



INTERNATIONAL ENERGY AGENCY

**From
oil crisis
to climate
challenge**

**UNDERSTANDING
CO₂ EMISSION TRENDS
IN IEA COUNTRIES**

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IN IEA COUNTRIES**

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The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-six* of the OECD's thirty Member countries. The basic aims of the IEA are:

- to maintain and improve systems for coping with oil supply disruptions;
- to promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations;
- to operate a permanent information system on the international oil market;
- to improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- to assist in the integration of environmental and energy policies.

* IEA Member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, the Republic of Korea, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States. The European Commission also takes part in the work of the IEA.

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

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

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Introduction

OECD CO₂ emissions from fuel combustion increased 13% between 1990 and 2001. This signals an important shift since, over the 1973 to 1990 period, emissions only increased by 3.4%. As a result, CO₂ emissions from energy use (fuel combustion) contributed 81.1% of total OECD greenhouse gas emissions in 2001 compared to 77.7% in 1990.

As these figures make clear, reducing CO₂ emissions from fuel combustion constitutes a key challenge to combat climate change. Developing and successfully implementing the most efficient policies for reducing CO₂ emissions requires a good understanding of how factors such as income, prices, demography, economic structure, lifestyle, climate, energy efficiency and fuel mix affect energy use and resulting CO₂ emissions.

This paper presents selected results from the analysis of CO₂ developments included in the forthcoming IEA publication *From Oil Crisis to Climate Challenge: 30 Years of Energy Use in IEA Countries*. The paper gives a brief overview of aggregate CO₂ emission trends and of how recent developments in selected IEA countries compare to emissions levels implied by the Kyoto targets. A deeper understanding of the aggregate trends is provided by showing results from a decomposition analysis and by discussing developments in key end-use sectors.

The full publication presents a more detailed analysis of how various factors have shaped energy use patterns and CO₂ emissions since 1973. The analysis draws on a newly developed database with detailed information on energy use in the manufacturing, household, service and transport sectors. The database represents the most disaggregated information available on a consistent basis across countries and sectors. The study uses quantitative measures to illustrate the forces that drive or restrain energy use. These measures – or indicators – include: *activities* such as manufacturing output or heated-floor-area of homes; *structural* developments such as changes in manufacturing output mix or changes in the mix of transport modes; and energy *intensities* for sub-sectors and end-uses. Energy intensity is defined as energy per unit activity, representing the energy used to produce some output or provide a service. At a disaggregated level, changes in this indicator are closely related to changes in energy efficiency.

The decomposition approach used in the IEA study disentangles the impacts that changes in activity, structure, and energy intensities have on total energy use in each sector. For example, the analysis reveals that in some countries changes in manufacturing structure (the mix of goods produced) have been as important as changes in energy intensities in determining manufacturing energy use developments. The decomposition approach is also used to explain trends in CO₂ emissions. In this case, the energy decomposition is expanded with factors representing changes in fuel mix. To analyse trends at an economy-wide level, the results of the sector decomposition are re-aggregated into measures that represent the impact each component has had on changes in a country's total energy use and CO₂ emissions.

Highlights

- CO₂ emissions per unit of GDP vary widely among IEA countries. These variations are due to many factors, including differences in: the mix of fuels used at the end-use level and for electricity generation; industry structure; climate and geography, demographics; lifestyles; and energy intensities in sub-sectors and end-uses.
- A group of eleven IEA countries (IEA-11)¹ all experienced significant reductions in CO₂ emissions per unit of GDP between 1973 and 1990. After 1990, however, only a few continued to exhibit significant decoupling of CO₂ emissions from economic growth. While total IEA-11 CO₂ emissions in 1990 were only marginally higher than in 1973, they increased 12% between 1990 and 2001, a development that is in stark contrast to what is implied by the Kyoto targets.
- The lower rate of emission reduction relative to GDP after 1990 indicates that the changes caused by the oil price shocks in the 1970s and the resulting energy policies did more to reduce CO₂ emissions than the energy efficiency and climate policies in the 1990s have done. Two main reasons can explain this development:
- First is that switching to less carbon-intensive fuels contributed less to overall CO₂ emission reductions in most countries after 1990 than in previous periods. Increasing fossil fuel prices after 1973 led some countries to push for nuclear as an alternative for oil in electricity generation, and natural gas made in-roads as a substitute for oil in many stationary end-use applications, both helping to bring down the CO₂ intensities of the IEA-11 economies. After 1990, the nuclear expansion stagnated. While natural gas was increasingly used in electricity generation in many countries, coal still maintained its prominent role in IEA-11 electricity generation throughout the 1990s with the result that the decline in emissions per kWh was less after 1990 than before.
- The second and most important reason for the recent slow-down of the decline in CO₂ emissions relative to GDP is that the rates of energy intensity reductions in most sectors have slowed considerably. This is a uniform trend among the IEA-11 countries. Before 1973 energy prices were generally low, so when the price hikes kicked in after 1973 there was ample room for improving energy efficiency as a response. As energy prices fell in the last half of the 1980s while income levels kept accelerating, energy costs became a less of a concern and the rates of energy savings slowed.
- There are a number of other factors that have affected CO₂ emissions trends. In the manufacturing sector, the higher energy prices induced structural changes that reduced the overall energy intensity of most IEA economies. Yet, in a few countries where inexpensive domestic energy resources were available, increased production of raw materials injected an upward force on emissions. While the effect of structural changes generally slowed throughout the 1980s and into the early 1990s, the most recent trends show that in some countries the manufacturing mix again is moving towards less energy-intensive products as the manufacturing of products like electronics and information technology grows more rapidly than production of raw materials.

