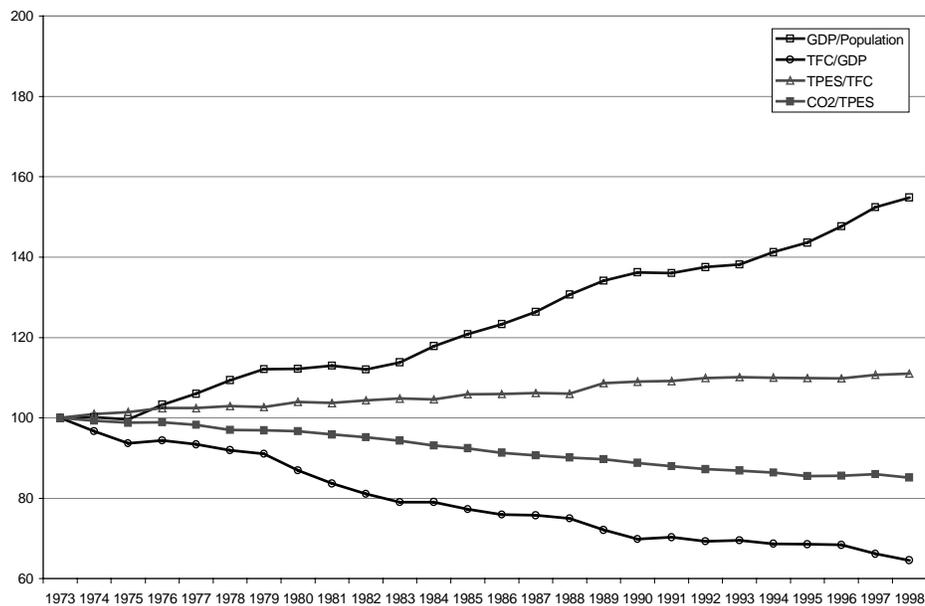
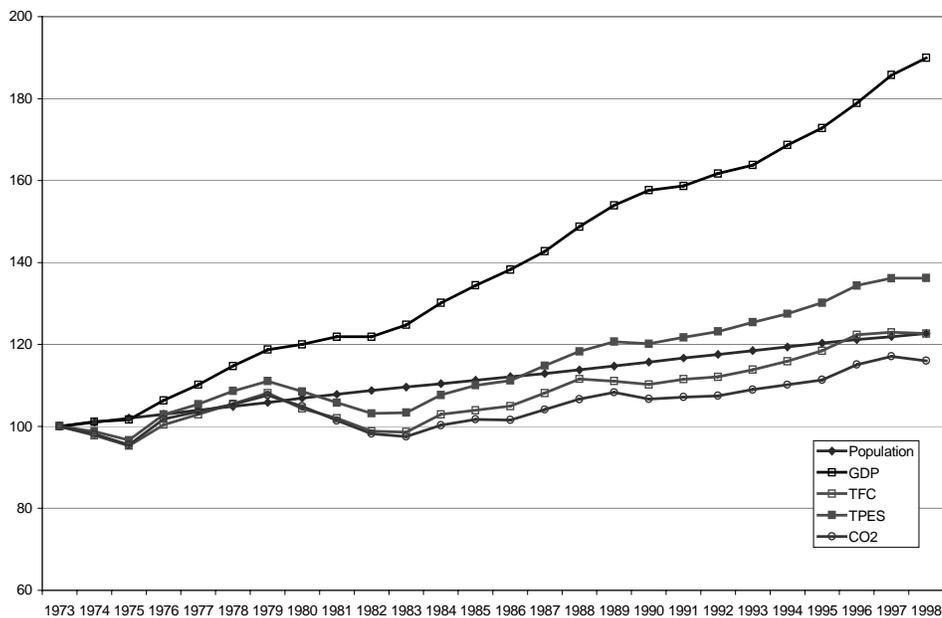
		OECD	OECD North America	OECD Pacific	OECD Europe	Former Soviet Union	Asia (except China)	China	Other	World
Levels										
Population (millions)	1973	897	289	159	449	250	1080	886	762	3874
	1998	1101	395	195	510	292	1821	1245	1381	5839
	Annual growth	0.8%	1.3%	0.8%	0.5%	0.6%	2.1%	1.4%	2.4%	1.7%
GDP (billions USD)	1973	10398	4335	1542	4520	1292	1118	561	2208	15576
	1998	19753	8412	3539	7802	1054	4219	4292	4335	33654
	Annual growth	2.6%	2.7%	3.4%	2.2%	-0.8%	5.5%	8.5%	2.7%	3.1%
TFC (Mtoe)	1973	2827	1499	298	1030	589	172	208	375	4171
	1998	3467	1710	528	1230	605	785	758	1030	6646
	Annual growth	0.8%	0.5%	2.3%	0.7%	0.1%	6.3%	5.3%	4.1%	1.9%
TPES (Mtoe)	1973	3742	1953	411	1379	869	382	429	620	6043
	1998	5097	2564	796	1737	893	1054	1048	1398	9490
	Annual growth	1.2%	1.1%	2.7%	0.9%	0.1%	4.1%	3.6%	3.3%	1.8%
CO2 (Mt of CO2)	1973	10359	5176	1163	4020	2589	505	960	1809	16222
	1998	12017	6243	1840	3934	2206	2076	2893	3533	22726
	Annual growth	0.6%	0.8%	1.8%	-0.1%	-0.6%	5.8%	4.5%	2.7%	1.4%
Ratios										
GDP/Population	1973	11.6	15.0	9.7	10.1	5.2	1.0	0.6	2.9	4.0
	1998	17.9	21.3	18.1	15.3	3.6	2.3	3.4	3.1	5.8
	Annual growth	1.8%	1.4%	2.5%	1.7%	-1.4%	3.3%	7.0%	0.3%	1.5%
TFC/GDP	1973	0.27	0.35	0.19	0.23	0.46	0.15	0.37	0.17	0.27
	1998	0.18	0.20	0.15	0.16	0.57	0.19	0.18	0.24	0.20
	Annual growth	-1.7%	-2.1%	-1.0%	-1.5%	0.9%	0.8%	-2.9%	1.4%	-1.2%
TPES/TFC	1973	1.32	1.30	1.38	1.34	1.48	2.22	2.07	1.65	1.45
	1998	1.47	1.50	1.51	1.41	1.48	1.34	1.38	1.36	1.43
	Annual growth	0.4%	0.6%	0.4%	0.2%	0.0%	-2.0%	-1.6%	-0.8%	-0.1%
CO2/TPES	1973	2.77	2.65	2.83	2.91	2.98	1.32	2.24	2.92	2.68
	1998	2.36	2.44	2.31	2.26	2.47	1.97	2.76	2.53	2.39
	Annual growth	-0.6%	-0.3%	-0.8%	-1.0%	-0.7%	1.6%	0.8%	-0.6%	-0.5%

Source: IEA Energy Statistics.

(1) Data on biomass consumption in TFC for non-OECD countries has limited reliability in 1973, so figures for non-OECD countries should be seen as broadly indicative only.

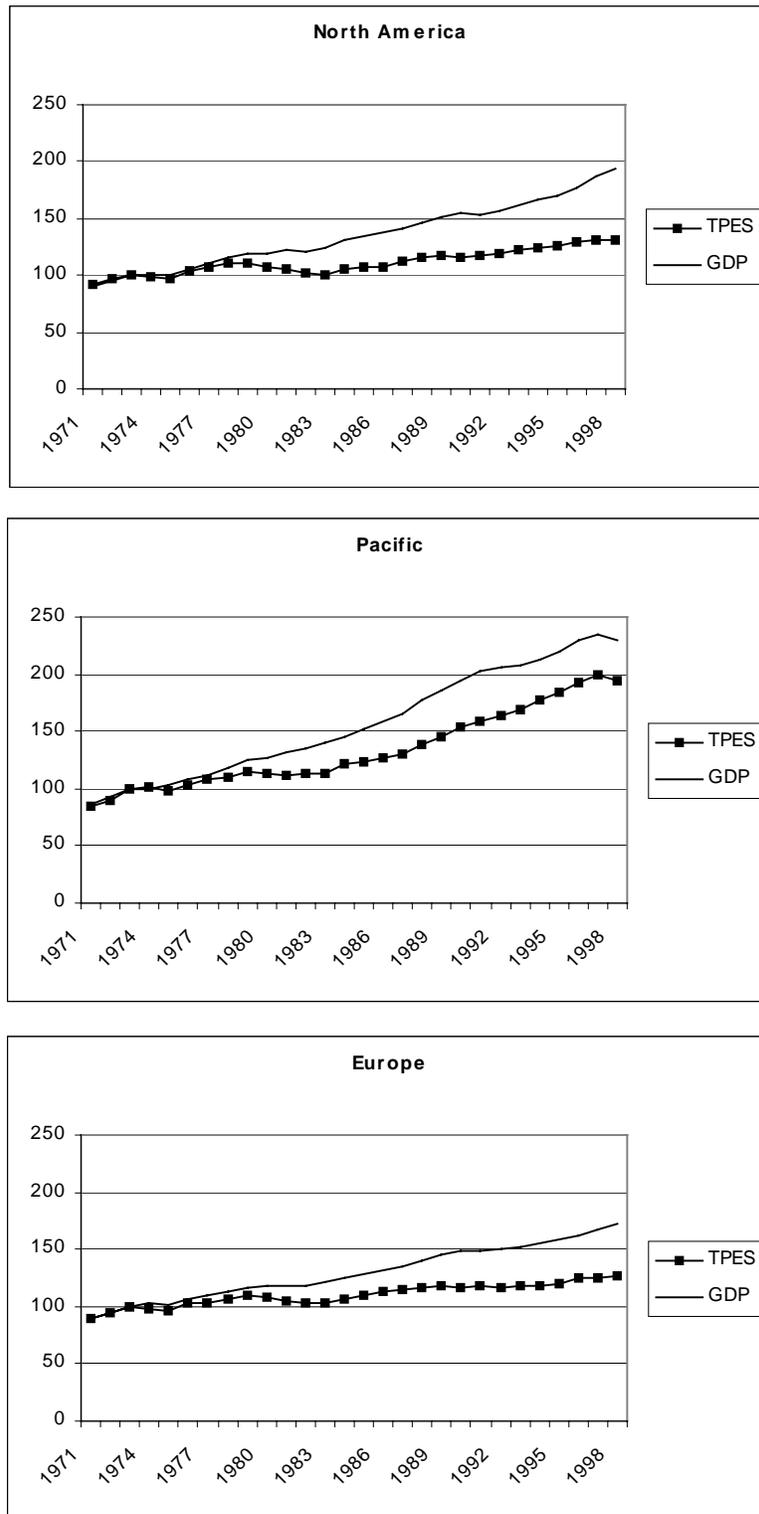
(2) Purchasing Power Parity Basis.

Figure 3.2 Contributors to OECD CO₂ emission changes, 1973-1998
(Indices: 1973=100)



Source: IEA Statistics.

Figure 3.3 Relationship between TPES and GDP in OECD regions



Source: IEA Statistics.

Although total energy use in OECD regions has been rising, the energy intensity of the economy (total primary energy supply per unit of GDP) has decreased by just over 16% since 1980. This mainly reflects improved energy efficiency across the economy, and fuel and technology changes in the power sector, and has largely been driven by changes in energy prices, as well as market reform policies. Energy intensity fell rapidly, especially in OECD countries, following the oil price rises of 1973/74 and 1979. Although the rate of decrease in energy intensity slowed after 1985, when real prices fell to about their pre-shock levels, there was no sharp rise in energy use following the fall in prices, indicating that some energy efficiency improvements have been “locked in” to OECD economies through infrastructure and permanent behavioural changes.¹⁵ Recent OPEC arrangements to reduce oil output were responsible for large price rises in 1999 and 2000. Future energy price trends are difficult to predict, but will depend largely on OPEC arrangements, and on the pace of energy market reforms

In OECD countries, there has also been a general decline the overall efficiency of converting primary energy to final energy. This reflects the increased share of electricity in final energy use, but will be offset to some extent by efficiency improvements in the conversion from primary to final energy. These will result when available higher-efficiency technologies (*e.g.*, combined cycle gas turbines, CCGT) will be brought on stream with the turnover of power generation capital stock. Improved technologies offer significant potential for high efficiencies, and the market potential for new gas-fired cogeneration is also high. The energy efficiency of OECD economies is therefore expected to improve to 2020, as measured by TFC/GDP.

CO₂ emissions have almost kept pace with population growth. Although GDP per capita has increased dramatically, energy intensity of the economy (TFC/GDP) and carbon intensity of energy supply (CO₂/TPES) have decreased, mostly reflecting improved energy efficiency and fuel switching. It is notable, however, that OECD TFC per capita was almost unchanged over the period, with increases in the OECD Pacific Region being responsible for the only significant increase. OECD countries have therefore been generally successful in keeping the demand stable for energy services *per capita*, but population has grown by 23% from 1973-1998, driving up energy demand as a whole.

The technical and structural changes underlying these broad trends are difficult to disentangle. Trends in the efficiency of, and CO₂ emissions from energy technologies in use generally have to be deduced from available statistics on energy use and related activity levels. It is often difficult to separate out the effects of technological change from those of structural change, as statistics are insufficiently detailed (IEA, 1997b).

3.3 Geographical differences

Energy consumption per GDP fell steadily from 1973 to 1988, but has been roughly steady since then, as energy demand in Eastern Europe plummeted following the recent major economic and political changes in that region. OECD countries are relatively efficient in terms of energy used per unit of GDP, but have very high energy use per capita due to high standards of living. In Asia and China, rapid economic growth has led to dramatic increases in energy use, although the energy intensity of these economies fell substantially over the period.

Within OECD regions, energy use has been growing more slowly in North America (1.1% p.a.) and Europe (0.9% p.a.) since 1973 than in the OECD Pacific countries (2.7%) (IEA, 2000a). Over the next two decades, the rates of increase in energy demand will be slower, particularly in Western Europe and Japan. In non-OECD regions, the demand for energy in China and East Asia will continue to increase

15 Price elasticities tend to be asymmetric, with consumers more responsive to a rise in price than to a decline.

rapidly over the next 20 years (at roughly 3% and 2% per annum respectively), driven by strong economic and population growth. The dramatic drop in final energy use that was seen in Eastern Europe and the former Soviet Union in the 1990s, due to major political reforms and economic decline will be reversed, and energy demand there is expected to grow again over the next twenty years.

Reductions in energy intensity (i.e. the energy required per unit of output) are common to most regions (Figure 3.3). In the OECD countries, this was especially true following major price and supply disruptions. Over the period 1973-1996, half of the improvement in energy intensity occurred in the years 1974-75 and 1979-82, following the major oil price shocks. During this period, governments instituted a range of programmes to improve energy efficiency, and industry and consumers responded to these and to market price increases. Some of these effects took longer to flow through the economy, as they required capital changes toward more efficient equipment. In more recent years, the link between GDP growth and energy use has been stronger, with only small improvements in energy use per unit of output. This period has been marked by relatively low, and steady or declining energy prices. Within the OECD Pacific region, the impacts of the oil price shocks were less marked, and GDP and energy use have grown more in parallel than in other OECD regions. In recent years, energy use has grown more quickly than GDP in this region.

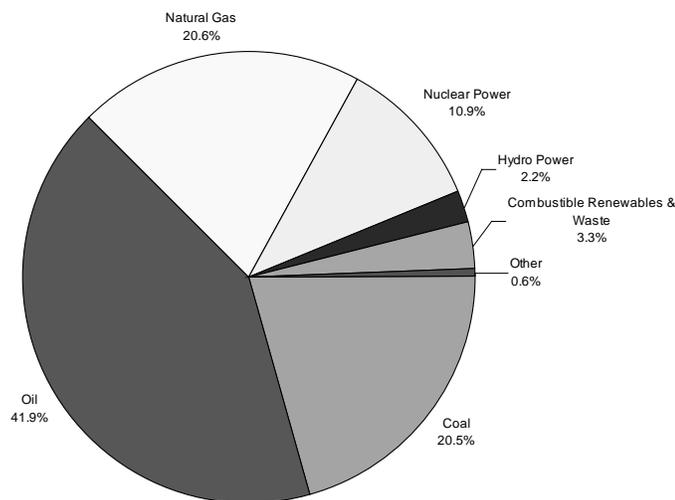
Globally, there was considerable regional variation in these ratios. Energy intensity fell rapidly, following the oil price rises of 1973/74. The rate slowed after 1985 when prices fell. Non-OECD countries showed less response to the oil price rises, but energy intensity reductions accelerated after 1985 in non-OECD Asia and Europe as a result of rapid economic development in the former, and restructuring in the latter. The carbon intensity of primary energy (CO₂/TPES) was hardly affected by the oil price rise in any region. There is also significant variation within OECD countries. North American and European OECD countries show similar patterns, with North America showing more significant improvements in energy intensity and a decline in energy use *per capita*. Pacific OECD countries show a much higher rate of growth, dominated by Japan and Korea (whose energy use increased by more than 500% over the period).

3.4 The fuel mix

The fuel mix strongly affects many of the key macro indicators of the energy system. Most obviously, it determines (via emissions factors) the amount of CO₂ emitted per unit of energy used. It also influences the relationship between TPES and TFC. The more electricity generated, the more the two types of energy differ.

Significant changes in the types of fuels used to feed energy production have occurred over the last few decades. The current fuel supply mix for the OECD area is dominated by oil, followed by solid fuels (largely coal) and natural gas (Figure 3.4). When transport energy is excluded (about half of oil use and small amounts of other fuels), a closer balance between coal, oil and gas is seen (Table 3.2). In the transport sector, the dominance of petroleum fuels has been maintained over the period, while growth in total energy use has been very rapid. The shares of coal, and to a lesser extent oil, in total energy supply has fallen steadily in OECD regions in recent years, reflecting increased electrification, relative reductions in the importance of energy-intensive manufacturing sectors and the substitution of natural gas for oil and coal, especially in the electricity sector (Table 3.2 and Table 3.3). In OECD countries, virtually all the increase in demand for coal stems from power generation. Gas has increased its share in overall energy use, and a further deregulation of energy markets and technological advances in combined-cycle gas turbines is expected to continue to increase the penetration of gas in electricity production and some industrial uses over the next two decades. New renewables have been growing at a very rapid rate in recent decades, but from a relatively small base.

Figure 3.4 Fuel shares of the OECD primary energy mix, 1998



Source: IEA Statistics.

Table 3.2 also illustrates that direct consumption of coal has fallen to negligible levels in the commercial and residential sector, and low levels in the industrial sector¹⁶. Oil has also seen a steady fall in share in all sectors, while gas has seen modest gains overall. This reflects the changing structure of energy uses as well as shifts to cleaner and more efficient forms of energy, partly in response to government policies to reduce oil use.

Perhaps the most important energy trend during the last few decades has been the rapid increase in the generation and use of electricity. In OECD countries, electricity use accounted for 19% of total final energy consumption in 1998, compared with 11% in 1973. The generation of electricity consumed 25% of primary energy supplies in 1998, compared with 37% in 1973. This trend is partly the result of increased growth in the electricity-intensive residential and commercial sectors. Many applications in these sectors, especially business equipment and residential appliances, have no realistic alternative fuel source to electricity. Furthermore, there has been a shift in all sectors to greater electricity use. This reflects the wide range of uses of electricity, its flexibility, safety and cost. In some regions in OECD countries, where the electricity supply system is too unstable to provide the continuous energy required for high-powered computer use, an increasing share of electricity is obtained from off-grid power sources.

Without considering the end-use efficiencies that can accompany electrification, there is a tendency for electricity generation and consumption to raise the primary energy intensity of an economy. Electricity generation can consume up to 3 units of primary energy for each unit of final energy produced. However, efficiencies of electricity are improving, and new combined cycle gas turbines can reach thermal efficiencies over 50%, and efficient cogeneration can reach over 70%. Also, where electricity can be applied more efficiently at end use, this can lead to overall efficiency gains. Nonetheless, the increasing share of electricity in end use indicates the need for environmental policy to focus on this source.

16 Coal in electricity production has maintained its share and so still plays an important role in overall energy supply.

Table 3.2 Shares of fuels in final consumption, OECD

	Coal	Oil	Natural Gas	Electricity	Renewables	Heat	Total
1973, MTOE							
Industry	178	426	258	157	41	11	1071
Transport	7	691	17	5	0	0	720
Agriculture	2	38	0	4	0	0	44
Commercial and Public	17	130	72	62	1	1	283
Residential	68	199	154	93	23	7	544
Other	13	125	12	1	13	1	164
Total Final Consumption	284	1608	514	322	78	20	2827
1998, MTOE							
Industry	110	338	275	262	44	13	1042
Transport	0	1135	21	9	2	0	1166
Agriculture	1	56	5	7	1	0	70
Commercial and Public	3	74	111	181	2	7	379
Residential	17	130	241	203	51	22	663
Other	2	126	12	2	2	3	146
Total Final Consumption	133	1859	666	663	101	45	3467
1973 – 1998, average annual growth %							
Industry	-1.9%	-0.9%	0.3%	2.1%	0.3%	0.7%	-0.1%
Transport	-15.7%	2.0%	0.8%	2.3%	29.9%	-	1.9%
Agriculture	-0.7%	1.5%	17.7%	2.3%	11.9%	-0.7%	1.9%
Commercial and Public	-6.3%	-2.2%	1.7%	4.4%	3.6%	9.7%	1.2%
Residential	-5.5%	-1.7%	1.8%	3.2%	3.1%	4.4%	0.8%
Other	-7.6%	0.1%	-0.1%	4.2%	-7.7%	6.3%	-0.5%
Total Final Consumption	-3.0%	0.6%	1.0%	2.9%	1.0%	3.3%	0.8%
1998, % of fuel use							
Industry	11%	32%	26%	25%	4%	1%	100%
Transport	0%	97%	2%	1%	0%	0%	100%
Agriculture	2%	80%	7%	9%	1%	0%	100%
Commercial and Public	1%	20%	29%	48%	1%	2%	100%
Residential	3%	20%	36%	31%	8%	3%	100%
Other	1%	86%	8%	1%	1%	2%	100%
Total Final Consumption	4%	54%	19%	19%	3%	1%	100%
1998, % of sector							
Industry	83%	18%	41%	39%	44%	29%	30%
Transport	0%	61%	3%	1%	2%	0%	34%
Agriculture	1%	3%	1%	1%	1%	1%	2%
Commercial and Public	3%	4%	17%	27%	2%	16%	11%
Residential	12%	7%	36%	31%	50%	48%	19%
Other	1%	7%	2%	0%	2%	6%	4%
Total Final Consumption	100%	100%	100%	100%	100%	100%	100%

Source: IEA Statistics.

As primary energy sources for electricity generation, coal has lost some of its share since 1973 while nuclear and, more recently, gas have increased theirs. But electricity has become a much larger component of energy consumption, so that total consumption of all of these fuels has risen. Shifts from coal and oil to gas and nuclear are environmentally positive from the perspective of climate change, air quality and acid rain production. However, they can present important other environmental challenges, especially in the case of nuclear.

The turnover of energy generation capital stock has a significant influence on the changing fuel mix in different sectors. The power sector typically has a slow capital stock turnover, as fossil fuel and nuclear stations have life spans of at least 20 to 40 years. As a result, the bulk of generation facilities needed to meet demand in 2020 in OECD countries have already been built, limiting the extent to which new sources, such as renewables, can penetrate quickly into the electricity generation market.

Nuclear electricity production accounted for nearly 40% of the increase in OECD energy use from 1973 to 1998. The OECD currently accounts for more than four-fifths of global nuclear energy production. Nuclear provides nearly a quarter of the OECD's electricity output and is the second largest single source after coal. It is expected that about 30% of existing plants will be retired from now to 2020. New construction in the OECD will be limited for two reasons. First, nuclear faces strong competition from fossil fuels, in particular natural gas-fired CCGT plants. Second, several countries have imposed restrictions on nuclear power (IEA 2000a). "New renewables" (i.e., renewables other than hydro and direct use of biomass) have grown at a very rapid rate, but from a small base, and so made little impact on total energy supply. Many governments have initiated programmes over the period to support the uptake of renewable energy. While renewable energy generally continues to suffer a cost disadvantage in mainstream applications, it is cost-competitive in many niche applications, and continuing cost reductions are now allowing some renewables to approach competitiveness in mainstream uses.

Outside the OECD, the fuel supply mix is much more reliant on biomass, and less on nuclear and oil. Non-OECD countries were responsible for 61% of the global increase in energy use and 71% of the increase in fossil fuel use since 1973. Nevertheless, their overall energy use remains slightly less than that of the OECD today.