1. IEA-11 denotes Australia, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, the United Kingdom and the United States. These are the countries for which the IEA has consistent time series with detailed energy and activity data going back to 1973. These countries together accounted for more than 80% of IEA CO₂ emissions in 2001.

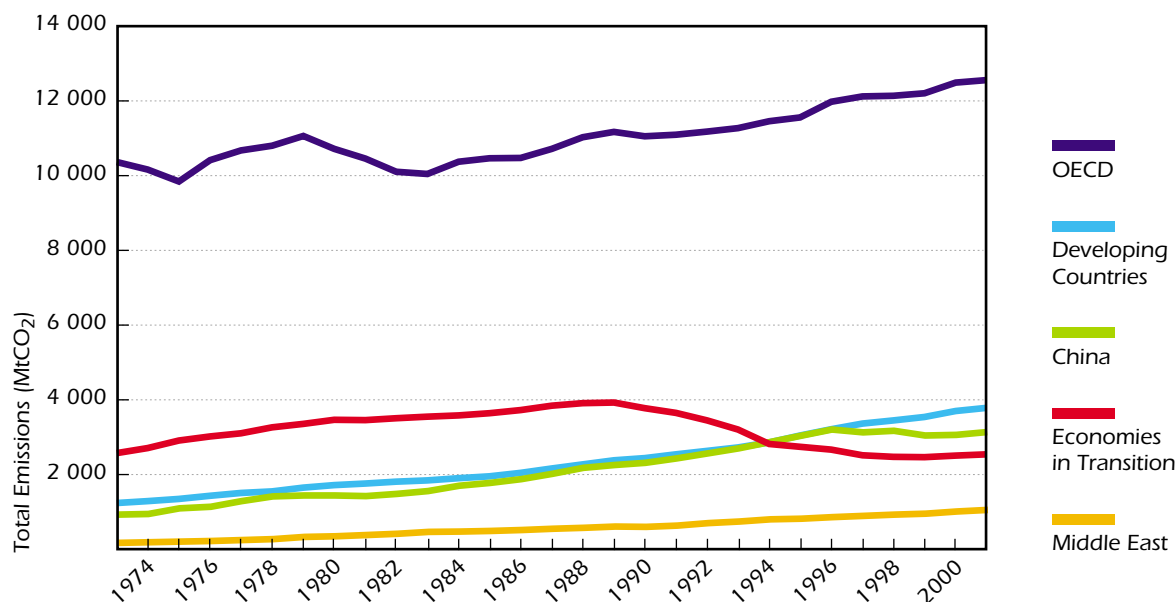
- On the consumer side of the economy there have been other forces at work in addition to prices. Technological, demographic and lifestyles changes combined with higher incomes have significantly altered energy use patterns the last three decades. For example, the increased availability and the reduced cost of electric appliances have boosted electricity demand. In countries where electricity generation is primarily based on hydro or nuclear this helped bring down CO₂ emissions relative to GDP. This had the opposite effect in countries where fossil fuel-based generation is predominant. Another example is that the consumer preference for larger, heavier and more powerful cars has offset most of the savings from significantly improved engine, transmission and aerodynamic efficiencies. This tendency has accelerated during the 1990s as minivans and sport-utility vehicles have captured larger shares of the car market. Similarly, the trend towards fewer persons per dwelling and larger dwelling sizes have increased heating, air conditioning and lighting needs per capita, offsetting some of the savings achieved from reduced energy intensities of these end-uses.
- The forthcoming IEA publication *From Oil Crisis to Climate Challenge: 30 Years of Energy Use in IEA Countries* provides a detailed review of how these and other forces have shaped energy demand and CO₂ emissions since 1973.