Most of the growth in the OECD's energy use to 2020 is expected to come from increases in oil and natural gas, with the former being driven by the demand for mobility in the oil-dependent transport sector, and the latter by increased use of gas for electricity generation. The share of renewables is expected to grow to represent as much as 6% of total fuel use by 2020 in OECD countries and 12% worldwide (largely due to biomass use in non-OECD countries).

Table 3.3 OECD fuel use changes in energy supply, 1973-1998

	TPES 1973 (Mtoe)	TPES 1998 (Mtoe)	Portion of TPES 1973	Portion of TPES 1998	Increase 1973-1998 (Mtoe)	Increase 1973-1998 (%)	Portion of 1973-1998 increase
Oil	1990	2137	53%	42%	148	7%	11%
Coal	835	1047	22%	21%	212	25%	16%
Natural Gas	704	1048	19%	21%	343	49%	25%
<i>Subtotal Fossil Fuels</i>	3529	4232	94%	83%	703	20%	52%
Nuclear Power	49	554	1%	11%	504	1026%	37%
Hydro	78	111	2%	2%	33	42%	2%
Combustible Renewables & Waste	80	169	2%	3%	89	112%	7%
Other	6	31	0%	1%	25	420%	2%
Total	3742	5097	100%	100%	1355	36%	100%

Source: IEA Statistics.

3.5 Sectoral components

Table 3.4 shows patterns of final energy demand for the main OECD regions. Transport accounts for one-third of current consumption, but was responsible for almost two-thirds of the growth in consumption from 1973-1996. The commercial and residential sectors have also contributed strongly to growth in energy use, while final energy consumption in the industrial sector has fallen slightly from 1973 to 1996. Within OECD regions, patterns have been broadly similar in North America and Europe, while growth in the OECD Pacific countries has been more rapid. In America and Europe, declines in energy consumption in the industrial sector have moderated growth in the commercial and residential sector, with an overall result of almost stable non-transport energy consumption. Within the Asia Pacific countries, growth in all sectors has been much more rapid, although industrial use is still the slowest growing of the four main sectors.¹⁷

In non-OECD countries, industry is by far the largest consumer of energy, followed by household and transport. Transport energy use is expected to increase dramatically in non-OECD regions to 2020, and will surpass household use by 2010. The service industry and agriculture represent the smallest demands on energy use in these regions, although agricultural use has risen as a result of increased farm mechanisation.

17 Within the OECD Pacific region, Korea is responsible for almost 80% of the growth in industrial sector energy consumption, reflecting a different stage of economic development relative to much of the rest of the OECD. As Korea is also different from most other countries in not being a member of Annex 1 countries under the Climate Change Convention, this may be important when looking at climate policy in the medium-term.

Table 3.4 **Patterns of OECD energy use (TFC) 1973-1998**

	OECD	OECD North America	OECD Pacific	OECD Europe
1973, MTOE				
Industry	1071	501	156	413
Transport	720	469	61	190
Agriculture	44	19	4	21
Commercial and Public	283	166	23	94
Residential	544	273	34	238
Other	164	70	21	73
Total Final Consumption	2827	1499	298	1030
1998, MTOE				
Industry	1042	453	209	379
Transport	1166	671	149	346
Agriculture	70	21	16	33
Commercial and Public	379	206	66	108
Residential	663	289	68	306
Other	146	70	19	58
Total Final Consumption	3467	1710	528	1230
1973 – 1998, average annual growth %				
Industry	-0.1%	-0.4%	1.2%	-0.3%
Transport	1.9%	1.4%	3.7%	2.4%
Agriculture	1.9%	0.5%	5.4%	1.8%
Commercial and Public	1.2%	0.8%	4.4%	0.5%
Residential	0.8%	0.2%	2.9%	1.0%
Other	-0.5%	0.0%	-0.3%	-0.9%
Total Final Consumption	0.8%	0.5%	2.3%	0.7%

Source: IEA statistics.

3.5.1 *Transport*

In OECD countries, transport accounts for one-third of current final energy consumption, but has represented almost two-thirds of the growth in consumption since the early 1970s. Industrial energy consumption constitutes almost a further third of current consumption, with the remainder split among households, services and, to a small extent, agriculture. According to the IEA World Energy Outlook 2000, by 2020 transport is likely to account for more than half of world oil demand, and 62% of OECD Primary Oil Demand, accounting for all oil-demand growth in OECD regions (IEA, 2000a). CO₂ emissions from transportation will continue to grow rapidly – by more than 60% until 2020 compared with 1990 in each region under the Reference Scenario policy assumptions. As early as 2010, emissions are estimated to increase by 44% in North America and Europe and 48% in OECD Pacific (IEA 2000a).

Emissions from road transport are a function of many factors:

- **Activity** - the level of transport tasks undertaken.
- **Structure** - the split between different modal shares (road, rail, air, water).
- **Intensity** - the efficiency with which energy is used to complete travel tasks.
- **Fuel** - the types of fuel used to power transport, and the emissions from each (noting that end-of-pipe controls can reduce per volume emissions considerably).

These can be broken down further. Modal activity, in passenger or tonne-kms, depends on vehicle activity, vehicle capacity, and actual capacity utilisation. Modal intensity in turn can be decomposed into vehicle intensity (fuel/km) and utilisation. Vehicle intensity depends on a vehicle's size and characteristics (speed, weight, and power), and on actual driving conditions. All of these variables are subject to policies that provoke changes in technologies and changes in consumer or user habits and behaviour. Good policy analysis depends on understanding these variables *ex ante*, and detailed evaluation to follow their evolution over time.

3.5.1.1 Activity

The level of transport activity relies on the underlying demand for mobility of people and goods, the nature of transport infrastructure and load factors. These are in turn driven by growth in wealth and trade, consumer tastes, lifestyles, urban development patterns and other factors. Historically, GDP growth and the expansion of the transport sector have been strongly correlated, while road transport has grown even faster.

While patterns vary somewhat from country to country, general trends in the last 20 years or so in passenger transport include:

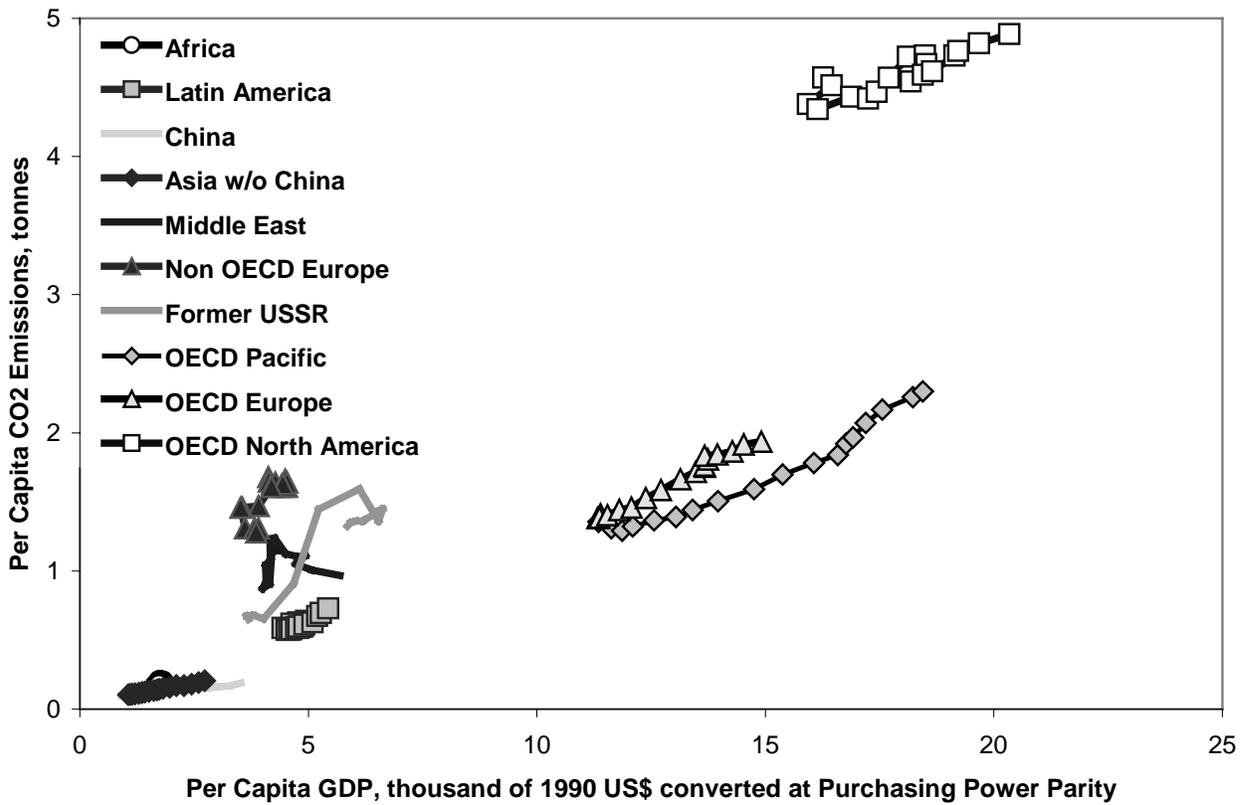
- Increasing levels of car ownership (which has impacts both on levels of travel and modal split).
- Falling average load factors (persons per car) due to more (mostly single-person) commuting trips, smaller households and higher car penetration.
- Increasing average distance travelled per capita, due to changes in urban settlement, patterns of work, shopping and leisure.
- Increasing road passenger-kilometres travelled in the OECD, up by about 1-2% per year. Meanwhile, growth in domestic and international passenger air traffic has been even more rapid, at 5-7% per year.

Figure 3.5 shows how *per capita* CO₂ emissions have grown with GDP/per capita. In most regions, emissions from transport have risen faster than those from all other energy-related sources since 1990, as shown in Figure 3.6, which means that the share of emissions from transport is increasing in OECD countries.

3.5.1.2 Structure

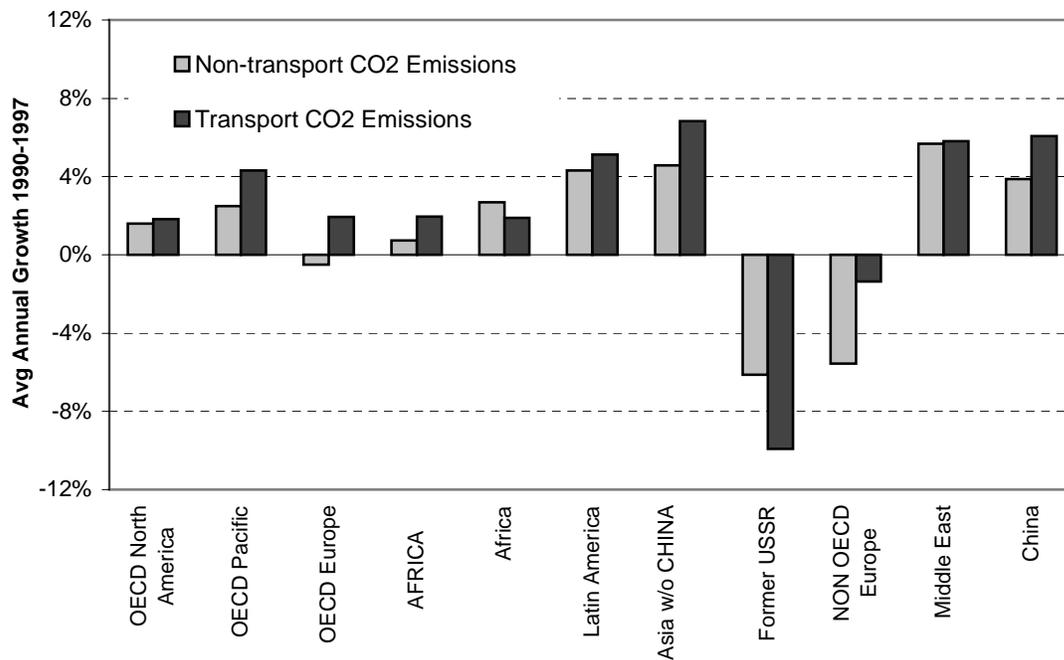
Modal shifts in the past have usually been in favour of more energy-intensive modes. Road transport dominates in passenger and freight, while aviation exhibits the highest rates of growth, but is still small on an absolute scale. Passenger air transport 20 years ago was the most energy-intensive mode of travel, but it is now less energy-intensive than road transport in many countries, and probably for the OECD as a whole. Aviation freight, while difficult to separate from passenger activity is considered by far the most energy-intensive freight mode (three to five times the energy intensity of trucks). Rail remains far less energy-intensive than either aviation or rail, with the exception of some commuter systems that have low load factors.

Figure 3.5 Per capita CO₂ emissions from the transport sector (tonnes CO₂)



Source: Schipper *et al.* 2000.

Figure 3.6 Growth in emissions from the transport sector and rest of the economy, 1990-1997



Source: Schipper *et al.* 2000.

Road transport, both passenger and freight, has experienced tremendous growth over the past 20 years, and how is the dominant transportation mode, with over 91% of passenger travel and 75% of goods transported (OECD 2000a). In freight transport, trucking has won an increasing share of goods transport, at the expense of rail and inland waterways. Trucking has benefited most from the growth in small volume and high value manufacturing goods and trade relative to bulk material such as coal, minerals or agricultural products, where rail and barge still play an important role. The expansion and improvement of road infrastructure, the technological improvements of vehicles (in power, speed and size) and a highly competitive environment have allowed trucks to offer expeditious, timely and door-to-door delivery of high value-added goods. The interplay between vehicle technology, and the increases and flexibility of the service provided and infrastructure provision have fuelled growth of road transport relative to other modes.

- The share of rail transport, both passenger and freight, has been declining over recent decades in almost all OECD countries, except for rail freight in the US. While passenger transport by rail has experienced an absolute growth over the past fifteen years, it accounts for only 6% of passenger travel, and a much lower share in North America (OECD 2000a). Trends in rail freight show maintenance of transport volume (tonne-km), but a diminishing share with respect to road freight.
- Water-bound transport has also experienced a declining market share, both for inland waterways and short-sea shipping, although these modes have been growing steadily in recent years. For maritime shipping, globalisation of production and expanding trade are driving its development. Like rail freight, maritime transport has seen market share eroded because of lower demands for bulk shipments of raw materials.
- Air transport's share of total passenger domestic travel is less than 3%, except in some Nordic countries (6%) and in North America and Australia (10-12%) (OECD 2000a). However, the international aviation industry has grown prodigiously over the past thirty years. Demand-side drivers include economic growth, globalisation of commerce and industry, higher disposable incomes, and increased leisure time. On the supply side, falling airline tariffs due to enhanced competition, technical efficiency improvements and the relatively low cost of aviation fuel due to lack of taxes are also factors. While aviation still accounts for only a small proportion of total greenhouse emissions, the release of greenhouse gases at high altitude leads to greater global warming effect than equivalent ground level emissions, so this sector is of concern, especially due to its rapid growth.

3.5.1.3 Intensity

Fuel intensity is generally measured either as energy use per passenger-km or tonne-km of freight. While there have been significant and continuous improvements in automobile engine technology over the years, cars are becoming heavier (in part to accommodate more accessories such as air conditioning, electric windows, stereos, etc.), more powerful, roomier and with larger engines. These increases in “hedonic” attributes have offset technical improvements, so that overall fuel intensity of vehicles has fallen only slowly, or even increased.¹⁸ In recent years, especially in the US, there has been

18 The exceptions to this were the U S and Canada, where vehicle fuel intensities improved dramatically from 1974 to 1990 due to combined effects of pricing, regulation and other policy and behavioural changes. However, as North American efficiency figures have approached those of other countries, there may be less scope for such dramatic improvements in the future.

rapid penetration of sport utility vehicles into the market. Together with passenger vans and pickup trucks, these now account for more than half of US passenger vehicle sales, and similar trends are appearing in other OECD countries. In addition to these trends, the load factor of automobiles and other household vehicles has fallen steadily in virtually all countries, from over 2 people in the early 1970s to around 1.5 in the mid 1990s, which also limited the net decline in the energy intensity of passenger transport.

Energy intensity of freight traffic is a complex function of many factors. For road freight, these include a mix of heavy and light trucks, traffic conditions, load factors and levels of packaging, and the fuel efficiency of the vehicles themselves. In most OECD countries, there has been an increase in the share of smaller trucks. While evidence is not complete, it appears that various factors have combined to leave the energy intensity of trucks relatively constant. However, the increasing share of road freight has led to an increase in aggregate intensity of the freight sector.

In passenger aviation, energy consumption per passenger km has decreased rapidly compared to other modes due to high technological efficiency gains, stock renewal (and growth), and substantial increases in load factors.

3.5.1.4 *Fuel*

Petroleum fuels dominate motor vehicle transport almost entirely. Typically, petrol comprises 85% or more of total transport fuel use, with most of the remainder being diesel. Diesel dominates the heavy truck segment. While there have been some attempts to introduce alternatives such as ethanol, natural gas and electricity into the mix, the combined share of these fuels in OECD countries is less than 1%. A few countries have been more successful in substituting LPG and diesel for petrol, strongly supported by highly differentiated pricing. The greenhouse impacts of these changes are limited.

Alternative fuel technologies, are beginning to gain credence. DaimlerChrysler plans to have fuel-cell cars on the market by 2004, and are expected to be joined by Honda, Toyota, and General Motors. The chairman of Ford, Bill Ford, recently stated that he believed "...fuel cells will finally end the 100-year reign of the internal combustion engine" (*The Economist*, February 2001).

Hybrid electric/petrol vehicles have recently been commercialised in Japan and US in small numbers. Due to still high cost per vehicles they are not likely to command large shares in new vehicles sales in the next 5 to 10 years but offer, if market penetration is successful, a large potential for fuel savings.

3.5.2 *Industry*

In the industrial sector, final energy consumption has been falling slightly in OECD countries, mainly due to changes in the structure of economic activities – with a shift from industrial manufacturing to services - along with increased efficiency in energy use. In parallel to this decrease in energy consumption, there has been a trend towards the increasing use of fuels from less carbon-intensive energy sources, for example the growing use of biomass energy in the pulp and paper sector.

Energy use in the industrial sector has grown more slowly than in other sectors, in part due to the declining share of GDP from this source. For example, the steel sector, which is a large, energy-intensive industry, fell as a percentage of GDP in 10 OECD countries studied by 20-80% from 1971-1992. From 1971 to 1992, the US, Germany and Japan all had energy use at least 10% lower than would have been the

case without structural shifts in the economy (IEA 1997b).¹⁹ Table 3.5 shows the contribution of structural change to improvements in energy intensity in 7 OECD countries. To some extent, this is due to a shift in industrial production from OECD to other countries, as non-OECD countries constitute an increasing portion of global industrial production and trade. Insofar as this is the case, local environmental problems may simply be shifted to other countries, while the impact on global emissions is uncertain.

Table 3.5 **Decomposition analysis of manufacturing energy use, 1973-87**

	Annual Change in Aggregate Energy Intensity (% per year)	Contribution of Structural Change	% Contribution of Structural Change
France	-3.1	-0.5	16%
West Germany	-2.6	-0.4	15%
Japan	-4.2	-0.9	21%
South Korea	-2.7	-0.6	22%
Sweden	-2.2	-0.5	23%
United Kingdom	-2.4	-0.1	4%
United States	-4.0	-1.1	28%

Source: Price *et al.* (1998).

Most OECD countries have active policies to discourage oil consumption by industry, and this is in part reflected in the declining share of oil use. Coal share has also fallen, due to relative reductions in sectors and processes reliant on coal, and to shifts to natural gas and electricity. The shift from coal and oil to gas and electricity has uncertain environmental implications, depending on the source of the electricity. There have also been substantial improvements in the energy efficiency of industrial processes over time in all countries. Included among these is a shift to greater use of biomass energy in the pulp and paper sector.

3.5.3 Residential and commercial (buildings and equipment)

The commercial and residential sectors are also contributing to greater energy use, with increasing and new uses of electric goods (such as more computing and internet time), more floor space per capita, and higher levels of cooling and heating comfort. Despite these trends, energy use by these sectors in OECD countries is expected to be relatively stable or even declining over the next two decades under the OECD Environmental Outlook Reference Scenario. This will be the result of continued improvements in the efficiency of appliances and a saturation of household electrical goods in many OECD countries.

In the residential sector, water heating and space heating and cooling are major components of energy demand. The residential sector has seen a number of trends, which explain the increased energy and electricity consumption. Household size on average has fallen in the OECD, contributing to greater floorspace per capita, and so a greater need for space heating and cooling. The ever increasing range of energy - (especially electricity-) consuming appliances also encourages greater energy use. These include consumer electronics such as stereos, televisions, VCRs, video games, etc., as well as increased penetration of refrigerators, dishwashers, clothes washers and dryers, central heating and air conditioning. On the other

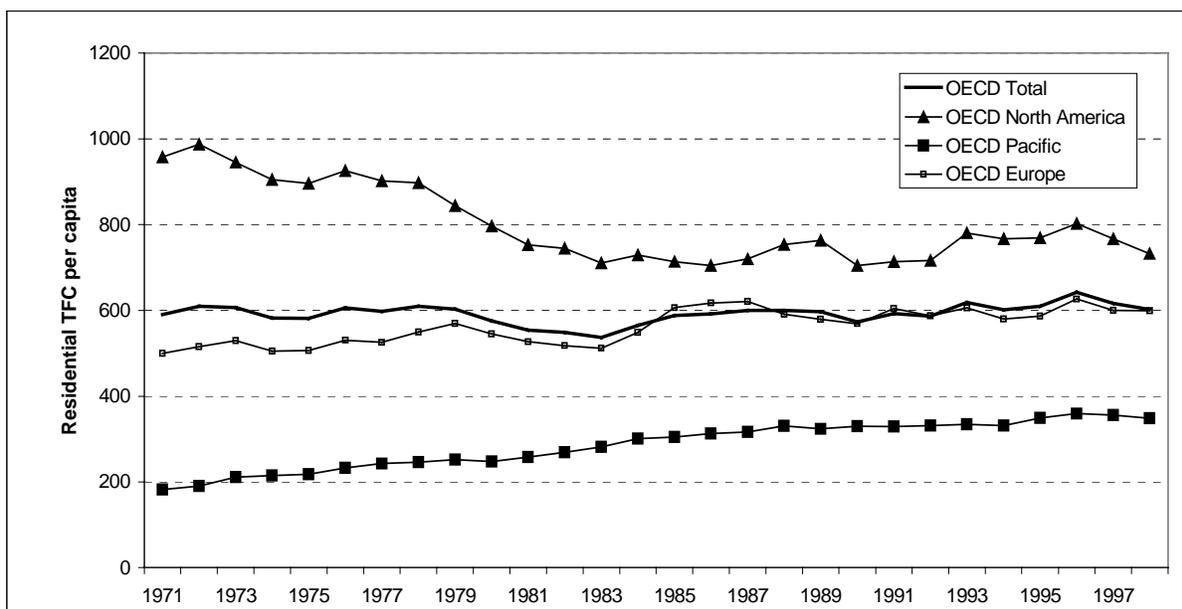
19 Norway experienced the opposite, with energy use 19% higher due to structural shifts. However, the economies experiencing declines include the largest OECD economies, so that the overall effect in the OECD was to energy reductions.

hand, there have been substantial improvements in the efficiency of appliances and equipment, which has had a moderating effect on energy use.

Electricity and gas have increased their share of overall energy use in this sector, at the expense of coal and oil. Renewables have also shown a noticeable increase. The environmental implications of this are uncertain, as the majority may represent combustion of wood, which has important emissions attached to it.

The net result is summarised in Figure 3.7, which shows that residential sector energy use per capita has been growing steadily in Europe and the Pacific OECD countries. In North America, however, per capita energy use fell throughout the 1970s and early 1980s, but has partially (and erratically) rebounded since then. This may have been a result of more active responses to the oil shocks of the 1970s, and the greater potential for action offered by the higher overall level of energy consumption. However, the trend across the OECD since the mid-1980s has been one of general increases, with efficiency measures unable to fully offset increasing demand for energy services.

Figure 3.7 Changes in residential sector energy use per capita



Source: IEA Statistics.

Note: does not include transport energy use.

In the commercial sector, many trends similar to those in the residential sector are apparent. Heating, cooling and lighting are the major sources of energy demand. There has been a trend to increasing floor area per capita and an increase in the range of energy using appliances, offset by improvements in the efficiency of heating and other end uses. In some buildings in the US, office equipment has become a bigger energy user than heating and cooling, and in any case, computer equipment is itself a major consumer of cooling. Clear trends are difficult to determine due to the lack of detailed data for this sector and the wide variety of building types used.

3.6 Energy trade and prices

As energy consumption in OECD regions rapidly outstrips energy production, the Reference Scenario indicates that more imports of fuels will be required over the next few decades, particularly of natural gas and oil. Currently, OECD regions produce roughly 74% of the amount of energy they consume. Energy self-sufficiency reached a peak of 79% in 1985. The import-export balance of different fuels varies substantially. While OECD countries are net exporters of renewable energy sources, and import only a small proportion (3% in 1998) of the coal they use, more than 15% of gas and more than 50% of oil used are imported from non-OECD countries.

Energy self-sufficiency is projected to drop to 60% in 2020, as total energy consumption rises by over 20% and energy production in OECD countries remains stable or declines slightly. An increasing percentage of world crude oil supplies is expected to come from the Middle East OPEC countries (from 27% in 1996 to over 60% in 2020) (IEA, 1998a). OECD oil import dependence is expected to rise from 54% in 1997 to 70% in 2020 (IEA, 2000a). OECD regions, particularly Western Europe, are projected to significantly expand imports of natural gas over the next 20 years, while non-OECD countries will expand exports. OECD natural gas import dependence is expected to rise from 15% in 1997 to 32% in 2020 (IEA, 2000a). These changes in trade patterns, and in dependence on non-OECD sources of gas supply, could have implications for gas supply security. As open regional electricity markets continue to expand, so will the inter-regional electricity trade and, depending on the fuel mix within the markets (hydro/fossil fuelled/nuclear), could either increase or decrease local and global emissions.

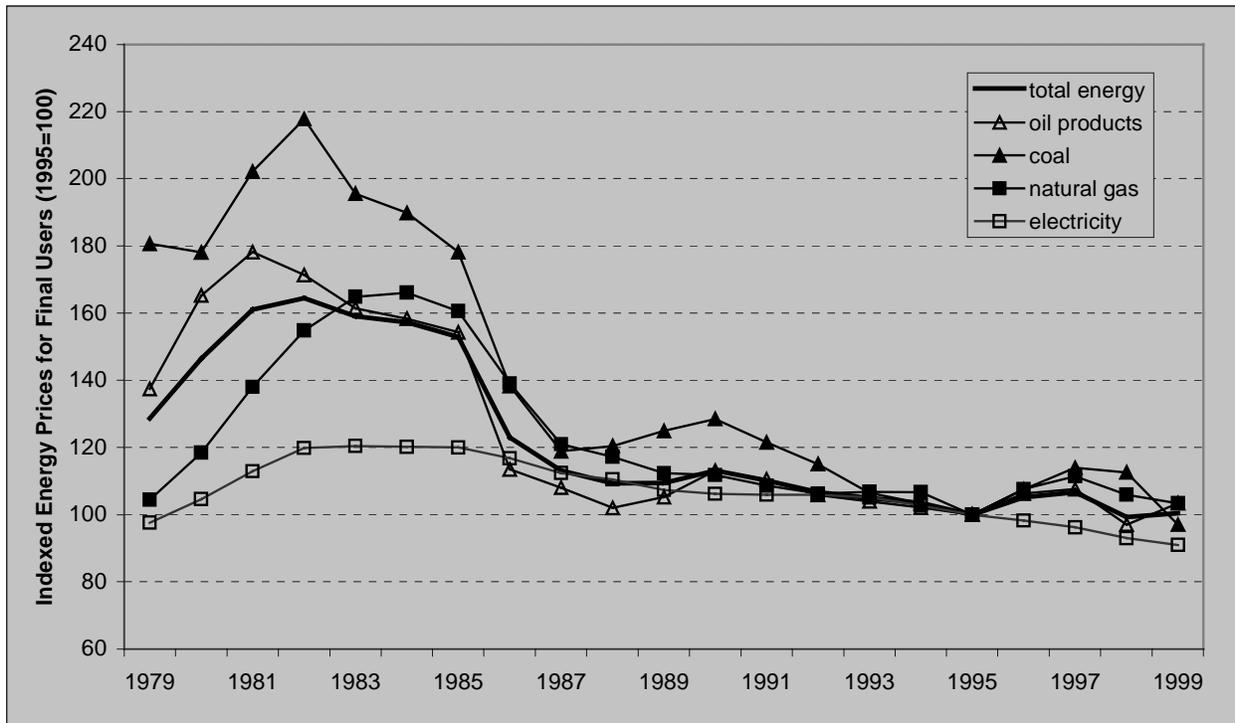
Major price rises in the 1970s led to significant reductions in energy demand. Since then, prices for end users in OECD countries have fallen to around their pre-shock levels and have been relatively flat through the end of the 1990s (Figure 3.8). The period of price stability corresponds roughly with the period in which GDP and energy use have continued to move closely together. There has been no sharp rise in energy use per unit of economic activity (TFC/GDP) following the fall in prices after the 1980s, indicating that improvements in energy efficiency have been “locked in” to OECD economies through infrastructure and permanent behavioural change. Recent OPEC arrangements to reduce oil output have seen large and rapid rises in prices over the last year. The duration of this price rise is uncertain, as it is reliant on cartel management rather than underlying market forces. However, there is no evidence that physical global supply shortages will influence prices significantly over the period to 2020.

Energy is considered to be one of the most heavily subsidised sectors in the OECD area (OECD, 1998a). OECD data on coal subsidies for selected countries shows that direct producer subsidy equivalents (PSE) have dropped significantly in recent years, but in 1997 the level of PSE for coal production in these countries still stood at almost US\$8 billion per year²⁰. Subsidies to the entire energy sector have been estimated as being an order of magnitude higher, with the bulk of support going towards nuclear, coal and oil production, often for purposes of maintaining regional employment (de Moor and Calamai, 1998).²¹ Subsidy reform could significantly influence energy prices, and thus emissions, over the period to 2020 (see Section 7).

20 Data is incomplete and identification of all subsidies and support programmes is difficult, so a definite assessment about whether overall support for coal (such as direct and indirect price support) is declining in the OECD area is difficult.

21 While subsidy removal to coal production is likely to lead to negligible but positive effects on net employment in the long run (through increased economic efficiency), this does lead to decreases in the affected sector and regions in the short term unless measures are taken to support transition to new employment or training opportunities. To allow time for adjustment, transition measures should be considered, and subsidies be removed gradually.

Figure 3.8 Energy price trends, OECD



4. OUTLOOK FOR ENERGY USE AND CO₂ EMISSIONS

To place the Reference Scenario of the OECD Environmental Outlook in a broader context, this section describes and compares that scenario to other scenarios in the literature. The time frame for this comparison is to 2020. It begins with a brief overview of the IPCC family of scenarios, which were released in 2000. It moves on to describe the OECD's own work, first a reference scenario used in recent OECD climate policy simulations based on the GREEN model (OECD 1999a), and finally the Environmental Outlook's Reference Scenario. The last sub-section outlines challenges in considering longer term outlooks for CO₂ emissions and the ultimate objective of the UNFCCC (to stabilise atmospheric concentrations of GHG), as well as the implications for nearer term mitigation.

4.1 Energy sector CO₂ futures: IPCC reference scenarios

Future trends in energy emissions are the results of changes in the underlying drivers discussed in the previous chapter. The IPCC recently developed six illustrative scenarios to provide a basis for future policy assessments. Each has a narrative storyline intending to represent vastly different views of the world and of how the drivers that determine energy demand and emissions will develop over time (summarised in Box 4.1). Once the storylines were developed, six different modelling groups produced a range of possible outcomes associated with each. A recent IPCC report describes these scenarios, which show great divergence. Even though none of the scenarios include new climate policies, they do characterise possible outcomes in a world that has various rates of change in environmental concerns, as well as policy, technology, and other socio-economic drivers (Figure 4.1).

No scenario group was considered by the IPCC as being more or less plausible than any other, even though they differed considerably in many key outcomes. Within each group, one scenario was chosen as a marker scenario, typical of that family. Table 4.1 summarises some key OECD aggregates for each of the four IPCC marker scenarios, and compares these with historical data over the period 1971-1996. Comparison of these scenarios provides some insights into factors that will affect future environmental impacts of energy use. As the authors of the IPCC report point out, it is not sufficient to compare these scenarios just with current trends. However, where there are projected discontinuities with historical trends, it helps to point out where future trends may take us, and where non-climate policy intervention could assist to achieve more sustainable development paths.

Box 4.1 The main characteristics of the IPCC illustrative scenarios

Each scenario assumes a distinctly different direction for future developments, such that the four scenarios differ in increasingly irreversible ways. Together, they describe divergent futures that encompass a significant portion of the underlying uncertainties in the main driving forces. They cover a wide range of key “future” characteristics, such as demographic change, economic development, and technological change. For this reason, their plausibility or feasibility should not be considered solely on the basis of an extrapolation of current economic, technological, and social trends.

The A1 scenarios describe a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

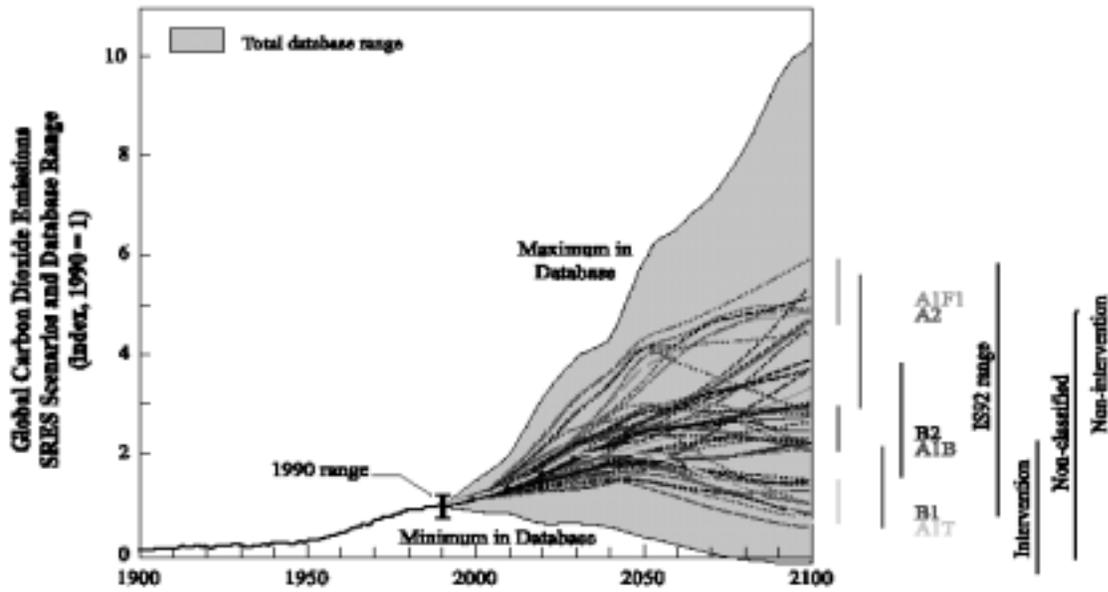
The A2 scenario describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other scenarios.

The B1 scenario describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline. However, the B1 storyline includes rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of low GHG-intensive (including nuclear power) and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

The B2 scenario describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population (at a rate lower than A2), intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 scenarios. While this scenario is also oriented toward environmental protection and social equity, it focuses on the local and regional levels.

Source: IPCC 2000a.

Figure 4.1. Global CO₂ emissions related to energy and industry



Source: IPCC (2000a).

Table 4.1 Summary of historical data and IPCC "marker scenarios"

OECD Aggregates	Historical Trends, Average Annual Growth Rates ²²				Average Annual Growth Rates, 1990-2020					
	1975-1998	1975-1982	1982-1991	1991-1998	Scenario A1C	Scenario A1FI	Scenario A1T	Scenario A2	Scenario B1	Scenario B2
Kaya Levels										
Population	0.8%	0.9%	0.8%	0.7%	0.5%	0.6%	0.5%	0.6%	0.5%	0.4%
GNP or GDP	2.8%	2.6%	3.0%	2.6%	2.2%	2.2%	2.2%	1.8%	2.3%	2.1%
TFC	1.1%	0.5%	1.4%	1.4%	1.2%	1.4%	0.9%	1.2%	0.9%	0.9%
TPES	1.5%	0.9%	1.9%	1.6%	1.0%	1.1%	1.0%	1.2%	0.9%	1.1%
CO ₂	0.8%	0.4%	1.0%	1.1%	0.7%	1.1%	0.4%	1.1%	0.4%	0.9%
Kaya Ratios										
GDP per capita	1.9%	1.7%	2.2%	1.9%	1.6%	1.6%	1.7%	1.1%	1.8%	1.6%
TFC/GDP	-1.6%	-2.0%	-1.6%	-1.2%	-1.0%	-0.8%	-1.3%	-0.6%	-1.3%	-1.1%
TPES/TFC	0.4%	0.4%	0.5%	0.2%	-0.2%	-0.3%	0.1%	0.0%	0.0%	0.2%
CO ₂ /TPES	-0.6%	-0.5%	-0.9%	-0.5%	-0.3%	0.0%	-0.6%	0.0%	-0.5%	-0.2%

Sources: IEA Statistics and IPCC (2000a).

4.1.1 Aggregate indicators

While all 6 marker scenarios (based on the four illustrative scenarios above) result in growth in emissions, there is a wide variety in the rate of growth, with OECD 2020 emissions rising to 13-40% above 1990 levels. While the rates of growth in CO₂ emissions are broadly comparable with rates over the 1971-1997 period (with the exception of Scenario B1), this is largely due to the post oil shock period of 1975-1982, when there were rapid increases in prices, new forms of energy regulation, and vastly increased concern for and knowledge of energy efficiency. The rates of CO₂ growth in the scenarios are slower than

22 Based on IEA Energy Statistics.

during the last 15 years, and Scenario B1 shows growth even slower than the post-oil shock period. The other 3 scenarios have broadly similar CO₂ growth patterns, with levels 23-35% above 1990 levels in 2020. In 1998, CO₂ from energy in the OECD was already roughly 9% above 1990 levels, according to IEA statistics (reference approach).

Similar to CO₂ growth, energy growth in the scenarios is slower than at any period in the last 25 years, other than the post-oil shock period, and much slower than the historical average. Some of these slower growth figures are in part due to slower population and GDP growth. There is little variation in the four scenarios in total energy use growth. The real difference in the environmental outcomes is due to the emissions intensity of the energy used, with scenario B1 showing a rapid decline in emissions intensity.

4.1.2 Population

This is essentially a function of the storyline chosen, and virtually all future projections show that population growth in the OECD will slow over the next 20 years. The OECD Reference Scenario shows a slowing OECD population growth as well: 0.58% (1995-2000), 0.49% (2000-2005), 0.38% (2005-2010), 0.33% (2010-2015) and 0.26% (2015-2020).

4.1.3 GNP/capita

While the A1 scenario has the fastest global growth rate in GNP per capita, the OECD region grows faster in the B1 than the A1 scenario. This could be consistent with the need for rapid technological change, but raises the question of what social and policy changes would be needed to achieve this outcome. One possibility is the growth of the Internet and electronic commerce. Some analysts perceive that this has raised the allowable growth rate in the US economy, and could spread to other economies. Others contend that e-commerce has gone further, and changed the nature of growth in the future, making it less energy-intensive through teleconferencing, home shopping, electronic information access, improved logistics, etc. (Romm *et al.* 1999). Monitoring any such impacts would be difficult, as the changes in energy use can be in different sectors and over different time scales (e.g. less manufacturing energy, but more transport). While there are many questions raised in such an analysis, a key issue is that if e-commerce raises the rate of economic growth, then it must increase the rate of intensity decline by *more* than this increase in order to achieve actual energy savings. Nonetheless, the role of greater e-commerce could be important for environmental policy, and steps to encourage or discourage this growth (e.g., restructuring of telephone access and charging) could have significant effects. In any case, this view of future growth does not seem to be reflected in the B1 scenario, since it is the reduction in emissions intensity, not energy intensity, which is the most significant factor in reducing emissions growth.

The growth rate for income per capita in scenario A2 implies a reduction in consumer expectations that seems difficult to explain. However, it is notable that this low growth scenario shows the highest increase in energy use and CO₂ emissions. This indicates that reducing economic growth *per se* (in addition to being an unrealistic policy goal) would also be an ineffective abatement technique. Continued growth coupled with appropriate technological development may be more helpful from a GHG standpoint, as long as this is accompanied by continuing technological improvement. Environmental policies can be used as a driving force to push the development of environmentally-friendly technologies.

4.1.4 Energy intensity (TFC/GDP)

As illustrated in Table 4.1, the IPCC scenarios reflect the likelihood that energy intensity of OECD economies will continue to decline, for a number of reasons. Structural changes seem likely to

continue, with continuing faster growth in the tertiary sector than in manufacturing, leading to continuing falls in energy intensity. The role of information technology and the Internet could be a specific aspect of this shift, as mentioned above.

Other reasons for continuing declines in energy intensity include continuing investments in new, more energy efficient technologies. While it is widely (although not universally) accepted that such a trend exists, there is a considerable degree of uncertainty over the rate of this “autonomous energy efficiency improvement” (AEEI). AEEI is often assumed to lie around 1.0% per year. However, this appears based on longer term trends which include reactions to oil price shocks and enhanced regulation. Trends in the 1990s show that the “delinking” of energy and GDP is not as apparent as it was in the 1980s, and this may have to do with falling or stable energy prices. So, it may be necessary for governments to intervene even to maintain historical rates of improvement.

Many analysts also postulate the existence of an environmental Kuznets curve, where by increasing incomes at first increase environmental pressures, but then lead to declines, as wealthier citizens demand higher levels of environmental quality. However, the existence of such curves is debatable (see Pearce, 2001 for a summary of this debate).

However, there are some trends that indicate a potential ability to better integrate environmental and economic concerns of consumers through environmental policies. For example, with deregulation of energy markets, “Green Pricing” schemes have been introduced, whereby consumers can voluntarily pay extra for their electricity to ensure it is sourced from renewable energy. While such schemes currently have very low take-up, when combined with falling prices for renewables, they may offer potential for significant no-regrets emission reductions. Such schemes are similar to demands for organic produce, which is generally higher-priced, but delivers environmental benefits to consumers. Although such schemes may contradict the “polluter pays principle”, they potentially could be an important part of future environmental solutions.

Prices are themselves clearly an important driver, although hard to predict. The IEA’s World Energy Outlook projects that coal prices will remain flat over the period to 2020 while oil prices will rise from around \$16.50 per barrel through 2010 to \$22 per barrel by 2020. Gas prices are expected to largely follow oil prices, with more decoupling after 2010. The WEO also indicates that absolute energy use is not highly sensitive to changes in prices, although changes well outside the ranges projected could show different response effects. However, relative energy prices can be important in influencing demand for a particular fuel — especially in industry.

4.1.5 Conversion efficiency (TPES/TFC)

All the IPCC scenarios show an improvement in the efficiency of conversion from primary to stationary energy. This is a change from the last 25 years, although there are some indications that this long term trend may be plateauing. Whether a reversal in this trend will occur in the near-term is open to question.

A key factor affecting trends in the ratio of primary to final energy is the rate of electrification. Increasing electrification has been a clear trend for the past 25 years, and it seems likely that it will continue to do so. The IPCC scenarios show increases in electricity’s share of final energy consumption of 3-13%. In part, this reflects structural change toward more electricity-intense sectors, as well as continuing innovations in electric devices, and the replacement of old capital. Whether this process will continue at the same rate as the past is unclear, although there is already considerable penetration of electric cooling and heating technology, and many electric appliances will be replaced by more efficient models in future.

The ability of electricity to compete with gas is less certain (Table 4.2). While deregulation of energy markets is widely expected to lead to greater penetration of gas in electricity production and some industrial uses, its ability to compete for household and residential uses is less certain. This is reflected in the IPCC scenarios, where the share of gas in primary energy supply rises more rapidly than in final consumption and with the exception of Scenario A1, has stable or declining share of TFC. The exception is Scenario A2, which projects an overall decline in gas use due to more use of local fuels.

Table 4.2 IPCC scenarios - Projected changes in gas share, 1990-2020

	Share of Gas in TPES			Share of Gas in TFC		
	1990	2020	1990 – 2020	1990	2020	1990 – 2020
	(%)	(%)	(% points)	(%)	(%)	(% points)
A1B	20%	31%	+11%	20%	28%	+8%
A1FI	19%	39%	+21%	20%	30%	+9%
A1T	21%	32%	+12%	18%	21%	+3%
A2	22%	20%	-3%	21%	18%	-3%
B1	19%	22%	+4%	20%	17%	-3%
B2	21%	28%	+7%	18%	15%	-3%

Source: IPCC 2000a.

Note: Figures may not add up, due to rounding.

Offsetting the reduced conversion efficiencies from increasing electrification will be improvements in the thermal efficiency of this electricity. Improved technologies, especially improved gas turbines, offer significant potential for high efficiencies, and gas-based cogeneration even higher. Coal technologies will also improve, although they will continue to operate at efficiencies below 50%, and the high efficiency applications still seem some way off.

Improvements in conversion efficiency are strongly limited by the slow turnover of energy generation capital. Power stations typically have life spans of 20-40 years, so the bulk of generation in 2020 may already be built. Projections by the US EIA show that by 2000, it is expected that two thirds of US electricity supply for 2020 will already be built. In such conditions, rapid changes in operating characteristics are difficult without government intervention or major changes to the economic environment. On the other hand, over the longer-term, substantial change is possible if appropriate incentives are provided early on.

4.1.6 Carbon intensity ($CO_2/TPES$)

Nuclear power seems unlikely to grow as quickly in the OECD to 2020 as it has in the past 25 years. All other things being equal, this would lead to an increase in emission intensity for a wide range of air pollutants. On the other hand, reduced reliance on nuclear would lower the chance of nuclear accidents or waste disposal problems.²³ The question is what fuels will be used to supply this reduced capacity. All indications are that a significant portion would be taken up by natural gas. This fuel has relatively low greenhouse gas and sulphur emissions, and would generally lead to lower NO_x emissions. However, gas-fired co-generation may lead to co-location of power generation facilities in more densely settled areas, which could increase NO_x concentrations where they have more impact (i.e. in urban areas).

23 However, growth in nuclear in developing countries seems more likely, and many of these plants would potentially pose risks to OECD countries.

The IPCC B1 scenario, with the lowest growth in emissions for the OECD90 region, assumes that nuclear power generation may more than triple 1990 levels by 2020, accounting for 39% of total growth in primary energy use over that period²⁴. While perhaps technically feasible, it seems unlikely that such a scenario could be realised, given concerns in many OECD countries over nuclear use. This scenario also indicates a significant drop in the proportion of the OECD's energy needs being met by coal. This relatively rapid transition away from coal as an energy source would also imply important changes in economic and/or regulatory approaches to energy supply. The B2 scenario also indicates significant growth in nuclear power.

Renewables also seem set to pick up a larger share of OECD electricity generation in all scenarios, although this increase is small in some scenarios. Government requirements and support for renewable energy will assist increased penetration of renewable energy this, as will the increasing cost-competitiveness of many renewables. Renewables will widely have environmental benefits, although there may be local air quality problems associated with increased biomass use, especially emissions from inefficient wood stoves. In the time frame to 2020, it is unclear that renewables can take up a major share of energy demand without considerable and continuing government intervention of some sort (which could include pricing to reflect externalities). The IPCC Scenarios all show relatively rapid increases in the absolute level of renewables use, but the highest market share for renewables in primary energy supply is still only 7% in 2020.

Overall, OECD countries may have trouble matching historical trends in carbon intensity improvements in the period to 2020, if nuclear (as seems likely) continues to play a declining role. While both gas and renewables can enhance their role, it is unclear that they can fully compensate.

In terms of non-greenhouse gases, all of the IPCC Scenarios show declines in sulphur emissions of 50-75%, and small declines to moderate increases in CO and NO_x. While some of these effects will be partly due to fuel switching, these also imply improvements in end-of-pipe controls.

4.2 GREEN Model baseline

The OECD has analysed the economic impacts of climate change policies since the early 1990s. Much of this analysis is based on the use of the GREEN model. It is worthwhile to briefly review the business-as-usual scenario in this model, which is the basis for assessment of economic impacts of policy changes. *Action Against Climate Change OECD* (OECD 1999a) contains a more detailed description of the model, and its use in climate policy analysis. Table 4.3 summarises some relevant historical aggregates, and compares projections from recent OECD work.

24 Unlike the other 3 scenarios, the B1 scenario aggregates nuclear and solar energy into non-fossil electricity production. Given the high cost of solar, it seems likely that the bulk of this would be nuclear, although precise figures are impossible to calculate. In any case, the growth in nuclear would be very rapid.