Global CO₂ Emissions from Fuel Combustion

Global CO₂ emissions continue to increase

Figure 1

CO₂ Emissions by Region



Global CO₂ emissions from fossil fuel combustion increased from 20.7 billion tonnes (Gt) in 1990 to 23.7 Gt in 2001, a 14.6% rise, albeit with significant variations among regions.

The OECD countries account for the overwhelming majority of total CO₂ emissions. The trend shows dips in emission levels corresponding to the mid-1970s oil price shock and economic slowdown in the early 1980s with a rather steady increase since then. However, trends within the OECD group of countries vary considerably.

China is the world's second-largest CO₂ emitter after the United States. Emissions in China reached their peak in 1996 and then decreased slightly to 2000. Emissions in 2001 were up in association with an escalation in GDP. China's ratio of CO₂ emissions to GDP has shown an impressive decline.

In developing countries as a group, CO₂ emissions have increased rapidly since the mid-1980s as total primary energy supply (TPES) and GDP have grown. The link between energy use and CO₂ emissions remains strong in most developing countries because of the predominance of fossil fuels in the commercial energy supply.

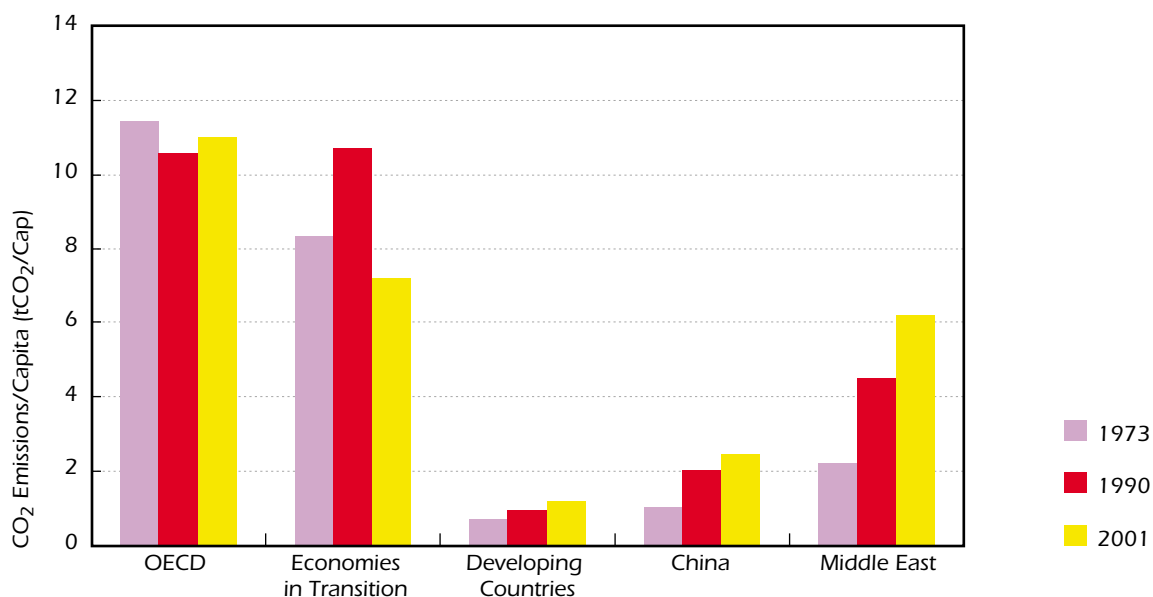
The sharp downturn in CO₂ emissions in the Economies in Transition countries (EITs) reflects the collapse of the formerly centrally-planned economies of Central and Eastern Europe. Emission levels have increased slightly in the last two years, but remain some 30% below 1990 levels.

Global CO₂ Emissions per Capita

OECD countries emit about three times as much CO₂ per capita as the world average

Figure 2

CO₂ Emissions per Capita 1973, 1990 and 2001



Historically, CO₂ emissions have come overwhelmingly from industrialised countries, but the growth trend has been shifting. However, on a per capita basis the ratio is still disproportionate: OECD countries emit almost three times as much CO₂ as the world average and about six times more than in developing countries. The main factors explaining these differences are the relative wealth of countries, types of economic development, climate, natural resource endowments and population growth.

As a driving factor, population growth is, and is expected to remain, much higher in developing countries than in OECD countries. For example, the OECD population increased by 9% between 1990 and 2001, while the population rose 22% in Asia, and 30% in the Middle East and in Africa. Along with economic development, population growth will continue to put upward pressure on the demand for energy services in the foreseeable future. This will have implications for CO₂ emissions.

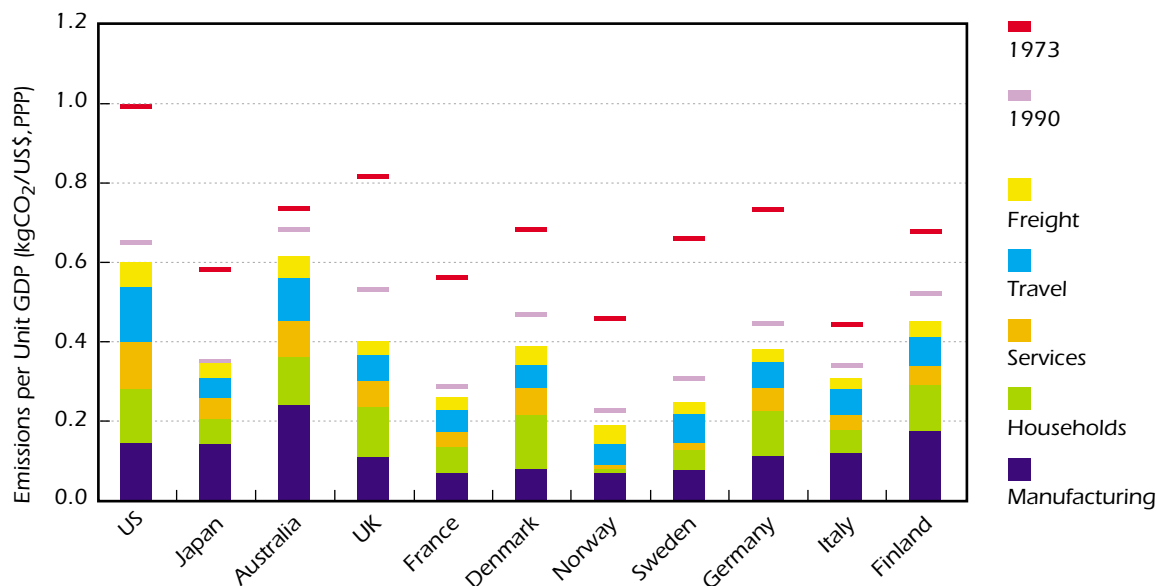
The relative levels of CO₂ emissions for these five groupings has not changed much if viewed from 1973 to where they were in 2001 except for the EITs, China and the Middle East. In the EITs the dramatic decline in CO₂ emissions through the 1990s reflects economic restructuring and an almost 3% population decline. China, on the other hand, experienced enormous GDP growth (174%) and a 12.1% surge in population. Increased oil and gas production in the Middle East led to increased emissions in this region.

CO₂ Emissions per GDP and Sector

Emission levels per GDP vary considerably among IEA countries

Figure 3

CO₂ Emissions per GDP and Sector, 1998*



* Emissions from electricity and district heat are allocated to end-use sectors using average yearly CO₂ emission coefficients for electricity and district heat, respectively. This approach is used throughout this paper.

CO₂ emissions per unit of GDP varied by more than a factor of three across the countries shown in Figure 3, with most of the differences being in the stationary sectors (manufacturing, households and services). This indicates that the fuel mix, especially for electricity generation, is an important determinant. For example, Norway's hydro-based electricity supply has almost no CO₂ emissions. Since Norway also has a very high share of electricity in the final fuel mix it is not surprising that emission levels per GDP from the stationary sectors are low, despite a very energy-intensive manufacturing structure and a cold climate. In other countries where hydro and/or nuclear dominate electricity generation, such as France and Sweden, emissions are also low from the stationary sectors.

Australia, at the other extreme, has both high emissions from its largely coal-based electricity production and an energy-intensive industry structure. These conditions combined with a high share of coal in the manufacturing fuel mix explain why manufacturing production in Australia is the most CO₂ intensive among the IEA-11. While the high share of low carbon electricity in the Norwegian space heating results in almost no emissions from buildings, Finland, which also has a very cold climate, has among the highest buildings emissions. The United Kingdom, Germany and Denmark also have relatively high building sector emissions, but for these it is the significant share of coal in the electricity mix rather than cold climate that is the key explanation.

The passenger and freight transport sectors are almost entirely based on oil products and the more modest variations in CO₂ emissions per GDP levels reflect differences in transport distances per unit of GDP, energy intensities and, to a minor degree, differences in the mix of transport modes.

All countries in the figure had significantly higher emission levels per GDP in 1973 than in 1998. However, after 1990 only a few continued to see a significant decoupling of CO₂ emissions and GDP.