Table 4.3 Indicators of OECD CO₂ and economic growth

Average Annual Growth Rates	Historical Trends, Average Annual Growth Rates ²⁵				GREEN	JOBS/ Polestar	IEA WEO
	1971-1998	1975-1982	1982-1991	1991-1998	1995-2020	1995-2020	1997-2020
OECD Aggregates							
CO ₂	0.9%	0.4%	1.0%	1.0%	1.4%	1.1%	1.0%
GDP	2.8%	2.6%	3.0%	2.4%	1.9%	1.9%	2.0%
CO ₂ /GDP	-1.8%	-2.1%	-2.0%	-1.4%	-0.5%	-0.8%	-1.0%

Source: OECD and IEA statistics; IEA World Energy Outlook (2000); OECD GREEN model (1999a); OECD Environmental Outlook (2001).

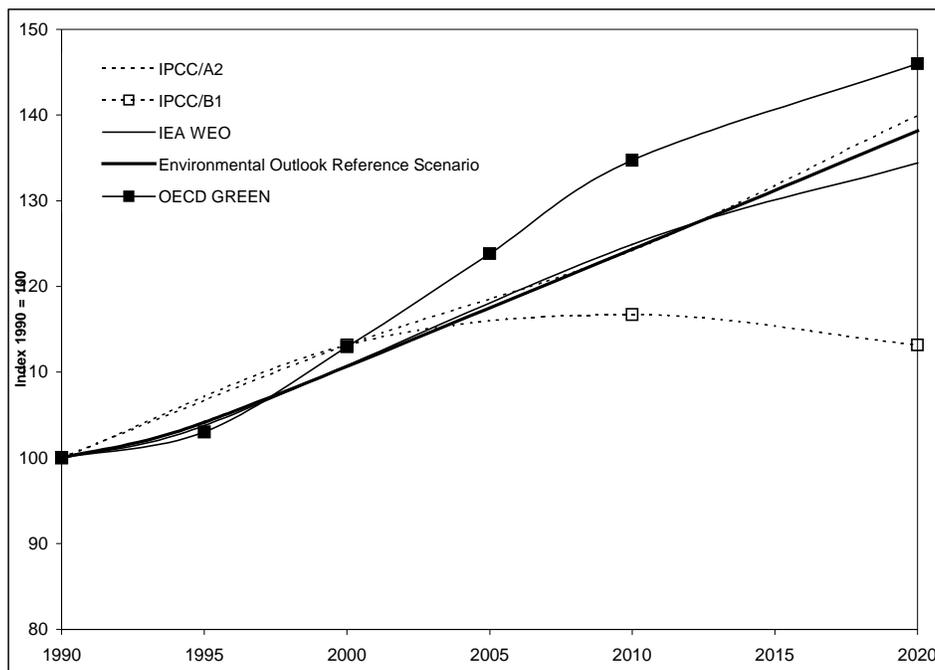
The GDP growth rate shown in the GREEN model indicates a slowing in GDP growth over the next 20 years, broadly consistent with most models. On the intensity side, however, which is summed up by the ratio of CO₂ emissions to GDP, the GREEN model shows a significantly slower decline than has been the case historically, and slower than all the IPCC marker scenarios. This appears due to two main factors. First, GREEN assumes that AEEI improves at 0.4 times the rate of labour productivity growth. This leads to an average annual AEEI of around 0.5-0.7% over the period from 1990 to 2020. JOBS uses 0.75%, and the World Energy Outlook does not use an AEEI. Second, the model assumes that as oil and gas reserves are being depleted, energy demand shifts toward coal and a carbon-based fuel substitute, so there is an increase in the carbon intensity of fuel use.²⁶

4.3 Reference scenario in the OECD Environmental Outlook

A comparison of OECD CO₂ emission trends and other main indicators to 2020 is shown in Table 4.4 and Figure 4.2. The Reference Scenario in the OECD Environmental Outlook, as with other scenarios, shows that CO₂ emissions are likely to increase substantially to 2020, both in OECD and other regions. Emissions in OECD countries are projected to increase by approximately 33% from 1995 to 2020, and by almost 100% in the rest of the world. CO₂ emissions in Central and Eastern Europe are projected to grow by 78% during 1995 - 2020, while in Australia and New Zealand, the projected increase is by 38%; in North America by approximately 35%; and in Western Europe and in Japan and Korea, by 23% and 17% respectively (Table 4.4). The Environmental Outlook baseline was calibrated to the IEA Reference Scenario, which explains the close fit for these two trends.

²⁵ Based on IEA and OECD statistics.

²⁶ GREEN assumes backstop energy technologies are available after 2010 priced at \$7,333 per terajoule for carbon based fuel, \$13 333 for carbon-free fuel and \$27 778 for carbon-free electricity generation.

Figure 4.2 Projected CO₂ emissions from OECD countries, 1990-2020

Sources: OECD Env. Outlook Reference Scenario, Bumiaux (2000), IEA (2000a) and IPCC (2000a).

Notes: 1990 data for the GREEN and WEO scenario's are calculated from IEA (1998b).

Table 4.4 Projected CO₂ emissions in the OECD regions in 1995-2020

	CO ₂ emissions 1995 (GtC)	Projected CO ₂ emissions 2020 (GtC)	Projected total change in CO ₂ emissions 1995-2020	Projected annual change in CO ₂ emissions 1995-2010	Projected annual change in CO ₂ emissions 2010-2020
North America	1.726	2.335	35%	1.3%	1.1%
Western Europe	0.966	1.190	23%	0.9%	0.8%
Central and Eastern Europe	0.243	0.432	78%	2.5%	2.1%
Japan and Korea	0.433	0.507	17%	0.7%	0.6%
Australia and New Zealand	0.086	0.119	38%	1.4%	1.1%
OECD	3.455	4.582	33%	1.2%	1.1%
Non-OECD	2.690	5.336	98%	2.7%	2.9%
World	6.144	9.919	61%	1.9%	2.0%

Source: Reference Scenario in OECD Environmental Outlook (2001).

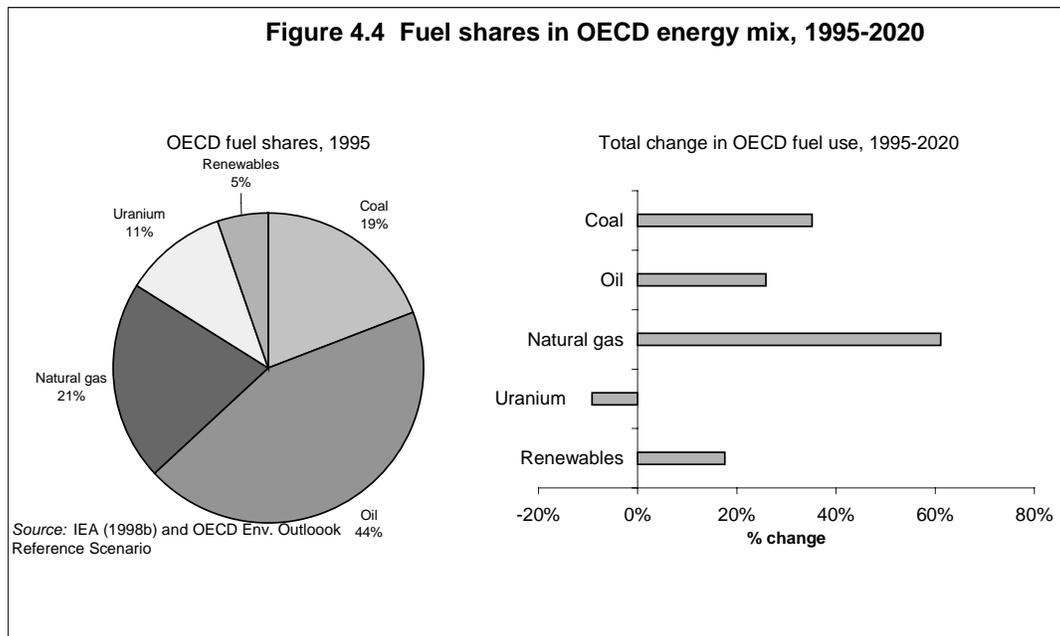
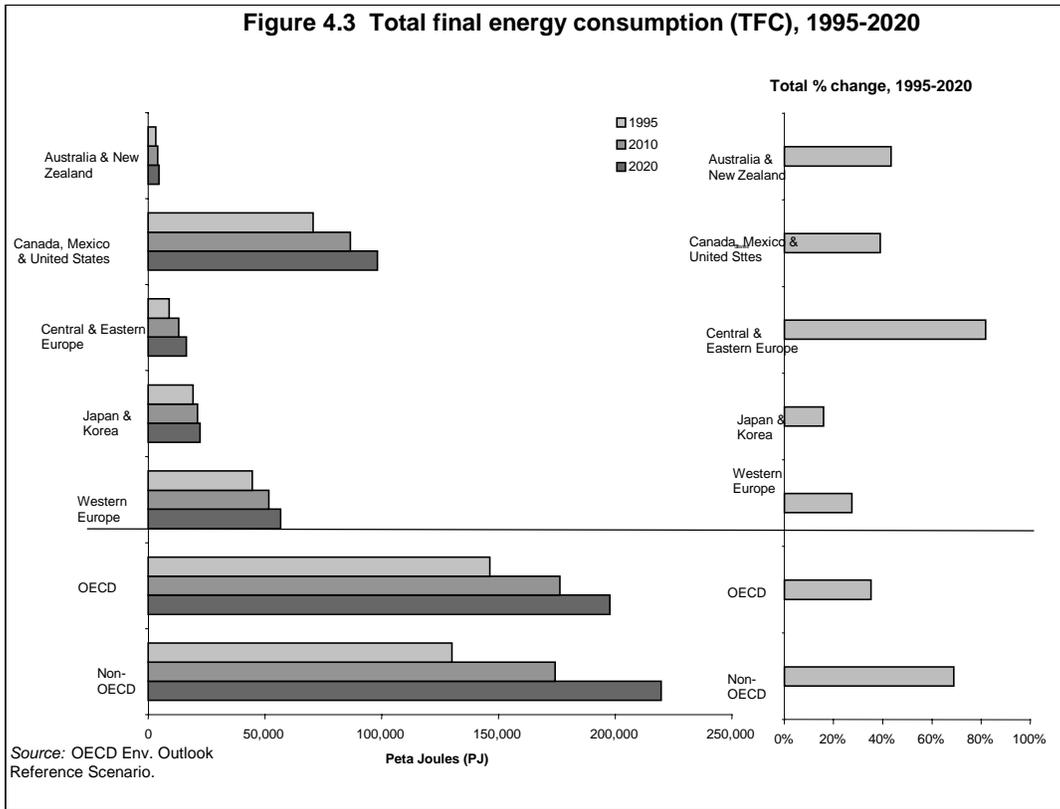
4.3.1 Demand for energy

Under the OECD Reference Scenario, world-wide total energy use is projected to grow by about 52% between 1995 and 2020 (Table 4.5), with much of the increase arising in non-OECD countries. Annual growth in energy consumption in OECD regions will be considerably slower, at just over 1% per annum, compared with global increases of almost 2% per annum over this period. The share of OECD area energy consumption in the world total is projected to fall from 53% in 1995 to 47% in 2020 (see Figure 4.3). Compared with recent trends in energy demand, these figures represent a decline in the energy intensity of the economy both for OECD regions and world-wide, indicating that some decoupling of energy use from economic activity is taking place (see Table 4.5). However, *per capita* energy use is expected to continue to increase to 2020 in both OECD countries and world-wide.

Table 4.5 Key energy sector statistics and projections: OECD Environmental Outlook

		1980	1998 (or latest available year)	2020 projected	1995-2020 Projected annual change	1995-2020 Total change
Total primary energy supply (TPES) (PJ)	OECD	170 068	213 400	275 622	1.1%	30%
	World	299 817	402 569	586 193	1.7%	52%
Total final energy consumption (TFC) (PJ)	OECD	123 636	145 155	197 768	1.2%	35%
	World	202 096	278 244	417 460	1.7%	51%
Energy intensity of economic activity (TPES/GDP) (GJ/1 000 US\$ GDP)	OECD	13.0	10.9	8.0	0.7%	-19%
	World	-	15.5	12.9	0.5%	-13%
Energy intensity per capita (TPES/capita) (GJ/ capita)	OECD	177	196	221	0.7%	18%
	World	68	70	78	0.6%	15%

Sources: IEA (2000c), IEA (2000a), GTAP database, JOBS/Polestar Reference Scenario.



4.4 Estimating the long term baseline

Two issues dominate the discussion on how to shape future mitigation policies: How to share the burden of the required emission reductions? What is the timing for such reductions? The answers to both questions will shape the costs of responding to climate change, in the aggregate and with respect to any one nation or actor.

Deep global emission reductions and lead times of half a century or more will be required to achieve any reasonable stabilisation target. Freezing emissions at current day levels, for example, would only postpone the doubling of CO₂ concentrations until 2100 and would not be enough to prevent a continuing rise thereafter. Even relatively high concentration levels (750-1000 ppm), would require emissions to be less than half current levels per unit of economic activity in the coming century and thereafter (IPCC 1996a).²⁷ Reaching lower stabilisation levels (350-500ppm) by 2100 would require earlier and more significant reductions, especially for the longest lived GHG (e.g. CO₂, HFC, SF₆). The timing of required reductions could also be effected if a decision were made on the need to limit the rate of climate change (e.g. decadal change in global average temperatures) (Alcamo and Kreileman 1996). The level and timing of required emission reductions for any one country will therefore depend upon international agreement on the concentration target level and possibly other environmental criteria for climate change. It will also depend upon emission reduction responsibility and economic burden. A number of alternative pathways to stabilisation are possible and have been analysed in the literature (e.g. Figure 4.5). Success of the climate regime in the long-term will hinge upon finding internationally acceptable rules or measurable benchmarks for both.

Initial agreement on specific ecological objectives to guide future mitigation commitments could advance agreement on burden-sharing and help different actors shape expectations about future requirements. For example, a concentration level of 550 ppm²⁸ represents an approximate doubling of the pre-industrial concentration and has often been considered as an implicit target for the end of the 21st century. However, there is no international agreement on this. Another relevant issue for the setting of climate of mitigation objectives is society's preference for risk aversion. High risk aversion may argue for stronger concentration targets, and possibly also for earlier emission reduction.

Early emission reductions may be justified by at least two arguments – one is ecological and the other pertains to technical innovation. The ecological argument identifies environmental limits or thresholds beyond which irreversible change or change with major economic damages could occur (IPPC, 2001a; Berk *et al.* 2001). Avoiding rapid change is the most frequently cited objective of this type, where a benchmark could be rates of global temperature change per decades. Under scenarios of particularly rapid change, scientific evidence indicates some risk of major economic damages resulting from climate change, in part because the pace of change would seriously limit the ability of humans or other species to adapt in a timely manner. The argument to avoid irreversible change is of course strengthened by concern

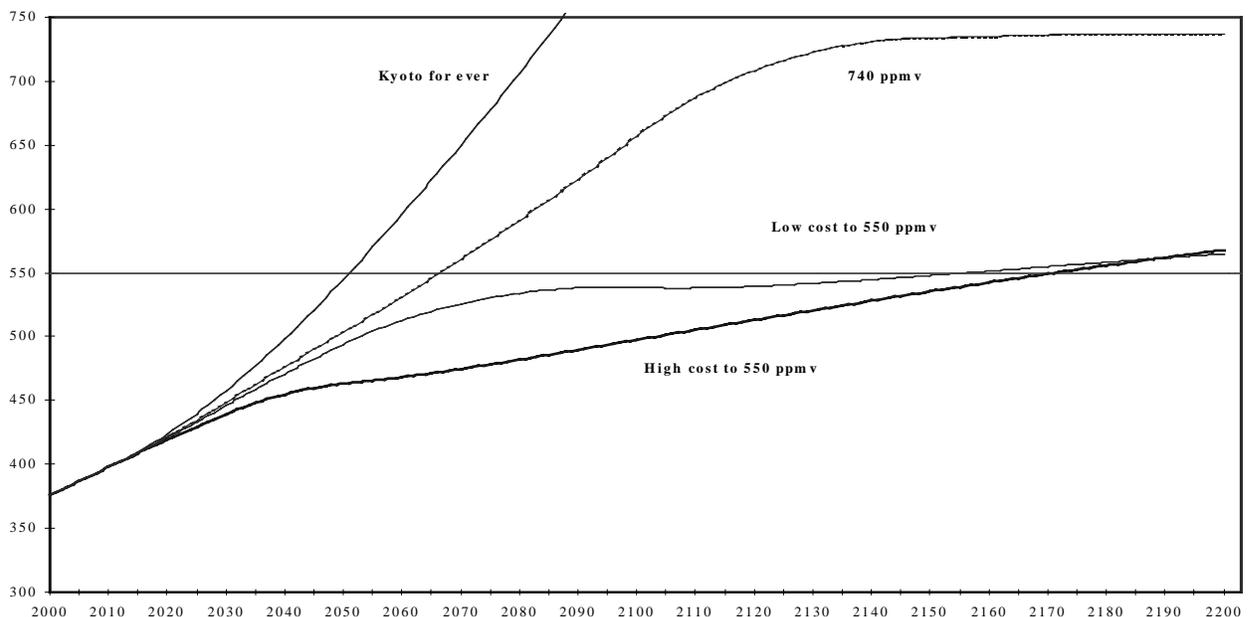
27 Early estimates, considering CO₂ alone, indicate that 60% reductions in current day emission levels would be required by 2100 to achieve stabilisation of atmospheric concentrations of this greenhouse gas. Using Wigley's (1993) carbon cycle model, OECD (1999a, Annex 2) develops a few alternative scenarios to explore stabilisation of CO₂ concentrations at 550ppm levels. The results confirm that any strategy to stabilise emissions at 550 ppm or lower, and including egalitarian rules such as equivalent emissions per capita, would require world emissions to decline to levels well below current emissions.

28. Carbon dioxide, parts per million by volume. It is estimated that the level of atmospheric concentration increased from around 280 ppmv in pre-industrial times to some 360 ppmv today. The UNFCCC does not specify a target value.

about future generations or even intra-generational equity among different regions of the world. International agreement on a maximum threshold rate of change would likely require much earlier emission reductions than otherwise. Some have suggested the use of threshold targets on rates of change for one to several variables to be combined with an overall target concentration level (Alcamo and Kreileman 1996; Berk et al. 2001).

A second argument for early mitigation is related to incentives for technology innovation. Much debate has focused on this with respect to the Kyoto Protocol and the debate has relevance to the long term horizon. Some analysts argue that early emission mitigation will stimulate technical progress and innovation, leading to reduced abatement costs later (Grubb 1997). Others suggest that it could be beneficial to delay near term emission reductions, investing largely in R&D in the near term, until cheaper abatement technology is available in the future (Wigley, *e. al.* 1996). OECD simulations indicate that for given emission reduction targets, a gradual phasing in of action, starting as early as possible, incurs lower costs than waiting and then introducing measures more abruptly (OECD 1999a). This is because it minimises the extent to which rapidly changing relative prices force premature scrapping of capital equipment. On both the technology and capital scrapping argument, early clarification of the terms and conditions for emission mitigation obligations, presumably under future Protocols of the Convention, will be important to accelerate progress.²⁹

Figure 4.5 The long term: alternative CO₂ concentration pathways



Source: OECD (1999a). Action Against Climate Change. OECD: Paris.

Note: ppmv = parts per million by volume. Concentration paths are derived from assumed emissions paths with model of Wigley T.M.L. (1993), "Balancing the global carbon budget" *Tellus*, Vol. 45. Coefficients are based on Ha-Duong, M., M.J. Grubb and J.C. Hourcade (1997), "Influence of socio-economic inertia and uncertainty on optimal CO₂ emission abatement", *Nature*, Vol. 390.

29 These conclusions are based on OECD simulations on implementation of the Kyoto Protocol, and are extracted to future commitment periods for this discussion, even though GREEN does not embody any forward-looking behaviour. If agents anticipate future relative price changes (e.g. the introduction of a carbon tax), the advantages of targeting early emission reduction would probably be reduced. Early clarification of the terms of a binding agreement can also help formation of such expectations.

4.5 Lessons from existing outlooks

Examination of various baselines provides a number of lessons for policy-makers.

- Of the IPCC marker scenarios, the B1 world implies the lowest level of greenhouse and other air emissions. Therefore, this scenario provides some examples of how economic and environmental goals can be made more sustainable. This implies greater focus on the direction of growth and technological change to make it more environmentally friendly. Even this scenario does not, however, lead to a *reduction* in greenhouse gases, or in all conventional air pollution, compared to today's levels.
- Current trends are unsustainable. Greenhouse gas emissions are rising far faster than consistent with achievement of targets. While some air quality concerns have been effectively addressed, ozone and particulates remain a problem, and improved stringency of controls will be required in future to maintain these outcomes. More policy action is needed. Given the long lead times for investment in many relevant sectors, policy incentives must be designed now, if the OECD is to move onto a sustainable path in the medium-term.
- Technology should play an important role in meeting future environmental needs. To achieve significant GHG emission reduction, action to support more rapid development of environmentally friendly technologies will be required. Special challenges are presented here, to make government intervention wide enough to support a range of technologies while specific enough to achieve sufficiently rapid changes in the right directions. Improvements in traditional fossil fuel technologies will be needed, as these fuels will continue to be the majority of energy supply for some time. This can include switching to natural gas, as well as improvements in combustion efficiencies and greater penetration of cogeneration. Greater penetration of zero- and low-emission fuels will also be required. Programs to promote greater uptake of renewable fuels already exist in most countries, but these may need to be more ambitious. The future of nuclear should be addressed. Current trends indicate this fuel will play a declining role within the OECD. This will require even more urgent action to develop alternative GHG-emission reduction options.
- Even with enhanced rates of improvement, technology change alone will not be sufficient to achieve sustainability. Behavioural change, potentially of significant proportions, will also be required. Some trends, such as the growth in electronic commerce, may be harnessed to achieve improved efficiencies.
- Action should be comprehensive across sectors and approaches. All uses of energy, waste, industrial production and agriculture must play a part in addressing environmental concerns, especially greenhouse. Non-CO₂ gases can make achievement of targets easier for two reasons. First, their underlying rates of growth are slower. Second, there are a number of cost-effective opportunities to abate emissions in these sectors.
- Solutions will not come through environment policy alone. Finance, economic, trade, industry and other ministries must all incorporate sustainability concerns more fully and effectively in their own policy-making. Governments may need to consider more comprehensive changes to administrative structures to ensure this outcome.
- Transport should be a major focus of policy-making. This sector accounts for more than half of the growth in energy use and greenhouse emissions, and is the major source of many other air quality and noise problems. End-of-pipe and efficiency regulations have achieved

dramatic improvements in air emission intensities. However, problems such as ozone and particulates remain, and ongoing improvements will be required to match the rapid growth in transport levels. More significantly, the rapid growth in greenhouse gas emissions from transport continues largely unabated. The transport sector appears to offer tremendous potential for integrated achievement of a wide range of environmental and social objectives. Analysis indicating the likely successful measures is already available. What is lacking is the political will to implement effective policies.

- Electricity should also be a major focus of attention. As this is likely to be a major source of growth in energy consumption, it will be essential that electricity is produced and delivered efficiently. The question of fuel choice is also crucial in electricity production. A key issue will be how to manage the transition to greater use of natural gas, and how to address concerns raised by the use of nuclear fuels.
- The climate change problem, and other issues associated with global energy use, cannot be solved by OECD countries alone. While strong action within OECD countries to develop policy to meet domestic targets is an essential element of a global response framework, more extensive involvement of non-OECD countries is also required. The OECD may therefore need to expand its dialogue with non-Member countries to assist with the implementation of effective policy frameworks.

5. ASSESSING COSTS

5.1 Estimated costs of climate change

The costs of climate change are largely unknown, partly because its likely physical impacts are not easy to predict in sufficient regional and local detail. Even for the broadest of indicators, such as global mean surface temperatures, there is quite a wide range of uncertainty attached to the IPCC projections. Nevertheless, temperature changes and, more importantly, changes in the quantity and distribution of precipitation, will certainly have economic consequences.

Several studies have attempted to quantify the impact of climate change on human welfare. While the IPCC has focused to a large extent on describing physical impacts, studies range in their coverage of regions, and types of damages assessed. The most comprehensively covered topics are agricultural impacts, and the costs of sea level rise, but estimates can vary widely.³⁰ In a recent example using two alternative data sets, uncertainty regarding the value of dryland lost to sea level rise (endowment values) led to a 17% difference in coastal protection, a 36% difference in the amount of land protected, and a 36% difference in direct costs globally (Darwin and Tol 1999).³¹ Obtaining more accurate measures will depend to a very large extent on improved modelling capabilities, and on more certainty about endowment values.

Based on a survey of three main studies undertaken since the IPCC Second Assessment Report (SAR), Table 5.1 summarises estimates of aggregate monetised impact for a 1.5 to 2.5 degrees Centigrade increase on current economy and population (Tol *et al.* 2000).³² The table also shows, for comparison, the range of estimates found in the ‘first generation’ range of estimates in the IPCC’s SAR (Pearce *et al.* 1996). Population and income figures are kept constant at 1990 levels, obviating the need to use discount rates. The higher benefits for Russia in the Mendelsohn model are largely predicated on the assumption of lower heating costs, reduced cold-related mortality/morbidity, and agricultural productivity gains. Tol argues that at a lower level of warming (1 degree Celsius) impacts are obtained in some regions through reduced cold-related deaths, and some reduced agricultural benefits. Various methods of weighting are

30 See, for example, Yohe and Schlesinger (1998) and Darwin and Tol (1999).

31 Direct-cost estimates. They are usually employed to measure the economic damages of sea level rise, but this approach has its limitations. This is because values of threatened land and biodiversity are uncertain, because these do not affect consumer prices, and because effects on international trade are not taken into account. If accurate values for dryland and wetland were to include market and non-market components, direct cost estimates would differ significantly.

32 One exception is Mendelsohn’s estimates, which are calculated based on a future population-economy scenario. It is also important to note that the figures in the table correspond to a ‘with policy’ scenario, since the temperature changes represented would require limiting atmospheric concentrations of GHG to levels below what they would be in a reference (“do nothing”) scenario. In the real world, damage costs could also be higher or lower for a variety of reasons (e.g. population growth or an improved ability to adapt with economic development).

employed, with output weighting referring to GDP weights; world average prices referring to a valuation of health, agricultural productivity, etc. calculated globally, to avoid controversial regional assessments; and equity weighting calculated as damages before aggregation - the weight being world average income over regional average income.

Table 5.1. **Estimates of the regional impacts of climate change^a (Tol *et al.* 2000)**

	First Generation	Mendelsohn <i>et al.</i>	Nordhaus / Boyer	Tol ^b
	2.5°C	2.5°C	2.5°C	1.0°C
North America	-1.5			3.4 (1.2)
- USA	-1.0 to -1.5	0.3	-0.5	
OECD Europe	-1.3			3.7 (2.2)
- EU	-1.4		-2.8	
OECD Pacific	-1.4 to -2.8			1.0 (1.1)
- Japan		-0.1	-0.5	
Eastern Europe & fUSSR	0.3			2.0 (3.8)
- Eastern Europe			-0.7	
- fUSSR	-0.7			
- Russia		11.1	0.7	
Middle East	-4.1		-2.0 ^c	1.1 (2.2)
Latin America	-4.3			-0.1 (0.6)
- Brazil		-1.4		
South & Southeast Asia	-8.6			-1.7 (1.1)
- India		-2.0	-4.9	
China	-4.7 to -5.2	1.8	-0.2	2.1 (5.0) ^d
Africa	-8.7		-3.9	-4.1 (2.2)
World				
- output weighted	-1.5 to -2.0	0.1	-1.5	2.3 (1.0)
- population weighted			-1.9	
- at world average prices				-2.7 (0.8)
- equity weighted				0.2 (1.3)

Source: Pearce *et al.* (1996); Mendelsohn *et al.* (1996); Nordhaus and Boyer (2000); Tol (1999).

Notes:

Estimates are expressed as per cent of Gross Domestic Product. Positive numbers denote benefits, negative numbers denote costs.

a. Estimates are incomplete and there is a considerable range of uncertainty around estimates. Tol's estimated standard deviations are lower bounds to the real uncertainty. Figures, except Mendelsohn's, are expressed as impacts on a society with today's (1990) economic structure, population, laws, etc. Mendelsohn's estimates denote impact on a future economy.

b. Figures in brackets denote standard deviations.

c. High-income OPEC

d. China, Laos, North Korea, Vietnam, Mongolia.

Available studies indicate a greater vulnerability of developing countries to climate change. They also show that at lower levels of climate change, damages might be mixed across regions. For example, poorer countries are likely to be net losers, and richer countries might gain from moderate warming. At higher levels of change (more than 2-3 degrees C), net damages occur in almost all regions. The higher vulnerability faced by developing nations is due to their greater reliance on agriculture, and their lower tolerance to coastal and water resource changes. This, combined with less financial, technical, and institutional capacity to adapt (causing higher health impacts, for example) suggests that they have the most to lose from climate change. While sustainable development might reduce this vulnerability, uncertainties about the rate of climate change, and pattern of economic development of poorer countries,

raises concerns about whether development could occur fast enough to significantly reduce this vulnerability.

Very few studies have taken into account dynamic responses to steadily increasing GHG concentrations, and the implications of multiple stress factors. The IPCC noted this in the Second Assessment Report (1996b), calling for increased development and use of time-dependent integrated assessment models. This issue was highlighted again more recently (Watson 2000) as critical for further research. Among the few explicitly dynamic analyses are Sohngren and Mendelsohn (1999) and Tol and Dowlatabadi (forthcoming 2001). In the absence of dynamic analyses, it is hard to determine whether certain impacts are in fact best mitigated or avoided through greenhouse gas emissions reduction or through other policies, such as improved health care or infrastructure development.

Available estimates of costs of moderate climate change would suggest that, for OECD countries, damages may be modest, especially for low levels of temperature change. However, there are a number of reasons for continuing the commitment to mitigation in OECD countries. First among these is the potential for significantly higher costs associated with higher levels of climate change (e.g., at the high end of the range projected by IPCC of 6 degrees Centigrade). Moreover, near term ancillary benefits are likely to be considerable, and should be taken into account. Nevertheless, high degrees of uncertainty remain, making cost assessment difficult - including a limited knowledge of the level of future physical impacts and insufficient recognition of welfare criteria. Regional and national assessments are beginning to provide better estimates of the costs of climate change.

It will take many years before a reasonable degree of consensus is achieved on how big the costs of climate change are likely to be. Climate change predictions with regard to impacts on most sectors and ecosystems are still highly uncertain. The focus should shift from single predictions, or extreme ranges of uncertainty, to more comprehensive risk assessment. It seems reasonable to take account of the risk that climate change will turn out to have much more costly impacts than central estimates imply, and to recognise its irreversible nature – something that is not usually reflected in economic assessments due to discounting procedures.³³ As the Chairman of the IPCC pointed out at the Sixth Conference of the Parties in November 2000: "...if policy formulation waits until all scientific uncertainties are resolved, and carbon dioxide and other greenhouse gases are responsible for changing the earth's climate as projected by all climate models, the time to reverse the human-induced changes in climate and the resulting environmental damages would not be years or decades, but centuries to millennia, even if all emissions of greenhouse gases were terminated, which is clearly not practical" (Watson 2000).

5.2 Costs and ancillary benefits of near-term mitigation policies

5.2.1 Costs³⁴

The costs of responding to climate change are controversial and uncertain, and the subject of great interest. Studies of mitigation costs are usually performed using either technology-centred or economy-centred approaches. In a 1998 workshop, the OECD brought together economic modellers to share, among other things, results of preliminary cost assessments of Kyoto targets (OECD, 1999c). The results, and those from subsequent comparisons (IPCC 2001c, Weyant 1999), demonstrate wide variation in estimates of the marginal and average costs of emission reduction for different OECD regions. OECD estimates that achieving the targets unilaterally for OECD countries, by reducing energy-related carbon dioxide emissions only, results in cost of less than a half a percent of baseline GDP (OECD, 1999d).

33 For a discussion, see Arrow *et al.*, (1996), and Portney and Weyant (1999).

34 This section draws heavily from OECD (1999a) and OECD (1999b).

Though economic costs are more difficult to compare than marginal emission reduction costs, this is consistent with an earlier survey results from other models assessing Kyoto targets, which also show GDP losses to be less than 1% of baseline estimates (van der Mensbrugge, 1999).

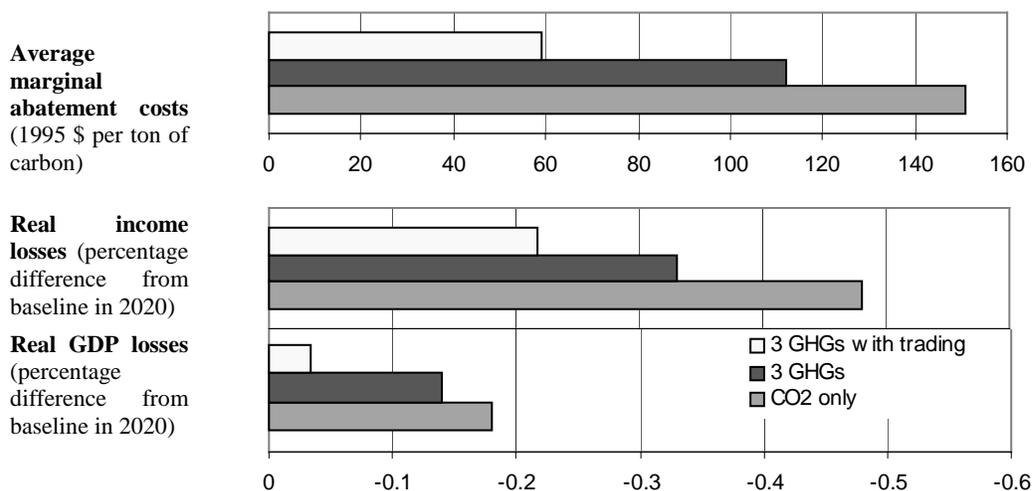
Multiple gas mitigation policies, extending mitigation from CO₂ alone to include CH₄ and N₂O, is estimated to lower the marginal and average costs of achieving Kyoto targets by 20-30% (Burniaux 2000) as seen in Figure 5.1. The lower costs associated with this wider coverage are due to at least two important influences. First, lower growth trends in emissions of non-CO₂ gases affect overall abatement needs, and thereby economic costs. Second, there may be large differences of marginal abatement costs across different gases, and the fact that the Protocol allows substitution among gases implies that efficiency gains can be achieved by substituting low-cost emission cuts for high-cost ones. However in the long-term, cost-saving due to multi-gas mitigation policies are likely to be less significant, due to the more rapid growth of CO₂ emissions and their long-term dominance in the mix of greenhouse gases.³⁵

Recent OECD analyses (OECD 1999d; Burniaux 2000) estimate that the aggregate average cost of meeting Kyoto targets for Annex I countries is estimated to be low (0.2% of GDP per year in the 2010 time frame, CO₂ only), and even lower with an effective international emission trading system and multi-gas mitigation (less than 0.1% of GDP) as seen in Table 5.2. IPCC's recent review of similar estimates suggests costs for OECD countries in the range of 0.2 to 2% of GDP in 2010, when meeting the Kyoto targets with cost-efficient domestic measures to reduce CO₂ alone (and without international emission trading) (IPCC 2001c). Thus, recent GREEN model estimates would appear to fall at the low end of this range.

For a number of reasons, these costs might be considered to be over or under-estimated. Most of the models still do not include non-CO₂ greenhouse gases, which are expected to provide low-cost mitigation potential, at least in the near term, to achieve Kyoto targets. Most models also underestimate endogenous technical change over time, which could lower the marginal cost of mitigation (Azar, 1996 and Repetto *et al.* 1997). Further, the models do not generally account for market distortions. Removing these distortions, (e.g. environmentally-damaging subsidies), can achieve emission reductions and are likely to be accompanied by a net economic gain. Finally, ancillary benefits are not considered in the economic models, yet these could significantly offset the costs of mitigation (see below). On the other hand, the costs of significant structural adjustment required in all countries may be underestimated, and marginal costs may be relatively high. Thus, the impact on some sectors and in some countries may be significant, even if aggregate economic costs are modest. Initial analysis suggests that costs could be increased several-fold when considering additional costs, due to labor market rigidity.

35 Sensitivity analyses, reflecting uncertainty about emission trends and costs, indicate that these conclusions hold, though their quantitative implications might vary.

Figure 5.1 Costs of implementing the Kyoto targets under alternative assumptions, 2010



Source: "A Multi-gas Assessment of the Kyoto Protocol," OECD Working Paper, Burniaux, 2000.

Note: Marginal abatement costs are expressed in 1995 dollars per ton of carbon equivalent (top axis). Real GDP and income losses are expressed in terms of billions of 1995 dollars (bottom axis). The "no flexibility" case corresponds to domestic cost-effective implementation by individual Annex I countries. Under "full Annex 1 trading" abatement costs are equalised between Annex 1 countries. Figures for trading assume unrestricted trade among Annex I countries.

The Kyoto Protocol includes provision for "flexibility mechanisms", designed to reduce the aggregate costs of abatement by allowing action to take place where it is most cost-effective-emissions trading, Joint Implementation and the Clean Development Mechanism. The first two of these allow for adjustment of commitments between Annex I countries, thus maintaining the overall level of abatement required within Annex I, but altering the distribution. The CDM allows for abatement projects in non-Annex I countries, which create new emission reduction credits, thereby reducing the overall level of Annex I abatement required, by allowing action outside Annex I to be credited under the Protocol. All of these mechanisms require further elaboration before they can become effective and are a major element of ongoing negotiations. The choice between domestic action and use of these flexibility mechanisms will be an important element of national policy selection.

Table 5.2 Effects of international emissions trading

	% Change to GDP /Household Real Income to achieve Kyoto targets in 2010	
	Without international emissions trading	With international emissions trading
United States	-0.3/-0.3	-0.2/-0.4
European Union	-0.2/-0.9	-0.1/-0.4
Japan	-0.3/-0.2	-0.0/-0.2
Other OECD	-0.3/-0.7	-0.2/-0.6
CIS	-0.3/-1.7	-1.1/8.5
Eastern Europe	-0.2/0.1	-0.5/1.1
Total OECD	-0.2/-0.5	-0.1/-0.4
Total Annex 1	-0.2/-0.5	-0.1/-0.1

Source: OECD 1999d, fully flexible wage case.

In summary, modelling results point to significant uncertainty in understanding of the economic costs of mitigation. However, they also suggest that certain types of government policy can bring costs down significantly. Economic costs can be lowered through market-based policies that equalise the marginal cost of reduction among countries, regions and sources; that comprehensively and systematically address all gases, sources and sinks; and that increase energy efficiency and accelerate development and diffusion of low-carbon "back stop" technologies.

5.2.2 *Ancillary benefits*

Greenhouse gas mitigation has benefits beyond those directly associated with climate change — the so-called "ancillary benefits". In particular, reductions in emissions of greenhouse gases also have positive effects on urban air pollution, and thereby on human health. Estimates of the magnitude of such ancillary benefits per tonne of carbon reduced in OECD countries vary widely. Nevertheless, even the most conservative estimates suggest that they are substantial, and may offset as much as a third of the abatement costs for modest mitigation efforts. A study in Hungary estimated that a 7.7% reduction in CO₂ emissions would result in health benefits of US\$ 650 million — enough to cover the investment required to implement the CO₂ reduction measures (Aunan *et al.*, 2000). A second example of ancillary benefits is greenhouse gas reduction policies that lower demand for transport and lead to social benefits, such as reduced traffic congestion.

Ancillary benefits therefore have the potential to lower the net costs to society of reducing greenhouse gas emissions. It is therefore important to identify the major areas where these benefits are present, to develop methods to quantify them and find the best ways of injecting this information back into the regulatory and decision-making process.

6. POLICY OBJECTIVES, OPTIONS AND RECOMMENDATIONS

This chapter outlines the main policy options being used or considered to counter climate change and other energy-related environmental problems. It also presents general recommendations for a coherent and viable climate change mitigation strategy. The point of departure for this discussion is a presentation of the principal policy objectives — the technological, behavioural, and infrastructure changes that policies seek to induce.

6.1 Background and context

Modern energy and environmental policies have their roots in the 1970s. The oil price shock of 1973 made energy security a high-priority concern and led to, among other things, the development of numerous energy efficiency programmes. The primary energy-related environmental issue of the time was *local* air quality, in response to which governments tended to enact technology-based regulations.

Through the 1980s, energy security remained an important issue, but the attention paid to it diminished as markets matured and world prices fell, then stabilised. Increasing concern over acid rain, a *regional* environmental issue, was expressed in various agreements to curb the sulphur dioxide (SO₂) emissions causing this phenomenon. Environmental policy continued to be dominated by regulatory approaches, but with increasing sophistication and analysis. Experience was also gained with the use of economic instruments.

The 1990s saw a stable, low-price world energy regime, and consequently a declining focus on energy security. Many countries replaced the drive for energy security with a strong drive for energy market deregulation, in order to enhance competitiveness and remove distortions, and privatisation to reduce the public sector role in energy provision. On the environmental side, significant successes were seen in addressing air quality and sulphur dioxide emissions. A wider range of policies was used, including much more extensive use of economic instruments, and voluntary agreements between industry and government (with varying degrees of stringency and regulatory support). Meanwhile, a *global* issue, climate change, grew to be the major environmental concern associated with the energy sector.

Now, in the early 2000s, it appears that OECD countries have made considerable progress in relation to the policy concerns of the 1970s and 1980s. Reliance on oil in the power, industrial, residential and commercial sectors (but not the transport sector) has declined, renewable energy is growing quickly (although absolute shares remain at a low level) and reaching cost-competitiveness in more applications, and major energy efficiency improvements have been "locked in" to the economy. Levels of key air pollutants have declined in many OECD countries, and the risk of acid rain damage has now been substantially reduced. While continuing attention to these problems is necessary, attention has focused on the unresolved issues of 1990s. Climate change is the most obvious of these, with greenhouse gas emissions continuing to rise quickly despite agreement to reduce emissions under the Convention and the Kyoto Protocol. Energy market reform remains largely incomplete in many countries, and it is unclear how these reforms will progress, or what their environmental implications will be.

6.1.1 *International climate change policy - Rio, Kyoto and beyond*

Impacts and costs of climate change are likely to be unevenly distributed among major regions of the world and among sectors of the economy within a country. In addition, countries that have caused the bulk of emissions in the past differ from those most likely to suffer the worst impacts. The majority of harmful impacts will occur in developing countries, possibly aggravating current economic disparities between the North and the South (IPCC, 2001b). The UN Framework Convention on Climate Change establishes an initial framework for international action and basic principles for burden-sharing. Devising a framework for sharing the costs of climate change mitigation and adaptation will be key to an effective long-term policy response.

Following the signature of the Framework Convention on Climate Change in 1992, climate change rose quickly to the top of the environmental policy agenda in OECD countries. With the Convention's entry into force in 1994, OECD nations accepted their responsibility to protect the atmosphere and agreed to take a global lead in emission reduction.³⁶ The Convention sets out a framework for action, with all Parties aiming to achieve:

... stabilisation of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. Such stabilisation should be achieved with a time frame sufficient to allow ecosystems to adapt naturally, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable matter. (UNFCCC, Article 2).

As a framework for policy action the Convention is not prescriptive and does not set out legally binding emission targets for Parties. Rather it requires Annex I Parties (most industrialised countries) to adopt programmes and policies that aim to stabilise greenhouse gas emissions at the 1990 level in 2000.

In Kyoto in 1997, signatories of the Convention negotiated legally binding targets for industrialised countries to reduce emissions in 2008-12. The Kyoto Protocol establishes binding, greenhouse gas emission reduction targets for individual developed countries with a view to achieving at least a 5% aggregate reduction from 1990 emissions levels in the period 2008 to 2012. In addition, the Protocol provides flexibility to Parties to achieve some portion of the required emission reductions beyond their own borders through the use of a variety of innovative economic instruments known as the "Kyoto mechanisms" (see Box 6.1).

The Kyoto Protocol is clearly only one, small step towards implementing the Convention. IPCC assessments indicate that to achieve stabilisation of GHG concentrations, much more radical emission reductions will be necessary. Global average annual emissions would need to be less than half of current levels per unit of economic activity even to achieve what is considered to be relatively high atmospheric stabilisation levels of 750 to 1000 parts per million by volume (ppmv). If more ambitious stabilisation levels are targeted, such as 550 ppmv, deeper and earlier reductions will be required globally (IPCC, 1996c; OECD 1999d).

36 Turkey (an OECD Member country) has never ratified the Convention. Korea and Mexico became Members after the signature of the Convention. Thus, they are not listed in Annexes I or II of Convention. Poland, Hungary, the Czech Republic and Slovakia also became Members of the OECD since the signature of the Convention. While they are listed in Annex I, they are treated there as countries with "economies in transition".

Box 6.1 The Kyoto Protocol and market mechanisms

The Kyoto Protocol also calls for the establishment of three types of market mechanisms to help Parties to the Protocol achieve their national emission targets at lowest cost :

- *International emissions trading*: Allows any Annex I Party or authorised legal entity to trade a portion of its allowable emission level; any additional emission reductions below a Party's target level may be traded to another party or any legal entity to another Party. (Article 17 of the Protocol)
- *Joint Implementation*: Allows any authorised legal entity in any Annex I Party to achieve emission reductions through specific projects and to transfer them to another Annex I Party. The Party acquiring a certain amount of project-level emission reduction units is permitted to increase its level of allowable emissions, while the transferring Party would decrease it. (Article 6 of the Protocol)
- *Clean Development Mechanism*: Allows developing countries (i.e. non-Annex I Parties) to transfer certified emission reduction units from projects to Annex I Parties. The Article allows Annex I Parties to count such project-level emission reductions achieved from the year 2000 towards their compliance in the first commitment period (2008 to 2012). (Article 12 of the Protocol).

The specific design and rules governing these mechanisms are still the subject of international negotiations.

6.1.2 Sustainable development

In a separate but related development, OECD governments have committed themselves on numerous occasions to the goal of sustainable development, which seeks to maximise human welfare and provide a sound economic, social and environmental base for both present and future generations. The 1987 report of the World Commission on Environment and Development (The Brundtland Commission) contained what has become perhaps the most widely accepted definition of sustainable development, describing it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development has three dimensions: economic, social and environmental. In a sustainable development perspective, environmental protection has to be balanced with economic growth when the two are in conflict, although policy should be aimed at integrating environmental concerns with economic and social imperatives and, whenever possible, exploiting complementarities. (OECD 1998b).

Some developing countries have taken policy action in the context of other development priorities, which indirectly address climate change. OECD countries are also assisting developing and transition countries to respond to climate change in various ways (Box 6.2).³⁷ However, by and large, climate change does not figure highly on the policy agenda of most non-OECD countries. There are many reasons for this, including the urgency of other policy priorities, such as eradicating poverty, building institutional frameworks for private investment, providing water, sanitary and other services and infrastructure in cities and access to electricity in rural areas.

37 This refers to countries listed in Annex II of the Convention, which corresponds to OECD countries at the time of signature in 1992 – the present Membership, except recent Members: Korea, Mexico, Poland, Hungary, the Czech Republic and Slovakia. Turkey, having never ratified the Convention, is listed in Annex II, but is not a Party, and thus is not bound by its provisions.

Box 6.2 Assisting developing countries to respond to climate change

The Convention and the Protocol require Annex II countries to provide new and additional financial resources, including the transfer of technology, for the purpose of assisting developing countries to implement their obligations under the Convention (e.g. reporting) and, more generally, to build capacity to respond to climate change. The Global Environment Facility (GEF) is the main financial mechanism, however assistance is also provided through bilateral co-operation. Capacity building, technology co-operation or transfer, and adaptation are the main targets for action:

- *Financial assistance:* The GEF is an independent multilateral financial mechanism established in 1991 to assist developing countries to protect the global environment in four areas: biodiversity, climate change, international waters, and ozone layer depletion. The GEF, which is jointly managed by the United Nations Development Program, the United Nations Environment Program, and the World Bank, currently funds approximately 300 projects in developing countries, having committed \$1.1 billion in grants, and raised several billion in co-financing. In the area of climate, the GEF assists developing countries to comply with their obligations under the UNFCCC to elaborate GHG inventories and report on these to the Conference of the Parties to the Convention. In addition, it assists developing countries in formulating national action plans to mitigate and adapt to climate change. The GEF also provides financing to cover the incremental costs of investment projects that deliver additional benefits for climate change.
- *Capacity building:* Some developing and transition countries have sought to integrate climate change objectives into national development plans and to develop the necessary policy frameworks. Many capacity needs identified in the Convention have relevance beyond climate change. For example, the development of capacity in emission forecasting, monitoring of ecological and socio-economic conditions, awareness-raising and disaster prevention are also relevant to desertification and biological diversity, notably for countries vulnerable to the impact of climate change. Capacity development for policy-formulation and planning in agriculture, energy, and transport also have relevance beyond climate change. Capacity development programmes should foster policy integration across sectors and seek to exploit these synergies.
- *Technology co-operation:* Technology co-operation in the context of climate change includes technology needs assessment; identification of sources and suppliers; determination of optimal modalities for the acquisition and absorption of relevant technologies; provision of training for firm managers, engineers and technicians; demonstration and pilot projects; and dissemination of best practices at the national and international level. In this way it is similar to technology co-operation in other areas and can draw on considerable experience accumulated over the years.
- *Adaptation:* The Convention commits developed country Parties to “assist the developing countries that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects” (Article 4.4). The Protocol calls for a share of the proceeds from CDM investments to be used to help vulnerable developing countries to meet the costs of adapting to climate change. More detailed regional impact assessments in developing regions are a prerequisite for adaptation planning.