Kyoto Targets and Trends in CO₂ Emissions

CO₂ emissions have been on the rise in most countries since 1990

Table 1

Changes in CO₂ Emissions from Fuel Combustion and Kyoto Targets*

	1990 emissions = 100				Average % Change/year			
	1973	1998	2001	Target** 2010	1973- 1990	1990- 1998	1998- 2001	2001- 2010***
Australia**	61	123	142	[108]	3.0	2.6	5.1	[-3.0]
Denmark	112	114	100	94	-0.7	1.6	-4.2	-0.7
Finland	88	104	110	100	0.8	0.5	1.6	-1.0
France	139	109	109	100	-1.9	1.1	0.0	-1.0
Germany	110	90	88	79	-0.5	-1.4	-0.6	-1.2
Italy	84	106	106	93.5	1.1	0.7	0.1	-1.4
Japan	87	108	111	94	0.8	1.0	0.9	-1.8
Norway	85	131	133	101	1.0	3.4	0.5	-3.0
Sweden	166	104	94	104	-2.9	0.5	-3.4	1.1
UK	114	95	97	87.5	-0.8	-0.7	0.6	-1.1
US**	97	114	118	[94]	0.2	1.6	1.1	[-2.5]
EU-7****	111	98	97	87.7	-0.6	-0.3	-0.2	-1.1
IEA-11	99	109	112	92.7	0.1	1.1	0.9	-2.1
EU	106	102	103	92	-0.3	0.2	0.5	-1.3
IEA	98	110	113		0.1	1.2	1.1	

*The targets reflect each country's Kyoto target, with EU-burden sharing targets used for EU countries. Regional targets are based on weighted national targets. The Kyoto targets apply to a basket of six greenhouse gases and take sinks into account. The Protocol provides for the use of "flexibility mechanisms" with emission reduction credits that count towards meeting the target.

**Australia and the United States have announced that they do not intend to ratify the Kyoto protocol.

*** Annual percentage reduction needed to get CO₂ emissions in line with targets by 2010.

**** EU-7 includes the European Union countries: Denmark, Finland, France, Germany, Italy, Sweden and the United Kingdom.

Table 1 lists CO₂ emissions relative to 1990 levels and average annual percentage change in emissions over three historical periods for the IEA-11 countries, the European Union (EU) and IEA totals. It also shows Kyoto targets and the annual percentage reductions in emissions that are needed to achieve the targets.

Between 1973 and 1990, CO₂ emissions declined or grew only modestly in most countries. In the IEA as a whole, CO₂ emissions in 1973 were just under 1990 levels and EU emissions fell slightly over this period. After 1990 the results are more mixed. Emissions declined only in a few countries between 1990 and 2001 and many countries saw emissions increase significantly. The most recent developments (1998 to 2001) do not indicate any acceleration of emission reductions even though by 1998 many countries had implemented policies to lower emissions. In fact, in the EU the annual growth in emissions between 1998 and 2001 was stronger than over the previous eight years. In part this reflects the downward push EU emissions got in the early 1990s as a result of the German reunification and the considerable fuel switching from coal to gas in the UK electricity sector. In Japan and the United States, the annual growth in emissions since 1998 was a little lower than the average for the 1990-1998 period, while it was significantly higher in Australia.

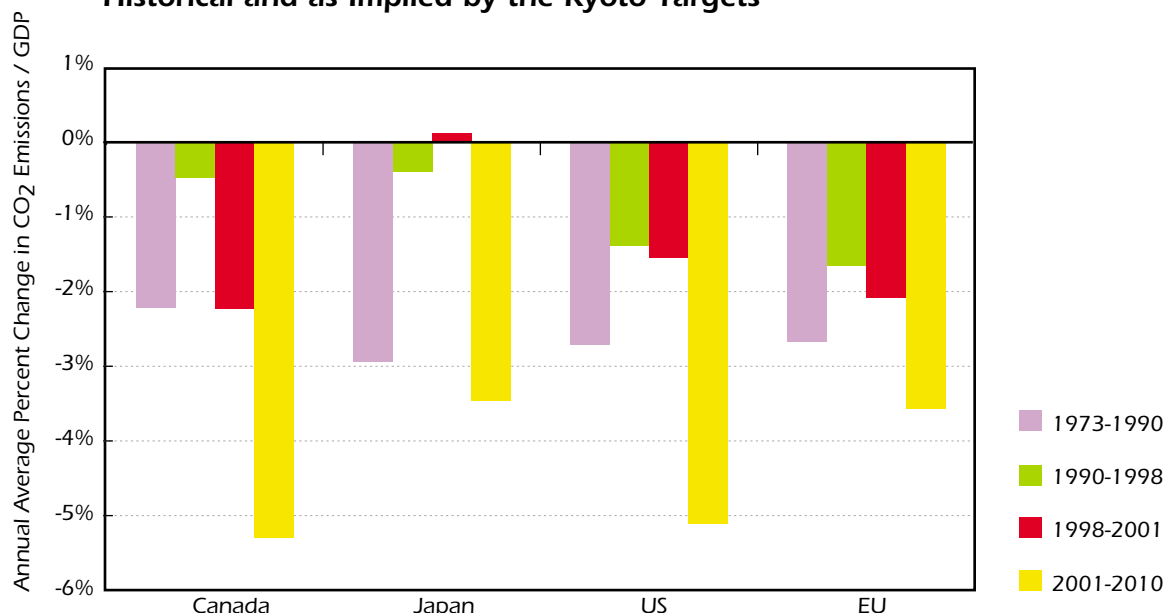
The developments during the 1990s paint a gloomy picture of the prospects of reducing CO₂ emissions to the levels called for by the Kyoto targets by 2010. With few exceptions, emissions will have to be reduced at significantly higher rates than have been seen in previous periods.

CO₂ Emissions/GDP and Kyoto Targets

Slowdown in the decline of CO₂ emissions per GDP since 1990 is in stark contrast to the reductions implied by the Kyoto targets

Figure 4

Average Annual Change in CO₂ Emissions per GDP, Historical and as Implied by the Kyoto Targets



Economic growth is the primary driver behind increases in energy-related CO₂ emissions. Figure 4 shows that CO₂ emissions fell considerably relative to GDP in Canada, Japan, the United States and within the EU before 1990. Between 1990 and 1998, however, the rate of decline slowed significantly, especially in Japan and Canada. This can be explained at least partly by lower overall economic growth as most countries experienced recession in the early 1990s. The most recent trends show that Canadian emissions are again falling strongly relative to GDP and that the rates of decline in the EU and the United States have picked up a little since the previous period. In Japan, however, CO₂ emissions per GDP actually increased between 1998 and 2001, although only very marginally.

The figure also illustrates what the annual average decline in CO₂ emissions per GDP would need to be if each country's Kyoto targets are to be met.² In all cases, CO₂ emissions will need to be decoupled at a much stronger pace than what is indicated by recent trends.

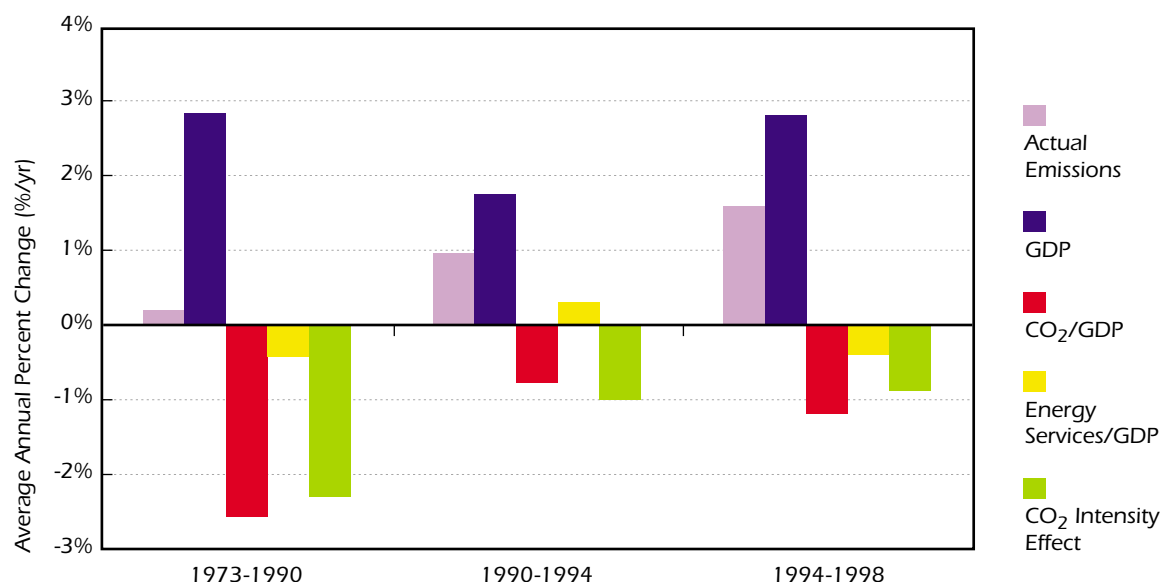
2. The GDP development between 2001 and 2010 are based on assumptions made for the IEA World Energy Outlook 2002. According to these, annual GDP growth will average 2.5% in the United States and Canada, 2.3% in the EU and 1.6% in Japan between 2000 and 2010.