6.1.3 Energy security

Public concern about energy security waned somewhat during the 1980s and 1990s, but was re-ignited in the late 1990s and early 2000s. Crude oil prices plummeted to 21 year lows (24 years in real terms) in 1998, and then climbed to 17 year highs (14 years in real terms) in 2000. Neither situation was considered to be in the best long-term interests of OECD and IEA countries.

Moreover, energy self-sufficiency is projected to drop to 60% in 2020 (from 74% in 1998), as total energy consumption rises by over 20% and energy production in OECD countries remains stable or declines slightly. An increasing percentage of world crude oil supplies is expected to come from the Middle East OPEC countries (from 27% in 1996, to over 60% in 2020) (IEA, 1998a). OECD regions,

particularly those in Western Europe, are projected to significantly expand imports of natural gas over the next 20 years, while non-OECD countries will expand exports. These changes in trade patterns, and in dependence on non-OECD sources of gas supply, could have implications for gas supply security. As open regional electricity markets continue to expand, so will the inter-regional electricity trade and, depending on the fuel mix within the markets (hydro/fossil fuelled/ nuclear), could either increase or decrease local and global emissions.

6.1.4 Energy market reform

Most OECD countries have begun a process of liberalising energy supply and distribution services. In most cases, policy reform in the electricity sector is leading to lower electricity prices as industry becomes more efficient and competitive. The continuing reform of these markets can be expected to further drive down electricity prices, increasing demand. In addition, previous energy-environment policy tools such as demand-side management (DSM) or integrated resource planning (IRP) and differential pricing policies, are being re-examined in this liberalised market context. In order to counter-balance the negative environmental impacts that will result from these reforms, it will be necessary for countries to adopt policies to encourage greater energy efficiency, emission reductions, and use of cleaner fuels.

6.2 Policy objectives

There are a multitude of technology and behavioural changes, and infrastructural developments, that society could adopt to counter climate change and the environmental effects of the energy system. Table 6.1 summarises some of the changes in energy and climate policies that might include positive environmental results.

While there is clearly a complex mix of sometimes competing objectives in energy and environmental policies, there are also considerable overlaps and synergies. Enhanced energy efficiency, for example, leads to improvements in air quality, greenhouse emissions, and SO₂ emissions, as well as contributing to the goals of energy security and efficient domestic energy markets. Similarly, switching to natural gas from coal, or from fossil fuels to renewables, generally supports a range of environmental objectives, and can enhance energy security and efficient markets through diversity.

Where conflicts between policies do arise, they sometimes relate to aspects of specific technologies. For example, while nuclear power meets many policy objectives, it raises concerns about accidental radioactive releases. Various end-of-pipe technologies are available to address air pollutants, but these may reduce combustion efficiency, and increase greenhouse emissions. Such conflicts can often be addressed through packaging of policies or development of alternative technologies.

It is important to recognise that greenhouse gas mitigation policies can be closely linked to resource-saving projects in other sectors. For example, the promotion of energy efficiency measures will also lead to CO₂ reduction. In the transport sector, investment in public transportation and effective transport planning policies reduces local pollution and congestion in addition to greenhouse gas emissions.

The need for further investment in the research and development of alternative transport fuels and renewable technologies, tied with the efficient marketing of these products, is vital to climate policy. Given that most manufacturers of vehicles, and developers of these technologies are in OECD countries, it is clear that these countries must take the lead in research and development in this area. The potential for expansion of markets in non-OECD countries is a further incentive for investment in these areas.

Table 6.1 Principal objectives of climate change and other energy-related environmental policies

Policy Objectives	Greenhouse Gas Emissions/Sinks				Other Environmental Effects
	CO ₂	CH ₄	N ₂ O	HFCs, PFCs and SF ₆	
Energy sector	81.7%*	9.7%*	6.6%*	2.0%*	
83.0%*	79.2%*	2.7%*	1.1%*	0%*	
Energy conservation (reduced energy services**) and improved demand management	X	X	X		X
Improved energy end-use efficiency	X	X	X		X
Improved energy production and conversion efficiency	Improved fuel combustion (including CHP, CCGT)**	reduced fugitive fuel emissions from natural gas networks and coal mines	Improved fuel combustion (including CHP, CCGT)**		X
Fuel switching	Towards low/no carbon primary energy sources	depends on changes in natural gas and coal use			Towards renewable energy sources
End-of-pipe emissions treatment/sequestration	Capture, transformation and storage				Off-gas scrubbers, catalytic converters, ...
Non-energy sector	17.0%*	2.5%*	7.0%*	5.5%*	2.0%*
Improved agricultural management		with respect to: <ul style="list-style-type: none"> • Livestock production • Animal manure management • rice cultivation 	With respect to: <ul style="list-style-type: none"> • nitrogen fertilisers, • animal manure 		
Improved landfill operations and waste management		recycling, incineration and methane recovery			
Improved resource efficiency of industrial production	Cement, lime, iron and steel		Nitric and adipic acid	aluminium, magnesium, halocarbons	
Use of substitute products				X	
Enhancing natural CO₂ sinks					
Improved agriculture, forest and ocean management	X				
Climate change adaptation					
Changes to health services, settlement and land use patterns, water provision, ...	X	X	X	X	

* Share of total greenhouse warming potential of 1998 OECD emissions of CO₂, CH₄, N₂O, HFCs, PFCs and SF₆ (UNFCCC,2000).

** Energy services refer to heating, cooling, lighting, communications, motive power, personal and freight mobility, ..

*** CHP = combined heat and power; CCGT = combined cycle gas turbines.

An early review of policies conducted by the OECD secretariat and UNFCCC reviews of national communications shows similar tendencies across national mitigation strategies (OECD 1999b, UNFCCC 2000). Policies undertaken to date aim to achieve multiple policy objectives. Policies that impact greenhouse gas emissions include market reform and subsidy reform, particularly in the agriculture and energy sectors. In addition, governments are using a variety of approaches to overcome market barriers to energy efficiency improvements and other “win-win” actions that make economic sense without considering impacts on climate change. The large majority of measures in most countries target CO₂ emissions from the energy sector. However, nearly all countries also have some policies aimed at achieving emission reductions from waste, industrial processes, agriculture and forestry/sink enhancement.

6.3 Policy framework

Establishing a market framework that prices GHG emissions (or energy and other GHG sources) at their full social costs, including climate change mitigation charges, is the economic foundation for cost-effective actions to counter climate change and other energy-related environmental problems. Prices directly influence the millions of consumers, producers and market intermediaries who ultimately decide through their behaviour, purchases, product designs, research activities and investment decisions how energy and other GHG sources are used. The potential for energy efficiency and other "green" actions can never be fully realised unless these energy actors take into account, either explicitly or implicitly, the energy-economic consequences of their everyday decisions .

However, for political and administrative reasons, the process of "getting the prices right" is likely to take a very long time. Obtaining the right prices – through the removal of energy subsidies and the imposition of GHG-based taxes and/or tradable permits — is not likely to be implemented quickly enough or forcibly enough to meet short-term (and perhaps even medium-term) climate change mitigation goals. Other policies will be a key element of a viable climate change mitigation strategy. Common instruments—such as enhanced technology research, development and diffusion; public infrastructure planning and construction; legal and regulatory instruments; voluntary agreements; information and technical support - can all help markets deliver more of the economic potential for GHG emissions reductions that exist (at any price) because of market failures and barriers. These policies can also help realise some of the technical potential for emissions savings that lower-than-correct prices leave untapped. Table 6.2 illustrates some examples of how these various policy measures might be used to address the objectives discussed in the previous section.

Many of these instruments have been applied and studied extensively in other environmental fields. However, instruments such as carbon taxes, emissions trading (domestic and international) and voluntary agreements have tended to receive considerable attention in the climate change context.

Table 6.2 General policy objectives and options for countering climate change and other energy-related environmental problems

Policy Objectives	Policy Options¹	Economic instruments	Technological development and diffusion	Public infrastructure planning and construction	Legal and regulatory instruments	Voluntary agreements	Information and other instruments
Energy							
Lower energy intensity of economic activity							
Reduced energy services ²	- Higher energy prices ³ - Road use taxes - Fiscal incentives ⁴				- Road use restrictions		- Campaigns against energy and water wastage
Improved energy end-use efficiency	- Higher energy prices ³ - Motor vehicle registration taxes (based on emissions) - Fiscal incentives - Fair market access/ rules for energy service companies (ESCOs) or energy performance contractors -- Tradeable permits	- More energy-efficient building, industrial and transport technologies. (see Table 7.3)	- Road and railway networks, - Mass transit systems - District heating networks		- BAT ⁵ prescriptions - More stringent: - building codes - appliance and equipment standards - motor vehicle fuel economy standards - Requirements for power plant DSM/IRP ⁵	- Voluntary/negotiated commitments for more efficient: - products and buildings, - production processes - Voluntary/negotiated commitments for power plant DSM/IRP ⁵	- Appliance and equipment labelling - Building efficiency ratings - Auditing, technical assistance and support for EMSs ⁵ - Driving behaviour modification campaigns - Government facilities leading by example
Lower carbon intensity of total primary energy supply (TPES)							
Improved energy production and conversion efficiency	- Higher energy prices ³ - Power plant emissions charges - Fiscal incentives - Tradable emissions permits	- Cleaner power generation from fossil fuels. (see Table 7.3)	- District heating networks		- BAT ⁵ prescriptions - Power plant minimum efficiency standards	- Voluntary/negotiated commitments to improved power plant efficiency	
Fuel switching	- CO ₂ and CH ₄ taxes, - Emissions charges, - Tradable emissions permits - Fiscal incentives	- Greater power generation from renewable, nuclear, and hydrogen sources. (see Table 7.3)	- Natural gas, electricity and hydrogen-based transport refuelling network		- Power plant fuel portfolio standards - Motor vehicle fleet fuel portfolio standards	- Voluntary/negotiated commitments to fuel portfolio changes in: - power plants - motor vehicles	- Green electricity validation
End-of-pipe emissions treatment/sequestration	- Emissions charges, - Tradable emissions permits	- Chemical and biological sequestration - Deep ocean sequestration			- Emissions restrictions for major point source emitters		

Table 6.2 *continued*

Policy Objectives	Policy Options¹	Economic instruments	Technological development and diffusion	Public infrastructure planning and construction	Legal and regulatory instruments	Voluntary agreements	Information and other instruments
Non-energy							
Improved agricultural management		- Nitrogen fertilizer taxes	- Advanced agricultural systems		- BAT ⁵ prescriptions		- Agricultural auditing and technical assistance
Improved waste prevention and management		- Recycling incentives - CH ₄ emissions charges, - Tradable emissions permits	- Improved recycling, incineration and methane recovery	- Recycling network	- BAT ⁵ prescriptions - Recycling requirements		- Waste dump technical assistance
Improved materials efficiency of industrial production		- CO ₂ , CH ₄ and PFC emissions charges - Tradable emissions permits	- Improved cement, aluminium and nitric and adipic acid production processes	Recycling	- BAT ⁵ prescriptions		- Industrial auditing, technical assistance and support for EMSs ⁵
Use of substitute products		- HFC, PFC and SF ₆ production taxes			- HFC, PFC and SF ₆ production restrictions		
Enhancing natural CO₂ sinks							
Improved agriculture, forest and ocean management		- CO ₂ credits, - Tradable emissions permits	- Ocean fertilisation, - Carbon sequestration in soils		- BAT ⁵ prescriptions		- Forestry management technical assistance
Climate change adaptation							
Changes to health services, settlement and land use patterns, water provision, ...		- Fiscal incentives					

1 The three other major policy types - monitoring, policy integration and international co-operation - are overarching activities that apply to all aspects of this table.

2 Energy services refer to heating, cooling, lighting, communications, motor driven services, personal and freight mobility, etc.

3 Higher energy prices via higher energy taxes, lower energy subsidies, reduced price controls and tradable permits.

4 Fiscal incentives include grants/rebates, loans, loan guarantees and preferential tax treatment.

5 BAT = Best Available Technology; DSM = Demand Side Management; IRP = Integrated Resource Planning; EMSs = Environmental management systems, such as ISO 14001 and EMAS.

6.3.1 *Economic instruments (subsidy removal, taxes and new markets)*

As mentioned earlier, the economic foundation for an effective climate change mitigation strategy is "getting energy prices right". Removal of subsidies having adverse environmental effects, taxation of energy based on its carbon content, and establishment of domestic and international tradable permit systems are the most discussed instruments for furthering this goal. It is also important to consider options other than fuel prices and CO₂ taxes. Vehicle, road and parking charges, fees related to freight capacity, property rates linked to energy efficiency could all be more effective signals for behavioural change. Taxation may also be an appropriate tool to help reduce emissions of non-CO₂ gases in a wide variety of non-energy sectors. These could include methane emissions from natural gas and oil production and from modern landfills, nitrous oxide emissions from industrial sources or from the use of fertilisers, production or sales of HFCs used in place of ozone depleting substances, and SF₆ used during magnesium production (OECD, 2000e). Balancing issues of administrative complexity and transparency is essential in designing effective price-based policies.

Use of price mechanisms in the transport sector can be more complicated. Fuel and other transport-related taxes comprise more than 90% of all environmental taxes in OECD countries, with fuels being one of the most heavily taxed expenditure items. Experience following the oil shocks of the 1970s and 1980s shows that significant price rises were successful in reducing some of the least efficient energy uses (especially in the US), but whether they would be as effective today is unclear, and the long-term price elasticity of demand for transport appears low. Price differentials may have greater impacts in fuel choice, as it appears that low diesel fuel prices played an important role in stimulating shifts to diesel cars in some European countries, and have also been a basis for promoting LPG use.

6.3.1.1 *Subsidy removal*

Subsidies to specific fuels lead to an economically inefficient energy supply level and mix, and discourage new fuel or technological developments that could reduce negative environmental effects. In OECD countries, the reform of environmentally damaging subsidies – particularly those tied to the use of more polluting fuels (*e.g.* fossil fuels, especially coal) or to energy production or consumption – could contribute to meeting greenhouse gas emission reduction goals or national environmental targets (see Box 6.3). While many OECD countries have started to reform or environmentally damaging subsidies, the process has been slow, and significant levels of support remain in place.

Various OECD studies have found a significant potential for greenhouse gas emission reductions through subsidy removal. OECD, 1997 concluded that removing coal and other energy subsidies, either at the world or country level, CO₂ emissions in 2010 would be reduced by 1 - 8%, compared to the business as usual scenario. Subsidies to specific fuels and energy use in non-OECD countries are also significant, and can contribute to divergences from an economically efficient energy supply level and mix. The IEA has recently estimated that removing energy price subsidies in eight key non-OECD countries³⁸ would reduce *global* energy consumption by 3.5%, global CO₂ emissions by 4.6%, and increase global GDP by almost 1%. Where the economic effects were analysed, most studies also suggested real increases in GDP or GNP, indicating that subsidy removal may be a "no regrets" policy (IEA 1999).

38 China, India, Indonesia, Iran, Kazakhstan, Russia, South Africa and Venezuela.

6.3.1.2 Taxes

If the Polluter Pays Principle is followed, removing support to energy production and consumption should be accompanied by levying charges or taxes on fuels in order to internalise their environmental impacts. Such charges would theoretically reflect the respective environmental damage caused by different fuels, for example reflecting their carbon content as a proxy for their contributions to climate change. A number of OECD countries (Denmark, Finland, Norway, the Netherlands, and Sweden) have implemented carbon taxes as a key element of their climate change policies. However, the success of carbon taxes to date has been limited, mainly because these taxes generally have low effective tax rates, for large industrial energy users, due to concerns about their international competitiveness.

Box 6.3 Effects of OECD energy subsidy removal and energy tax use

The table below provides the results of an energy policy simulation, prepared for the OECD Environmental Outlook (OECD 2001a). This simulation removes all subsidies to energy sources in *OECD* countries and all subsidies to energy production, combined with adding an annually increasing *ad valorem* tax on fuel use in OECD countries. The *ad valorem* tax increases by 2 percentage points per annum for coal, 1.6 percentage points for crude oil and 1.2 percentage points for natural gas, reaching a total tax levy of 50%, 40% and 30% of pre-tax prices respectively in 2020. The yearly increases in the taxes are linked to the carbon content of each fuel, but as the starting point for the increases have no such link, this shock should not be seen as simulating a proper “carbon tax”. As can be seen from the Table, the policy simulation has fairly significant effects on fuel demand in OECD countries, particularly on coal use. World-wide, there would also be reductions in total coal, oil and natural gas demand compared to the Reference Scenario, although in non-OECD countries a small leakage effect would be expected, with fuel use in these regions increasing marginally. The economic effects of these policies would be small, reducing expected GDP in OECD regions in 2020 by approximately 0.1% only. The environmental effects of the subsidy removal and energy tax implementation would be more substantial. Compared to the Reference Scenario, introducing these policies would result in 25% reductions in both SO_x and CO₂ emissions, thereby significantly improving air quality and reducing climate change effects of energy use in OECD countries.

(% change from Reference Scenario in 2020)

Effect on OECD demand for:			OECD GDP	OECD SO emissions	OECD CO emissions
Coal	Oil	Gas			
-32%	-18%	-17%	-0.11%	-25%	-25%

Notes:

(1) The energy subsidies reflected in the model are based on the data available from national accounts, and as listed in the GTAP database (OECD 2001a, Technical Annex). These reflect only a small proportion of actual energy subsidies. Thus, OECD energy subsidies listed in the GTAP database amount to US\$ 4.7 billion in 1995, while other estimates indicate these might be US\$ 70-80 billion (de Moor and Calamai, 1998).

Source: Reference Scenario and Policy Simulations.

6.3.1.3 New markets

Creating new markets can assist economies in locating and realising economical ways to reduce GHG emissions and other energy-related pollutants or to improve energy efficiency. For example, the

creation of permit trading markets have proven successful in reducing SO₂ emissions in the US. Another example is the creation of an energy services market. In this case, existing energy markets are reformed, as they allow greater participation of energy service companies (ESCOs) or performance contractors that help consumers reduce their energy use for fees based on the energy saving realised.

Domestic and international tradable permit systems are gaining recognition as a potential way to lower the costs of meeting climate change targets. When such permits are used in combination with an overall cap on emissions, and with specific allocations for individual firms or entities (cap-and-trade schemes), they can help to efficiently allocate a chosen level of emission allowances between competing firms and provide strong incentives to reduce emissions³⁹. OECD modelling (using the GREEN model) shows that with emissions trading in an international regime, the costs of achieving Kyoto targets in OECD regions could fall from 0.2% to 0.1% of GDP.

As permit trading may play a major role in the international policy response, many OECD countries are currently examining them for use at the domestic level. Unresolved issues, such as the allocation of permits, inclusion of non-energy emissions and other factors, have meant that no country has implemented a comprehensive national regime so far. The wide introduction of tradable permits would also require significant investment in emission monitoring systems and regulatory oversight to provide clear incentives for compliance. Denmark and the UK are already experimenting with limited systems for carbon trading at the national level. Australia and the Netherlands, are also looking at requirements for electricity utilities to source more electricity from renewable energy, with liable parties eligible to trade their requirements to enhance cost effectiveness.

6.3.2 *Technology research, development and diffusion*

Programmes supporting "clean technology" development and diffusion are a traditional focus of energy and environmental policy in OECD countries. They are also becoming an important part of national climate programmes. The energy technologies necessary to meet climate goals are largely "on the shelf" today, but diffusion is a problem due to their relatively high costs (IPCC, 2001; OECD 1999e). Going beyond current targets in combating climate change will require the development of new technologies. Table 6.3 provides a sampling of technologies whose further development could benefit consumers and reduce global GHG emissions.

Improvements in fossil-fuel combustion technologies, including advanced gas turbines and coal gasification offer considerable emission abatement potential over older fossil fuel technologies. Falling costs of renewable energy are making wind and biomass competitive in an increasing range of applications, and improved power storage and grid management technologies will help in the market penetration of renewable energy. For transport-related energy use, hybrid electric/petrol and bio-ethanol/petrol vehicles have recently been commercialised in several OECD countries and can offer a strong potential for fuel savings and emission reductions. Hydrogen fuel cell technologies are also nearing

39 In general, emission trading schemes make economic sense when there are many emitters with widely varying marginal costs of reduction, and where the environmental benefit does not vary widely with the location of the emission reduction. The latter is true for greenhouse gas emission reduction, but not necessarily for other pollution problems stemming from fuel combustion, such as thermal water pollution, conventional air pollution, or noise.

Table 6.3 **Examples of promising technologies to reduce energy GHG emissions**

	Near term impacts starting before Kyoto period (2008-2012)	Long term impacts starting after Kyoto period (2008-2012)
Energy Efficiency – Buildings	<ul style="list-style-type: none"> • More efficient heating and cooling technologies, such as heat pumps and condensing gas furnaces • Efficient lighting • Building envelope improvements: window and insulation retrofits • Building energy management systems • District heating and cooling systems • Technologies that reduce equipment standby power losses 	<ul style="list-style-type: none"> • Computer-based building design and optimisation • Manufactured wall systems with integrated superinsulation and electrochromic windows • "Superwindows" optimised for orientation, external temperate and internal needs • Integrated natural and electric lighting systems • Photovoltaic roof shingles, reflective roofing and strategic positioning of trees • Fuel cells for power generation and space conditioning • Sensor-controlled ventilation systems with air infiltration and heat exchange • Advanced building control systems • Energy storage systems
Energy Efficiency – Industry	<ul style="list-style-type: none"> • Process integration • High efficiency motors, drives and motor-driven systems • High-efficiency separation processes • Advanced end-use electro-technologies 	<ul style="list-style-type: none"> • Industrial ecology parks • Fuel cells and gasification of biomass and in-plant residues • Process efficiency via further advances in catalysts, separation technologies, materials, biotechnology and bio-derived substances • Decentralised micro-manufacturing with flexible process configuration and onsite/just-in-place production • Advanced resource recovery and utilisation
Energy Efficiency – Transport	<ul style="list-style-type: none"> • Efficiency conventional vehicles • Electric and hybrid vehicles • Fuel-celled-powered vehicles • Biofuels 	<ul style="list-style-type: none"> • Biofuel vehicles • Advanced fuel cell vehicles and a hydrogen production, distribution and storage infrastructure • Clean and efficient diesel technologies
Decarbonising Power Generation	<ul style="list-style-type: none"> • Natural-gas-fired technology • More efficient coal technologies • Renewable energy technologies: biomass and wind • Technologies for nuclear plant optimisation and life extension, • Fuel cells for stationary generation 	<ul style="list-style-type: none"> • More-efficient, reduced-fugitive-emissions, crude oil refining, through improved catalysts, separation methods, pretreatment processes, process optimisation and advanced sensors • Improved methods for converting natural gas into liquid products • Technologies for locating, developing and exploiting undersea methane hydrates reserves • Improved materials for use in high-efficiency coal-based power generation technologies • Low- and no-carbon fuelled gas turbines and fuel cells • Energyplex industrial parks, integrating energy generation and fuels and chemicals production • Further development of biomass, wind, photovoltaic, solar thermochemical conversion, and solar photoconversion energy sources • Advanced nuclear fission, thermonuclear fusion
Crosscutting Technologies	<ul style="list-style-type: none"> • Combined heat and power • Advanced gas turbines • Sensors and controls • Power electronics 	<ul style="list-style-type: none"> • Hydrogen technologies • Sensors and controls • Improved transmission and distribution systems • Energy storage
Carbon Sequestration	<ul style="list-style-type: none"> • Carbon dioxide separation technologies • Geologic storage of carbon dioxide 	<ul style="list-style-type: none"> • Ocean fertilisation • Chemical and biological sequestration • Elemental carbon sequestration • Carbon sequestration in soils • Deep ocean sequestration

Source: IEA, Energy Technology and Climate Change, A Call to Action, 2000 (IEA 2000d).

commercialisation in the transport sector and these could radically change the sector's energy requirements and environmental impacts. Technologies are also being explored for addressing greenhouse gas emissions from the energy sector, such as CO₂ scrubbing processes which would pump CO₂ into used gas wells for storage.