Decomposition of Changes in CO₂ Emissions

CO₂ emissions are increasing as rates of decline in CO₂ intensity have slowed

Figure 5

Changes in CO₂ Emissions per GDP Decomposed into Changes in Energy Services per GDP and CO₂ Intensity Effects, IEA-11



Why did the rate of decline in CO₂ emissions per GDP slow so markedly after 1990? To answer this a factorial decomposition approach is applied. This approach allows for separating impacts on energy use from changes in *activity* levels in each sector, for example tonne-km hauled in the freight sector; changes in *sectoral structure*, e.g., manufacturing industry mix; and changes in *energy intensities* of end-uses or sub-sectors, e.g., changes in energy per value-added from iron and steel production or changes in space heating energy per floor area. To analyse changes in CO₂ emissions, the decomposition is expanded with factors representing changes in the *end-use fuel mix* and changes in emissions per unit of electricity and district heat generated (the *utility CO₂ intensity*). By establishing indices for the changes in each of these components over time, they can be thought of “all else equal” indices, describing the evolution of emissions that would have taken place if all but one factor remained constant.

The indices for activity and structure developments in each sector can be combined into a measure of *energy services* demand which represents how changes in person-km travelled by cars, tonne-km by trucks, floor area of homes, appliance ownership, manufacturing output and structure, etc. affect the demand for energy services in an economy. Similarly, a measure for *CO₂ intensity* can be constructed by combining the effects of changes in CO₂ emissions per unit of electricity or district heat (utility CO₂ intensity), changes in end-use fuel mix and changes in sub-sectoral intensities have had on total emissions.

Thus changes in CO₂ emissions per GDP can be viewed as the product of changes in energy service demand per GDP and changes in CO₂ intensity. The results of this decomposition are shown in Figure 5 along with changes in actual CO₂ emissions and GDP. Between 1973 and 1990 CO₂ emissions were decoupled from economic growth at an average rate of about 2.5% per year, almost the same rate as the GDP growth rate, which resulted in only a minor increase in actual emissions. Most of the decoupling came from reductions in CO₂ intensities, although reduced demand for energy services relative to GDP also contributed.

The growth in GDP slowed over the next four years, but the decoupling of CO₂ emissions from GDP slowed even more, to only 0.8% per year, with significant increase in emissions as a net result. The low reduction in emissions per GDP can be explained by both that energy service demand grew faster than GDP in this period and by the slow rates of reduction in CO₂ intensity. After 1994 economic growth recovered, but still with a modest decline in CO₂ intensities. Even if accelerated decoupling of energy services from GDP helped to bring down CO₂ emissions per unit of GDP, this was by far not enough to offset the growth in GDP, with 1.8 % annual growth in emissions as a net result.

The slowdown in the decline of CO₂ intensities is apparent for most individual countries as well (Table 2). In all but Finland, Denmark and the United Kingdom, the intensity fell less after 1990 than in previous periods. These three countries also saw CO₂ emission per unit of GDP decline more after 1990. The latter holds for Australia as well, despite no decline in CO₂ intensity. Hence the 1.3% per year drop in Australian CO₂ emissions per unit of GDP was alone caused by a considerable decoupling of energy service demand relative to GDP.

Table 2

**Changes in CO₂ Emissions per GDP,
Energy Service per GDP and CO₂ Intensity Effect
Annual Average Percent Change**

	1973-1990			1990-1998		
	CO ₂ /GDP	Energy Services/GDP	CO ₂ Intensity	CO ₂ /GDP	Energy Services/GDP	CO ₂ Intensity
Australia	-0.5	0.2	-0.5	-1.3	-1.3	0.0
Denmark	-1.4	0.0	-1.5	-3.4	-0.7	-2.5
Finland	-1.5	0.1	-1.8	-1.8	0.6	-2.3
France	-3.9	-0.2	-3.6	-1.2	0.2	-1.3
Germany	-2.9	0.0	-3.0	-1.9	0.0	-1.9
Italy	-1.6	0.6	-3.0	-1.1	0.4	-1.4
Japan	-2.9	-0.1	-3.0	-0.2	-0.3	0.4
Norway	-4.1	-1.4	-2.8	-2.1	-1.5	-0.4
Sweden	-4.1	-0.5	-3.7	-2.7	-0.1	-2.4
UK	-2.5	-0.5	-2.1	-3.4	-1.0	-2.4
US	-2.5	-0.7	-1.9	-1.0	-0.2	-0.9
EU -7	-2.8	-0.1	-2.8	-1.5	-0.1	-1.9
IEA-11	-2.6	-0.4	-2.3	-1.0	0.0	-1.0

Factors behind Changes in CO₂ Emissions

Changes in the CO₂ intensity components since 1990 have not been enough, by far, to balance out emission increases driven by growing energy service demand

Figure 6

CO₂ Emissions Decomposed into Changes in Energy Services Demand; Utility CO₂ Intensity; End-use Fuel Mix and End-use Intensities, IEA-11