Ensuring price differentials that reflect environmental externalities between different fuels and energy technologies would provide significant incentives for developing and adopting cleaner energy systems. To accelerate the process, governments provide further support to research and development in these alternatives, and to their adoption. Government funding for energy technology research is typically in the domain of energy ministries and is closely monitored by the IEA. Data reveal that historically energy technology R&D investment has been heavily weighted to nuclear and coal technologies (IEA 1998c; OECD 1998c). Though research on renewable energy, energy efficiency technologies and other promising technologies is gaining ground in absolute terms, it is still a relatively small portion of overall energy R&D budgets in the OECD. Moreover, government funding as a whole for energy R&D appears to be declining (IEA 1997c). Private sector funding for energy R&D has also been declining in recent years. In a recent study conducted by Battelle, it was estimated that less than \$15 billion is invested annually into the development of improved energy technologies by the world's governments and private firms. The US commitment represents less than 0.05% of U.S. GDP, and less than 2% of all R&D conducted in the US. Between 1985 and 1995 public sector investment by the nine OECD countries undertaking research into improved energy technologies decreased by 23% in real terms. More recent data would seem to confirm the continuation of these trends (Battelle, 2001).

Besides providing direct government spending, governments can also foster industry research and development investment through a variety of fiscal instruments, such as tax incentives. These policies may accelerate the pace of clean technology diffusion by speeding up capital turnover in targeted areas. Under normal conditions, businesses only replace old technologies with new ones when the former have reached the end of their useful lives. Fiscal policies can allow businesses to accelerate depreciation schedules or provide tax credits for investment in clean technologies, although at the cost of premature scrapping of productive equipment. Experience with a limited number of these programmes suggests that they may be valuable, but more studies are needed on their effectiveness and efficiency. At a minimum, they may be useful if used in a temporary manner to help create niche markets for new, clean technologies. This in turn can bring down the cost of new technologies, allowing them to compete with conventional alternatives.

Green government purchasing is another fiscal mechanism that can be used to shift the focus of equipment and product development as well as increase size of markets and the speed of the diffusion of clean technology (IPCC 2001c; IEA 1997a; OECD 1998c). Such policies can create niche markets for new technologies and lower the perceived risk associated with new product development and marketing. The large size of the government as a consumer, sometimes accounting for 20-25% of GNP in OECD countries, make its impact on the environment and on product markets significant. Government purchasing may or may not be able to promote a fundamental change in products, however it can be effective in accelerating the uptake of commercially available technologies or practices (OECD 1998c).

6.3.3 *Legal and regulatory instruments*

In most OECD countries, the wide adoption of many end-of-pipe environmental technologies in the energy sector, in particular to reduce air emissions from fuel combustion, has primarily been driven by emission regulations. These include technical emission standards, product standards, and/or air quality standards. In turn, these regulatory policies have accelerated adoption of flue-gas desulphurisation, the use

of low sulphur fuels, low NO_x burners and catalysts for NO_x reduction, as well as the phasing out of leaded petrol.

In addition to encouraging further end-of-pipe emission reductions, regulations may increasingly be used in the energy sector to set specific targets and drive changes in the fuel mix and conversion efficiency towards greater use of renewables and high-efficiency applications, including co-generation and low emission motor vehicles. A number of OECD countries are already adopting portfolio standards, often as an accompaniment to general energy sector regulatory reform, which require that a certain percentage of new power generation or vehicles be fuelled by renewable or non-fossil fuel energy sources. An OECD modelling simulation of adopting a policy across all OECD regions that would require a minimum of 15% renewable energy in the energy supply to 2020 indicated that both CO₂ and SO_x emissions could be reduced by over 7% compared with the Reference Scenario. However, OECD research indicates that the such targets may be relatively costly policies for reducing greenhouse gas emissions when compared with the use of economic instruments (OECD, 2001b). Nonetheless, such targets can provide clear and consistent signals to the public and business community of government environmental aims, and may in many cases be the a practical option for ensuring reductions in the environmentally damaging effects of energy use.

Standards (voluntary and regulatory) can be useful in encouraging the development, marketing and purchasing of more energy efficient products, vehicles and buildings. Research indicates that energy efficiency standards can be particularly effective in overcoming market barriers to investment in energy efficient equipment (IEA, 2000e). The gap between real investment decisions and opportunities for cost-effective investment in more energy efficient products reflects high transaction costs, conflicting incentives (e.g. between tenants and building owners, or between building owners and developers) and information failures. Performance standards, when introduced with enough lead-time for manufacturers and builders to adapt, can overcome these barriers. They can help shift investment and narrow the efficiency gap (OECD, 1999e).

Experience with voluntary standards, such as the US Energy Star programme, demonstrates that they might be useful as an alternative to a regulatory approach. This is a voluntary product and labelling policy that solicits the participation of manufacturers to meet product specifications with energy efficient performance. Once the specifications are met, manufacturers can display the Energy Star label on their products.

6.3.4 Voluntary agreements

Voluntary agreements to reduce energy use in the industrial and power sectors have been in use for almost a decade. Their growing use reflects the search for greater flexibility and reduced regulatory burden. New voluntary, or negotiated, agreements are being set up for consumer appliances, such as clothes washers and consumer electronics (IEA, 2000e). The voluntary agreement on clothes washers as part of the EU's SAVE agreement succeeded in phasing-out the least efficient washers in 1998. Voluntary agreements figure prominently in OECD national climate programmes and target mainly the industrial sector, although they take many different forms (OECD, 1999e). The distinguishing features of these measures are whether they are enforced or closely monitored; the rigidity, clarity and magnitude of the emission reduction objectives; and the nature of the participants (e.g. whether industry associations or individual industry players have signed the agreements).

Voluntary agreements also vary by the degree of government involvement. Three main types of policy approaches are currently applied in OECD countries (OECD 1999e):

- **Public voluntary programmes** involve commitments devised by the environmental agency and in which individual firms are invited to participate. Since participation in the voluntary programme is a choice left to individual companies, they can be seen as "optional regulations". Examples are the US programme 33/50 or the Eco-Management and Auditing Scheme (EMAS) implemented in the European Union since 1993.
- **Negotiated agreements** are commitments for environmental protection developed through bargaining between a public authority and industry. They are frequently signed at the national level between an industry sector and a public authority, although agreements with individual firms are also possible.
- **Unilateral commitments** are made at the initiative of the private sector without any involvement of a public authority. The Responsible Care programme is a well-known example of a unilateral commitment made by the chemical industry in many countries.

There is enthusiasm for voluntary approaches, especially on the part of industry, as a means to prevent the enactment of new or more stringent environmental regulations or taxes. A recent OECD report finds that voluntary approaches are generally expected to provide increased flexibility in implementation and reduced administrative burden to both industry and government.

Nevertheless, voluntary approaches have several potential pitfalls, in particular:

- **Weak control:** the control of the outcome of voluntary approaches is potentially weak, either because industry does not provide adequate control mechanisms, or because of a lack of sanctions.
- **"Free riding":** if the agreement does not contain monitoring and sanction provisions, there is a risk that parties will not comply with it ("free-riders"), thus avoiding the costs of pollution abatement.
- **Transaction costs:** if the number of stakeholders is high, the cost of negotiation and of setting up the agreement may be high.
- **Regulatory capture:** there is a risk that powerful and well organised industry organisations may "capture" the policy and regulatory process by avoiding or obstructing the introduction of a regulation and/or influencing the regulatory process to their own benefit, and to the detriment of other parts of society. A typical consequence is a "business as usual scenario" in which the agreement does not in fact result in any additional action or environmental benefit, as the environmental protection measures taken are those which would have occurred.

The effectiveness of voluntary agreements in reducing industry energy use and emissions has been questioned. Moreover, some countries have found it difficult to attract a large number of interested private-sector participants from a broad range of sectors. And it is unclear how unilateral actions by multinationals can be taken into account in national policy frameworks.

Nevertheless, voluntary agreements (especially when implemented in conjunction within regulations) could be an important element in the policy mixes used by governments to achieve climate change objectives. They provide a flexible policy instrument and a means to fully engage industry in greenhouse gas mitigation. In addition, voluntary agreements can be particularly effective at promoting environmental awareness, learning and cultural change and. This makes them attractive for exploring

mitigation action in areas where learning about technical mitigation options and costs is essential, as with the industrial process emissions and HFCs, PFCs and SF₆, or where environmental awareness of some environmental issues may be relatively low, such as freight operations, waste management, forestry and agriculture (OECD 1999b). While the effects of voluntary agreements are difficult to measure, there is a broad consensus that they can influence the environmental culture of industries and businesses by raising the profile of greenhouse gas performance or energy efficiency objectives (OECD 1998d; 1999b).

6.3.5 Information and other instruments

Education, technical training and public awareness policies are an essential complement to other greenhouse gas mitigation policies. Attitudes in business and industry, and among consumers, will ultimately influence the acceptance and pace of uptake of new “green” products and technologies throughout national economies. Overall, education and information instruments should be seen as complementary to other policies that provide more direct and continuous incentives to think, act and buy “green”.

Information programmes help market actors recognise their best interest and act on it. Evidence shows that energy users adopt fewer energy efficient options than are in their financial interest. Part of the reason is that consumers often lack the information, time and skills to recognise their own interest in energy efficiency. In addition to receiving proper economic signals from the market, consumers need information and expertise to make better informed energy efficient purchases and behavioural choices. Other market actors may also need help in acting on their interests in energy efficiency. For example, in a true market, ESCOs or other intermediaries may be willing to tap some energy savings opportunities, but may need help in the form of technical training and general business advice (IEA, 1997a).

Energy-efficiency labels and standards for appliances and equipment — predominantly for household use — are being used in 37 countries, and the range of appliances to which they are being applied is continuing to expand. The use of such labels can influence consumer choice to a significant degree. For example, the sales-weighted annual average energy-efficiency index of “cold appliances” (refrigerators, freezers and combinations thereof) improved by 4.5% from 1994 to 1996 during the EU’s cold labelling programme (IEA, 2000e).

Green power schemes, where consumers may choose to pay more for electricity generated primarily from renewable energy sources, are an interesting example of combining information with real choice for the customer. While such schemes currently have very low take-up rates because the electricity is still relatively expensive, they may offer the potential for significant changes in fuel mixes driven by consumer demands in the future as the price for renewable energy falls (IEA, 1998d).

6.3.6 Public infrastructure planning and construction

It is clear that long-term mitigation of climate change will require widespread implementation of new personal transport technologies (motor-fuel systems), electricity generation technologies, as well as changes to the structure of cities and the transport system. Each of these are going to require large public investments in infrastructure. The markets may exhibit preferences in this regard, but it will fall to political leaders and citizens to actually choose, plan, and construct the infrastructure that will be required.

6.4 Major sectoral policy elements

The policy options described in the previous section have not been implemented uniformly in all countries and all sectors. Some, such as CO₂ taxes and tradable permits (economic instruments), are still at the discussion stage in most countries. Others, such as appliance standards (legal and regulatory instruments), are well-developed in some countries. Others, such as voluntary agreements, are applied to principally one sector (industry). This section describes how some of the principal policy elements apply in specific sectors.

6.4.1 Energy supply and transformation

National programmes incorporate a variety of approaches to lower emissions for the energy and transformation sector. However the main driving force behind changing emissions is the move towards privatisation and regulatory reform. These policies are largely undertaken to achieve economic policy objectives, but can have a significant impact on greenhouse gas emissions, because they shift the relative competitiveness of technologies and fuels.

Electricity market liberalisation and restructuring generally leads to the more rapid phase-out of older and inefficient generating technology in favour of small, high efficiency modular units. In competitive markets, investments in large capital-intensive facilities, such as nuclear power stations, become less likely. In a few countries, electricity market restructuring is stimulating fuel switching from coal to gas, especially when combined with the reform of coal and other energy subsidies (e.g. the UK). But this is not a general rule. For example, in Nordic countries, liberalisation of the electricity market is expected to accelerate a pre-existing shift to a higher carbon fuel mix for power production (moving away from hydro and nuclear towards natural gas). As trade barriers fall, electricity generation and emissions in one country, may increase to supply a neighbouring country with power. Thus, the environmental effects of market liberalisation policy are determined by the national or regional endowment of resources, the fuel mix and vintage of existing generation capacity, and the scope of restructuring and policy reforms.

Some OECD Member countries are accompanying energy market reform policies with regulations, subsidies, and taxes, to guarantee markets for and accelerate development of renewable energy. Policies also include expanded research and development of technologies. The extent to which market liberalisation policies can deliver environmental benefits will depend, to a large extent, on such complementary policies.

6.4.2 Transport

Regulations have played a major role in shaping the environmental character of the transportation sector. Due to a series of increasingly stringent emission regulations, cars have steadily become more fuel efficient (for a given weight class) and are equipped with highly effective end-of-pipe pollution control technologies. Current national and local policies in the transport sector have developed along two main lines: 1) improving fuel efficiency of individual vehicles through taxes, regulations and voluntary approaches as well as government R&D; and 2) expanding the role of public transport through public investments in rail and bus systems, limiting car use in cities and various instruments (economic, regulatory, voluntary) to promote usage. A more limited set of policies are emerging to address rapid emissions growth in the freight sector, such as those aiming to improve logistics and capacity rates of freight transport. Integrated transport planning, at the national and local level, is important for effective emission control in this sector, yet such planning exists in few OECD countries.

Energy consumption and consequent effects on the environment are increasingly important in transportation policy. There are four principal ways to influence the efficiency of the transport system, its energy consumption and environmental impact:

- vehicle efficiency and fuel choice;
- behavioural and operational aspects (occupancy of vehicles, driver behaviour);
- modal mix (cars, trucks, rail, air, etc.);
- urban and land-use planning.

6.4.3 Industry

Energy efficiency policies in the industrial sector tend to focus on two different industry groups: energy intensive industries or other industries. For energy intensive industries, concerns about industrial competitiveness rank highly. These concerns often override arguments for economic efficiency. Thus, where cross-cutting instruments, such as carbon/energy taxes, are in place, exemptions or special provisions for industry are common practice

The flexibility of voluntary measures makes them a preferred approach of industry. Voluntary measures may be useful to stimulate greater investment in energy efficiency and cleaner production processes than would otherwise occur. Different countries use different approaches, each adapted to its institutional and cultural preferences as well as the policy objective. Voluntary measures are also emerging with local governments and consumer organisations. As a relatively young policy instrument, experience with the performance and cost of voluntary measures is limited. While the “soft effects” of the measures can provide important environmental benefits through a change in corporate culture and long term corporate behaviour, there is a need for a strong regulatory regime to support such measures if they are to be fully effective.

Table 6.4 summarises the main aspects of voluntary agreements signed by OECD countries up to 1998 (Canada, Finland, France, Germany and Japan), which include specific reduction goals, statement of progress, or declarations of intent, depending on the strength of the agreement (OECD 2000f).

Given the increasing awareness with respect to the potential impacts of climate change and prospects of stringent regulatory requirements, it is likely that industry across OECD will follow the trend towards voluntary agreements as a flexible alternative to command-and-control regulations, or in some cases, GHG taxes, or other market-based instruments.

Table 6.4 Reduction targets in voluntary agreements on energy and CO₂ emissions

Countries	Conditions and Targets
Canada	Industry agrees “to make reasonable efforts to go beyond legislative requirements and to evaluate the most appropriate, economically effective means available to individual companies to achieve further reductions...” Participating Canadian steel-makers in the Canadian Industry Program for Energy Conservation (CIPEC) intend to reduce by 1%/year their energy use per ton of steel produced.
Finland	A reduction of total energy consumption by 10-15% of the levels set when companies will join the voluntary agreement Environmental auditing of 80% of total energy consumption to be performed by 2005
France	On the basis of production assumptions used in the voluntary agreement, it is expected that CO ₂ emissions should fall by about 2.97 Mt in 2000, which would represent a 12% reduction on 1990 levels.
Germany	A reduction of specific energy consumption by 20% of their 1990 levels by 2005
Japan	A reduction of energy consumption in the order of 17% of their 1990 levels by 2010 A reduction of the final disposal volume of waste of 75% of their 1990 levels by 2010

Source: OECD 2000f)

Information programmes (energy auditing initiatives and technical assistance programmes) are very well developed in non-energy intensive industry, and have generally shown good results.

In a number of OECD countries, policies are emerging to address industry process emissions of HFC, PFC, and SF₆, as well as N₂O. The origins of these emissions are diverse, hence policies must be structured accordingly. Voluntary approaches are emerging to deal some of the main sources of emissions (HFC-23 as a by-product of HCFC production, PFCs from aluminium producers, SF₆ from electrical equipment), as technical options for emission reduction are already available. Some countries are also regulating the use of PFCs. A few countries are beginning to restrict or phase out the use of HFCs and PFCs in consumer and commercial products. Countries are also supporting research to find replacement technologies, processes or substances. Voluntary measures are also being used in this sector to limit N₂O emissions. Governments in several countries are working with manufacturers of adipic acid to accelerate investment in new industrial technology to eliminate emissions from this process.

Market transformation programmes target the energy characteristics of the products that industry produces, rather than the energy consumed in the manufacturing processes. This approach endeavours to help groups of consumers exert greater influence on the development of technology. Market transformation will help to shift away from products with inferior energy use patterns by getting improved products introduced in the market and by rapidly increasing their share of the market. When carried out in combination with standards that eliminate the least efficient models from the market, it can be particularly effective. Initiatives such as innovative *technology procurement* or *green government purchasing* promote the commercialisation of efficient technology, thereby raising the average efficiency of available products

In Finland, MOTIVA, the Information Centre for Energy Efficiency organised technology procurements to promote new window technologies and a competition for an energy efficient refrigeration unit for supermarkets. In Sweden, NUTEK, the National Board for Industrial and Technical Development

(now STEM, the Swedish National Energy Administration) initiated some 30 technology procurement projects. Presently, five of these projects were subjected to in-depth evaluation. The results showed that procurement produced a clear technology leap for refrigerators/freezers and accelerated the mass-production of low-energy appliances, but was not successful in the case of high-performance windows.

6.4.4 Residential, commercial and institutional

The search for "easy" and low-cost measures explains a heavy emphasis in domestic programmes on energy efficiency measures. The majority of energy efficiency measures target the residential and commercial end-use in sectors where information and other market barriers are believed to be greatest. Market failures are caused by entrenched attitudes towards energy use, lack of information about the potential cost savings from increased energy efficiency, individuals who do not have the asset backing to make even small investments in efficient appliances in order to make long-term gains. Also, energy users are not always responsible for the purchase of energy using equipment or building structures, which hinders economic decision-making. Settlement patterns and urban development policies can also have huge influences on national energy and emission trends, and these may not be easily tackled as part of energy efficiency or climate policies.

National packages of policies and measures are triggering a range of different kinds of responses in the residential and commercial sector to achieve energy efficiency and minimise waste streams. The use of "social" policy instruments such as public awareness campaigns, information and technical assistance, is commonplace. Performance standards and product labelling are in place in many countries aiming to improve the energy efficiency performance of new appliances and buildings. These policies are usually part of voluntary or regulatory mixes of measures that are implemented by manufacturers and builders, ultimately influencing consumer choice.

There is continued growth in adoption and implementation of *energy efficiency standards for household appliances and equipment* designed to encourage the development, marketing and purchase of energy-efficient products. However, the degree of development and coverage varies greatly from country to country. *Information labels* are frequently used to inform consumers about equipment performance and energy consumption in order that they may more fully consider energy costs in their purchase decisions and thus choose the most efficient products available. Labelling also motivates manufacturers to produce more efficient products. Energy labels are typically applied to appliances and equipment, but can also be applied to buildings as in the Danish and Canadian energy certification of buildings.

Financial/fiscal incentive schemes in the residential/commercial sector are employed mainly to encourage building retrofitting.

6.5 Policy infrastructure

Although "getting prices right" is the economic foundation of a viable climate change policy, several other elements are also important. These include: emissions monitoring, programme evaluation, policy integration and continuity, and international co-operation.

6.5.1 Emissions monitoring and programme evaluation

Monitoring of the emission reductions resulting from climate change and other policies is an essential part of national policy frameworks. National inventories, usually updated on an annual basis, are

the backbone of the system. Analysts also need to study historical trends and consider the outlook for the future. Preferably this information is developed through national research and own-data collection efforts (Corfee-Morlot, 1998). Information gathered from a national monitoring system can help to confirm policy choices and strengthen instruments already in place. The information can also inform future policy decisions, providing a feedback loop for policy learning.

It is also vital that policies and programmes be routinely monitored, evaluated and revised, in order to keep them tuned to changing consumer demands, technologies and other parameters, and to bolster confidence in their effectiveness.

Monitoring greenhouse gas emissions, and the effects of policies and measures in particular, requires significant government administrative capacity. OECD countries have varying capacities to monitor emissions and policy performance and could benefit from stronger networking to share experience. Goal setting and comprehensive monitoring can also be effective at the local level to raise awareness and stimulate mitigation initiatives.

6.5.2 Policy integration and continuity

Greenhouse emissions arise from a number of sectors - energy, transport, waste, agriculture land use, forestry and industrial processes. These sectors differ in terms of their relative importance in different countries and their potential for cost-effective abatement. While energy is the main source of emissions globally and in most countries, there may be more cost-effective reduction opportunities in other sectors. Levels of certainty over measuring emissions also varies, with the energy sector relatively well-understood, while areas like land-use change and forestry present many difficulties.

The comprehensive nature of the greenhouse challenge argues for more integrated policy-making across a range of policy areas, most governments have decided not to implement comprehensive approaches such as carbon taxes and tradable permits, and are relying on more specific policies to achieve their energy and climate change goals. This has two clear implications:

- It requires a greater number of measures to address the full range of options. These measures can target more specific needs and market barriers but run the risk of policy confusion, as the target audiences for different measures may often overlap.
- It requires that sector-specific policies be designed to specifically address the perceived shortcomings of more general approaches. Because more specific policies include implicit judgements about the relative attractiveness of different technical options, they are likely to misjudge to some extent these relativities.

Developing a coherent and effective mix of the many policies targeting different stakeholders, technological choices and potentials for policy response represents a formidable policy challenge for OECD governments.

Developing and maintaining a supportive institutional framework means integrating energy and climate change consideration in sectoral policies; and ensuring the availability of impartial expertise. Because energy-use is so dependent on the infrastructure that societies create for themselves, it is vital that energy efficiency principles be embedded into sectoral policies on housing, commercial buildings, industry and transport. Stand-alone energy-focused policies themselves will do little to influence the millions of everyday energy use decisions. Collaboration with the relevant authorities is required to ensure that their policies reflect energy efficiency objectives. However, there remains a need for energy-focused

organisations. They link energy efficiency activities across sectors, join energy-specific efforts to environmental policy and assess overall supply/demand concerns. This expertise is needed at local, national and regional levels. There is no unique way to manage energy efficiency policy. In some countries, the energy efficiency body is centralised within a department or ministry. In others it is an independent public agency, or a consortium of public and private entities. In whatever form, an energy efficiency organisation needs well-trained experts who can provide impartial expertise.

As importantly, there are areas where non-environment policies can be in conflict with environmental objectives without careful design, or could more actively support environmental outcomes. Energy market reform, for example, with its focus on reduced prices could lead to higher energy use and emissions without offsetting policies. Urban development policies which promote greater transport use in energy-intensive modes, taxation systems which reward greater car use, communication policies which make use of energy saving e-commerce more difficult, and a host of other potential issues argue the case for greater integration across policy-making.

Strong institutions and a strong sense of policy continuity will be necessary to meet the multi-faceted challenge of climate change. Large scale energy and climate change improvements take time and require a policy approach that is clear, consistent and steadfast. Uncertainty and ambiguity in policies drain energy, effort and resources away from meeting goals. Governments must be clear about their goals and their expectations of individuals and businesses in attaining them. Their policies need to be based on strong analytical bases, including thorough assessments of what policies and measures have been successful in the past and why. This requires early engagement of many ministries, different levels of government and other stakeholders to build consensus and to take action. A key is to achieve multiple benefits simultaneously, for example, to curb fossil fuel and unsustainable land use, while at the same time improving the local environment.

6.5.3 *International co-operation*

International co-operation can facilitate domestic climate policy in several ways. Comparison of the costs and effectiveness of domestic climate strategies, policies and measures is an important function of the international community. Important examples include the collective exploration for policy action through subsidy and green tax reform as well as for the use of other policy instruments to promote cleaner technologies and practices (e.g. voluntary approaches and product policies). International collaboration can extend the factual basis for policy making and establish international benchmarks to monitor progress and change. Comprehensive and comparable international data collection is necessary to permit the assessment of environmental impacts and the cost of policy alternatives. Such assessments to raise the awareness of opportunities for reform. Through “peer” pressure, policy assessments can urge countries to act.

International collaboration can also support and minimise the risk associated with technology research and development, as well as policy experimentation. Examples of international collaboration include IEA implementation agreements on specific technologies, technology policies as well as the Climate Technology Initiative (CTI). The CTI is focused on expanding and improving North-South technology co-operation, while implementing agreements tend to be more narrowly aimed to advance individual types of technologies (e.g. biomass, clean coal, solar and wind). Policy experimentation and networking can also be supported through IEA implementing agreements (e.g. demand side management and market aggregation).

Some governments may lack administrative capacity to reliably monitor and enforce emission limits for individual participants in a trading system, or to oversee project performance under joint

implementation. International collaboration among Annex I countries and more widely could help to enhance national capabilities for implementation of the mechanisms and this could also speed adoption of domestic programmes. OECD analyses, as noted earlier, indicate wide economic benefits from implementation of the Kyoto mechanisms. Their successful implementation may be key to keeping mitigation costs low, as well as to the success of longer term mitigation efforts.

7. CONCLUSIONS

OECD countries have made considerable progress in relation to the policy concerns of the 1970s and 1980s. Reliance on oil in the power, industrial, residential and commercial sectors (but not the transport sector) has declined, renewable energy is growing quickly (although absolute shares remain at a low level) and reaching cost-competitiveness in more applications, and major energy-efficiency improvements have been "locked in" to the economy. Levels of key air pollutants have declined in many countries, and the risk of acid rain damage has been substantially reduced. While continuing attention to these issues is necessary, attention in this report has focused on what was perhaps the most discussed concern of the 1990s - climate change.

Establishing a market framework that prices GHG emissions (or energy and other GHG sources) at their full social cost is the economic foundation for cost-effective actions to counter climate change and other energy-related environmental problems. The potential for energy efficiency and other "green" actions cannot be fully realised unless these energy actors take into account, either explicitly or implicitly, the energy-economic consequences of their everyday decisions.

Correct pricing can be achieved through removing subsidies with adverse environmental effects, taxing energy based on its carbon and other GHG content, and the establishing domestic and international tradable permit systems. Charging and fee schemes provide another avenue – through the implementation of vehicle, road and parking charges; fees related to freight capacity, and the linkage of property rates linked to energy efficiency. These instruments can act as effective signals for behavioural change. Taxation may also be appropriate for methane emissions from natural gas and oil production and from modern landfills, and for nitrous oxide emissions from industrial and agricultural sources.

Domestic and international tradable permit systems are gaining recognition as a potential way to create new markets for GHG reduction and to lower the costs of meeting targets. Many OECD countries are currently examining these tools for use at the domestic level. Unresolved issues, such as the allocation of permits, inclusion of non-energy emissions and other factors, have meant that no country has implemented a comprehensive national regime so far. The wide introduction of tradable permits may also require significant investment in emission monitoring systems (particularly for non energy-related emissions) and regulatory oversight to provide clear incentives for compliance.

An efficient pricing and market regime for GHG emission reductions would in turn encourage the greater use of renewables and increased substitution to gas, especially in high-efficiency applications including co-generation. Falling costs of renewable energy have made wind and biomass cost-competitive in an increasing range of applications, and improved power storage technologies, such as flywheel and combined conversion systems can further assist in the penetration of renewable energy.

Obtaining the right prices and market incentives – through the removal of energy subsidies and the imposition of GHG-based taxes and/or tradable permits — is not likely to be implemented quickly enough or forcibly enough to meet short-term (and perhaps even medium term) climate change mitigation goals for political and socio-economic reasons. Even with technological and technical improvements,

greater attention to social or behavioural issues will be required to keep energy sector emissions from growing quickly. Policies aimed at consumer demand management can improve energy efficiency in the residential, commercial, agricultural and transport sectors as well as promote “green power”. Policies targeting manufacturers of energy using consumer products may also be essential to the mix of energy-environmental instruments to 2020.

Other policies are necessary elements of a viable climate change mitigation strategy. Common instruments - such as enhanced research technology development and diffusion, public infrastructure planning and construction, legal and regulatory instruments, voluntary agreements, information and technical support - can help the markets deliver more of the economic potential for GHG emissions reductions that exist (at any price) because of market failures and barriers. These policies can also help realise some of the technical potential for emission savings that lower-than-correct prices leave untapped.

To bring climate change objectives into reach, OECD countries will need to do more, and soon. More systematic and comprehensive policy frameworks are needed. Analysis suggests that gradual phasing in of action starting now will incur lower costs than waiting for cheaper abatement technology to emerge in the future. But there is no “one size fits all” solution for climate change. Different countries require different policy mixes. This report has led to a refinement of a general policy framework (Box 7.1). Nevertheless, it is only a general guide. Each country must adapt the framework to its own needs. The comprehensive nature of climate change calls for a wide-ranging number of measures to achieve greenhouse gas reduction goals while achieving energy security and other sustainability objectives, including keeping economics costs down. The challenge for OECD policy-makers is to develop an effective mix of policies targeting the diverse stakeholders, technological choices, and policy options available. This will require strong institutions, efficient knowledge-sharing, and a clear and consistent policy approach. It will also require an iterative step-wise approach, where in governments work with stakeholders to monitor and learn from past performance, and adjust policy over time, based on real-world experience.

Box 7.1 Policy framework

Based on an examination of policy experience to date, and the issues assessed in this report, the “good practice” framework set out by the OECD in 1999 (1999a) can be extended as follows:

1. Get the prices right:
 - subsidy removal
 - taxes to make prices more reflective of environmental and other externalities
2. Create new markets or allow greater market participation where needed:
 - tradable environmental permits
 - access to market for energy service providers ESCOs
3. Enhanced technology research, development and diffusion
4. Other instruments in the policy mix:
 - public infrastructure planning and construction
 - legal and regulatory instruments
 - voluntary agreements
 - public procurement, information and other instruments
5. Improved policy infrastructure:
 - monitoring and assessment
 - policy integration and continuity, including improved sector policies
 - international co-operation

APPENDIX 1. PRINCIPAL ENVIRONMENTAL EFFECTS OF ENERGY PRODUCTION AND USE⁴⁰

Energy is a fundamental element of modern, industrialised economies. Its production and use leads to vast and numerous benefits, but also to a multitude of adverse environmental effects, including:

- Greenhouse gas emissions
- Ambient air pollution
- Hazardous air pollution
- Acid deposition
- Stratospheric ozone depletion
- Water pollution
- Maritime pollution
- Land degradation
- Natural resource depletion
- Radiation hazards
- Solid waste accumulation
- Major Environmental accidents

Greenhouse gas emissions

Three greenhouse gases account for the majority of human induced global warming effects; CO₂, CH₄ and N₂O. Carbon dioxide is the dominant greenhouse gas, accounting for 75% of global emissions, and 81.7% of emissions from OECD countries (excluding land use and forestry uptake) (Table A.1). This is followed by methane (19% globally, 9.7% OECD regions) and nitrous oxide (roughly 6.6% both globally and in the OECD regions). HFCs, PFCs and SF₆ account for a small share (about 2%) of total emissions in the OECD regions, but they are growing quickly and thus are managed under the UNFCCC (Burniaux 2000; UNFCCC 2000).

40 Much of this appendix is extracted from IEA, *Energy and the Environment, Policy Overview*, 1989.

CO₂ emissions from fossil fuel combustion can be broken into emissions related to energy and transformation (to a large extent power generation) and emissions related to other energy end-use sectors (industry, transport, residential and commercial). Oil is the largest contributor to energy-related CO₂ emissions, accounting for 46% of OECD energy-related CO₂ emissions in 1998 (IEA, 2000b). More than half of this is from the transport sector. The largest CH₄ emission sources in OECD countries are the natural gas and oil industry, livestock enteric fermentation, and solid waste landfills – accounting for 75% of total methane emissions. The largest source of N₂O emissions in the OECD are from agricultural soil (over 60%), with industrial processes accounting for another 15%. N₂O emissions from transport grew rapidly (over 20%) over the last decade (EPA 2002).

Table A.1. **Contributions of energy use to anthropogenic greenhouse gas emissions in OECD Countries, 1998**

	CO ₂	CH ₄	N ₂ O	Others (HFCs, PFCs and SF ₆)	Total
Shares of Total GHG Emissions	81.7%	9.7%	6.6%	2.0%	100%
Energy Sector Share of Total GHG Emissions	79.2%	2.7%	1.1%	0%	83.0%
Main Source within Energy Sector	Fuel Combustion	Fugitive Fuel Emissions	Fuel Combustion	NA	
Main Sources outside the Energy Sector	Industrial processes	Livestock and Waste	Agriculture and industrial processes	CFC substitutes	

Source: UNFCCC 2000.

Ambient air pollution

Concern about ambient air quality is focused on two categories of pollutants:

- Emissions that have direct effects on human health and the eco-system such as sulphur oxides (SO_x), carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NO_x), volatile organic compounds (VOC) and ozone (O₃);
- Precursor emissions that lead to indirect effects through photochemical reaction (i.e. in the presence of sunlight), the most important ones being VOC and NO_x leading to the build-up of tropospheric ozone and peroxyacetyl nitrate (PAN).]

The majority of air emissions from energy result from the use of fossil fuels. The transport sector is the main source of CO and NO_x emissions, and consequent peaks in localised ozone concentrations (see Table A.2). The power sector is the dominant source of SO_x emissions, followed by stationary energy use in the industrial sector - which are also the sectors where coal use is highest. Emissions of particulate matter from fossil fuel combustion is also significant, but is declining rapidly under strict regulations and the introduction of more effective control technology.

Table A.2. **Contribution of energy use to air pollutants, mid 1990s**
(percentage of total emissions in OECD countries deriving from energy use)

	Transport	Electricity Production	Other Combustion (industry and residential)	Other
Air Pollutant				
SO _x	4%	23%	71%	2%
NO _x	52%	28%	16%	4%
CO	85%	2%	13%	0%
Particulates	17%	12%	26%	45%

Source: (OECD, 1999f).

Excessive concentrations of these pollutants have demonstrated health, welfare and ecological effects as well as nuisance effects (e.g. odours, decreased visibility), which are usually felt locally and sometimes regionally. VOC and NO_x are responsible for photochemical smog. In some cases, local and remote rural situations can also be influenced predominantly by up-wind emissions sources and long-range transport of air pollutants can be significant.

Air pollutants, as well as precursors of photochemical oxidants, are emitted from a variety of stationary and mobile fuel combustion sources; energy-related activities contribute significant quantities of all of the pollutants cited. For instance, stationary combustion facilities are a major source of SO₂ and NO_x emissions. Mobile sources (transport vehicles) account for most CO emissions in OECD countries.

Unlike SO₂ or NO_x, which are mainly related to combustion, and comprise only a few compounds, VOC are generated by a variety of sources, and comprise a large number of compounds with very different toxicities, reactivities, emission rates, etc. In terms of anthropogenic non-methane VOC, the transport sector is, (in Europe at least), the second largest source, after the solvent industry.

Emissions from transportation activities are a growing problem. This is the case in particular for the health threat presented by the respirability of particulates from heavy duty diesel engines and their presence near the ground in heavily populated areas. In addition, it now appears that those particulates not entirely removed by the efficient control technologies used for large combustion facilities are the smallest and are highly respirable as a result. They also offer a large surface area for fixing toxic substances, hence causing renewed concern about all sources of PM emissions.

Worries about air pollutants found indoors and which may affect human health are also growing, particularly in the case of radon but also of formaldehyde, CO, NO_x, PM and VOC. Both energy use and improved energy efficiency play an important role in indoor air quality. Some building energy efficiency measures tend to reduce the rate of air exchange and have resulted in increased concentrations of the pollutants involved. More sophisticated ventilation processes can remedy these problems.

Hazardous air pollution

Hazardous air pollutants are usually emitted in smaller (often locally concentrated) quantities than those that are the focus of ambient air quality concerns, though the definition of hazardous or toxic air pollutants varies. For instance, the long-range transport of certain hazardous air pollutants is a topic of increasing concern particularly in Scandinavian countries. Lead pollution from vehicles has been an ongoing problem for many years and its health effects are well documented. Organic compounds, and among them hydrocarbons, have long been considered traditional air pollutants because of the role they

plan in photochemical oxidant formation. More recent studies have shown that some organic compounds have adverse effects on human health.

For some hazardous air pollutants, dose-response relationships are only now being demonstrated for suspected health effects. Often complete data are lacking, however, the number of suspected hazardous pollutants is very large and knowledge of sources, emissions and effects is still developing. Toxic micro-pollutants, such as cadmium, lead and possibly PAH and mercury, can be transported over long distances and the effects are localised. A major potential difficulty with the control of some of these is that no threshold concentration has been clearly agreed as acceptable by the health community.

Several energy-related activities emit hazardous air pollutants:

- hydrocarbons, such as benzene, emitted fugitively from oil and gas extraction and processing industries.
- the use and combustion of petrol and diesel oil for transport causes emissions of hydrocarbons (including polycyclic aromatics or PAH) and dioxin and are a major source of energy-related toxic air pollutants like lead.
- small quantities of arsenic, mercury, beryllium and radionuclides can be released during the combustion of coal and heavy fuel oil in power plants and industrial boilers. These substances are trace constituents of coal and heavy fuel oil that become airborne during combustion;
- mercury, chlorinated dioxin, furan and other emissions from municipal waste incinerators are causing increasing concern. Whether they present a serious risk to public health is proving to be difficult to assess.

Acid deposition

Acid deposition has been found to be mainly related to emissions of SO₂ and NO_x. These pollutants have caused only local concern in the past, largely for health reasons. However, as awareness of their contribution to the regional and transboundary problem of acid rain has grown, concern is now also focusing on other substances such as VOC, chlorides, ozone and trace metals which probably participate in the complex set of chemical transformations in the atmosphere that result in acid deposition and the formation of other regional air pollutants. There are still uncertainties about the precise relationship between emissions and observed damage as well as levels of damage, though acid deposition is considered to have a wide range of environmental effects. Further effects can be spread over large areas due to the long distance transport of the pollutants involved. The most commonly cited effects include:

- acidification of lakes, streams and groundwater resulting in damage to fish and other aquatic life;
- damage to forests and sometimes to agricultural crops; and
- deterioration of man-made materials such as buildings, metal structures and fabrics.
- energy related activities are major sources of the main identified precursors of acid deposition:

- electric power stations, residential heating and industrial energy use account for 80% of SO₂ emissions, with coal alone producing about 70%. Other sources include sour gas treatment which produces H₂S which then reacts to form SO₂ when exposed to air;
- road transport is an important source of NO_x emissions: 48% of total emissions in OECD countries. Most of the remainder is due to fossil fuel combustion in stationary sources;
- as mentioned in the context of the ambient air quality discussion, VOC are generated by a variety of sources and comprise a large number of very diverse compounds.

Stratospheric ozone depletion

A global environmental problem is the distortion and regional depletion of the stratospheric ozone layer caused by chlorofluorocarbons (CFC), halons and N₂O emissions. Ozone depletion can lead to increased levels of damaging ultraviolet radiation which could cause a rise in skin cancer, eye damage and be harmful to many biological species.

Energy activities are only partially (directly or indirectly) responsible for these emissions. Though energy activities (fossil fuel and biomass combustion) are responsible for 65 to 75% of anthropogenic N₂O emissions, CFCs play by far the most important role in ozone depletion. The main energy-related sources are CFC used as refrigerants in transport and building air-conditioning and refrigeration equipment, or as blowing agents in foam insulation. These applications account for about 60% of CFC use.

Water pollution

A significant portion of the water abstracted in many OECD countries is used for cooling in electrical power generation, and the share of water used for this purpose has increased dramatically in recent years. While this water is generally returned to the source, it often has a higher temperature than when it was abstracted, and a lower oxygen level. This thermal pollution of waterways can lead to oxygen depletion in freshwater ecosystems. Thermal pollution is regulated in most OECD countries, usually through siting permits. Pollution of water and soil from energy use also occurs directly through leaking oil tanks and indirectly through acidic deposition caused by air emissions of NO_x and SO_x (predominantly produced from fuel combustion as discussed above). This has led to severe effects on lakes and rivers and on forests in some regions, with damage to freshwater fish, other fauna, and habitats.

In the area of groundwater pollution, there is still a considerable and widespread lack of information and associated uncertainty about the level of pollution and the identification of energy-related sources. A severe source of groundwater pollution in many countries is oil leaks from underground storage tanks. Waste disposal is a growing source of groundwater pollution. Concern that efforts to control air pollution might result in increased water and soil pollution is emerging as air pollution practices producing wastes such as FGD sludge, become more widespread.

Maritime pollution

Much concern has centred on maritime pollution resulting from large accidental oil spills. However, the main source of marine-based pollution remains shipping operations. It is estimated that one tonne is discharged for every 1 000 tonnes of oil transported by sea. If so, 1.1 million tonnes per annum

are the result of regular discharge of oil by ships at sea. The remainder, about 400 000 tonnes, is due to tanker accidents.

Spills can have serious impact in bays, estuaries or land-locked seas such as the Gulf of Mexico or the North Sea where coastal waters are important for fishing, tourism or industry. No comprehensive assessment has been made of the damage to marine ecosystems as a whole.

Land degradation

Land use pressure exerted by economic activities gives rise to concerns that land particularly suited for sustaining agriculture, housing or natural ecosystems could be lost. In the energy sector, mining sites (including land over existing underground mines where subsidence can take place) and hydroelectric reservoirs have attracted the most attention. Concern has also been voiced about the large land surfaces that might be needed for the large-scale exploitation of renewable energy forms such as wind power, solar power stations or biomass production (wood, peat, straw or sugar cane) which would compete with other land uses.

Other energy-related activities involving large facilities or complex industrial processes, such as fuel refining or electric power generation, are subject to, *inter alia*, environmental concerns about siting sometimes in addition to land-use concerns. In many cases, opposition to siting specific projects (the so-called “Not In My Backyard” or “NIMBY” syndrome) stems from a combination of concerns about land use, pollution and accidents, which are not easily separated and evaluated. In addition to energy activities which traditionally have run into siting difficulties such as power stations or refineries, growing siting problems are occurring for the disposal of solid wastes ranging from those generated in pollution control operations to high-level radioactive waste containing long-lived radionuclides.

Obviously, all energy-related activities have some sort of siting impact and levels of acceptability are evolving constantly. For instance, there is disagreement about the effects of the electromagnetic fields associated with transmission voltages up to 800 kV on humans and animals. Though evidence of such negative effects is scant, the outlook for utilities (particularly in North America) planning major new transmission projects is not bright. Another emerging concern which is difficult to assess is visual air quality such as plume and haze conditions in national parks and other scenic areas. Measuring visibility, identifying contributors to haze visibility and designing remedial measures is proving to be a difficult task.

Natural resource depletion

Fossil fuels are essentially non-renewable resources: as they are depleted they need to be substituted by other, more abundant or renewable, resources. Over the period to 2020, however, it is unlikely that constraints on fossil fuel resources will play a significant role in energy supply. The IEA’s World Energy Outlook 2000 projects that the world oil-resource base is adequate to meet demand over the projected period to 2020, but assumes a steady price rise to US\$ 28/barrel in 2020 to enable capital investments. Reserves of natural gas are estimated at 1.9 trillion barrels of oil equivalent, and although world demand for gas is growing faster than for oil, serious supply shortages are not expected until after 2020. World coal production is expected to match demand much beyond 2020, with any local supply deficiencies covered through the international market.

The environmental impacts of coal extraction include land degradation (and consequent changes in habitats) from open-cast coal mining and leaching of mine drainage water containing dissolved/suspended solids and acids into nearby waterways. Oil extraction and transport, particularly off-shore extraction, can result in spills and leaks, and gas and oil production results in emissions of CO₂

and CH₄. Coal mining is also a major source of CH₄. Uranium mining generates radon gas, dust, and contaminated rainwater streams, as well as mining waste which forms the bulk (in volume) of waste associated with nuclear power production. Large hydropower dams have a substantial impact on water flow, although effects on marine life are often reduced through minimum water flow regulations. Dams can also have potentially significant localised effects on bird life and flora/fauna through the flooding of land. Recent studies indicate that dams lead to significant releases of CH₄ from accelerated degradation of organic matter in flooded areas. Visual and noise pollution, together with bird kill, are frequently cited as negative environmental impacts of wind power. However, the negative environmental impacts of small-scale renewable electricity generation are generally limited (and site-specific).

Radiation hazards

Nuclear waste carries unique risks in relation to its transport and disposal, as it can remain highly radioactive for hundreds of years. Furthermore, there is a threat of accidental releases of radioactive material from nuclear power generation facilities. While many OECD countries have agreed that isolation of nuclear waste in stable geological structures is the most appropriate option, implementation of this policy has been slow for political reasons. In addition, there is no consensus on whether waste disposed in such a manner should be retrievable - in case another method of storage is subsequently preferred - or irretrievable, so as to minimise the risk that the storage facility could turn into an illegal source of nuclear materials..

Approximately 90% of exposure to radiation is due to natural causes. Nevertheless, supplementary man-made radiation causes considerable concern. Energy Activities contribute about 25% to total man-made radioactivity (i.e. about 2% of total exposure to radiation). Though fossil fuel combustion releases radionuclides, ongoing debate about man-made energy-related radiation focuses mainly on the nuclear fuel cycle and its various stages.

Normal reactor operation produces low-level radioactive emissions which are not considered to be harmful. Potential risk of a failure and the environmental effects of an accidental leak remain the major area of concern, though much has been done to demonstrate that safety in operation has been and will in the future be maintained and further improved. This issue has evolved over the last decade and now extends beyond the issue of reactor safety and accident prevention to include problems such as emergency planning and decommissioning. It has also taken on a more explicitly international dimension with heightened public and political awareness of the transboundary risks of accidents involving nuclear facilities.

Nuclear waste disposal involves varying degrees of hazards depending on the characteristics of the wastes and whether or not they are released into the environment or isolated from the biosphere. There are large differences in the perceived potential for damage and the corresponding level of concern about low-level waste containing short-lived radionuclides which need to be isolated for thousands of years.

Decommissioning of nuclear facilities has so far mainly concerned research reactors. According to current forecasts, only 61 commercial nuclear reactors will be decommissioned by the end of the century in Western Europe and North America. By 2030, this number should rise to 404. In the meantime, the environmental problems posed by the decommissioning of nuclear plants are still being identified. There is increasing worry that the risk of exposure to radiation would be high throughout the dismantling of the components, especially the reactor vessel.

Solid waste accumulation

Both coal mining and the combustion of coal generate significant quantities of solid waste (slag and ashes), which may cause pollution and reduce visual amenities. The amount of waste produced per tonne of coal mined or combusted will vary from site to site, depending on the chemical characteristics of the coal seam. Coal cleaning also results in emissions of particulates to air, and in emissions of “black water” (with suspended particulates).

Solid waste disposal can pose environmental problems of two types. First, if the waste is classified as hazardous, that is considered to be a potential health or environment threat (definitions of the term hazardous vary widely), it might release hazardous pollutants and result in air, water and soil pollution, which constitute major issues in themselves. Most of the solid waste considered hazardous is generated by the chemicals and metal industries. Energy-related activities accounted for about 12% of this waste in the United States in 1983. Secondly, though the waste may not be considered hazardous, it can still pose disposal problems merely for a question of space and appropriate containment. Solid wastes from energy activities include, for instance, bottom ash from power plants which is usually not hazardous.

A major and growing source of waste has developed along with air pollution control itself. Sludge from FGD devices and collected fly ash from particulate control devices contains trace elements such as arsenic, lead, cadmium, selenium as well as radionuclides, though the concentrations are so low that the waste usually is not classified as hazardous. This is the case of a number of energy-related solid waste types, as new techniques, such as FBC, produce waste that has not as yet been studied precisely. Quantities of scrubber sludge and fly ash produced are projected to grow dramatically over the next decades. In the United States, the majority of wet scrubber systems are designed to produce a waste requiring disposal. In Japan and Europe, limestone/gypsum systems are more widely used and are the fastest growing systems. The commercial use of wastes from pollution control as products for the building industry and transportation surfaces is limited by the size of the market. Accumulating over time, they might require large tracts of land for disposal with adequate containment practices to avoid water contamination.

Major environmental accidents

There is widespread and increasing public awareness about the risks posed by industrial activities. Some of the most important energy-related areas of perceived risk and/or actual accidents are listed below:

- on-shore and off-shore blow-outs, explosions and fires due to the production, treatment, transport and use of oil and gas, such as fires at refineries, oil rigs, gas storage tanks, explosions of pipelines, etc.;
- maritime pollution due to oil tanker accidents, as well as soil and water pollution due to spills from rail and road tankers;
- radioactive releases resulting from nuclear accidents in the course of the production of nuclear energy or the transport, treatment or storage of radioactive materials (fuel or waste);
- hydroelectric dam failures causing flooding and landslides;
- land subsidence and landslides due to mining activities as well as explosions in mines;
- spontaneous combustion of stored coal or spoil dumps as well as explosions due to methane build-up in refuse dumps and coal mines.

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