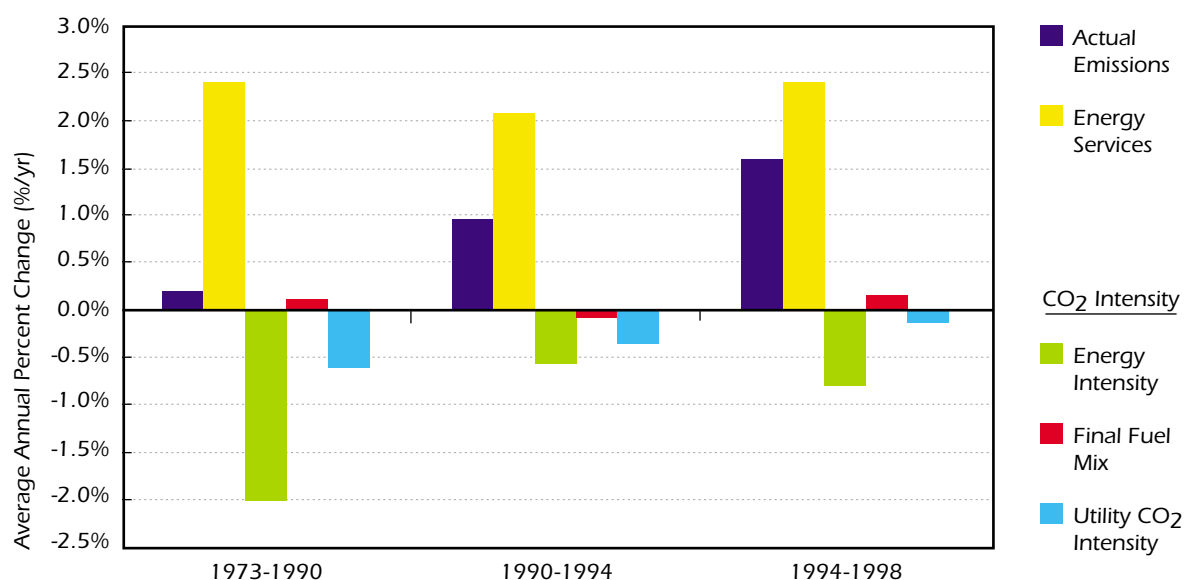


Figure 6 shows how the three components of the CO₂ intensity effect compare to the growth in energy service demand levels and how all four factors add up to changes in IEA-11 total CO₂ emissions. Increased demand for energy services has driven up emissions almost at the same rate over the three periods. Note from Figure 5 that energy services grew relative to GDP when economic growth was slow between 1990 and 1994, i.e., the variation in energy service demand between the three periods was less than the variation in GDP.

The decline in CO₂ intensity before 1990 was almost enough to offset growth in energy service demand. Roughly four-fifths of the decline in CO₂ intensity was caused by falling end-use energy intensities, with the rest being lower CO₂ emissions per unit of electricity and district heat produced in the utility sector. Changes in the end-use fuel mix had a marginal upward effect on emissions in this period, mainly due to increased use of electricity, which given the average IEA-11 electricity fuel mix is relatively CO₂ intensive.

The slowing rate of decline in CO₂ intensity after 1990 came both as a result of lower energy saving rates and more modest reductions in CO₂ co-efficients in the utility sector. In sum, the restraining forces from reductions in the CO₂ intensity components were not enough by far to hinder a considerable increase in IEA-11 emissions.

The tendency observed for the IEA-11 group is consistent to a large extent with trends in individual countries (Table 3). Growth in energy service levels drove up emissions in all countries both before and after 1990. However, the increase in energy service demand was lower after 1990 in all countries except Norway and the United States. On the other hand, the rate of decline in energy intensities slowed after 1990 in all eleven countries, although the intensity still fell between 1990 and 1998 in all but Japan, where the intensity development was severely impacted by economic recession.

The impact from changes in end-use fuel mix on CO₂ emissions was varied. In countries where the electricity fuel mix is based on fossil fuels, the increased share of electricity in stationary end-uses drove up emissions, while in countries where electricity generation is predominantly nuclear or hydro-power, the growing use of electricity reduced overall emissions. Generally, changes in end-use fuel mix have had less effect on emissions after 1990 than before.

The utility CO₂ intensity effect reduced emissions in almost all countries before 1990, reflecting increased shares of nuclear power in some and natural gas replacing coal and oil based generation in others. Also improved efficiency of fossil-fuelled plants contributed to this development. After 1990, some countries experienced less emission reductions from the utility sector, while in others the sector contributed significantly to overall lower emissions. This was especially the case in Denmark, Germany and the United Kingdom where increased use of natural gas at the expense of coal played an important role.

Table 3

**Factors Behind Changes in CO₂ Emissions
Annual Average Percent Change**

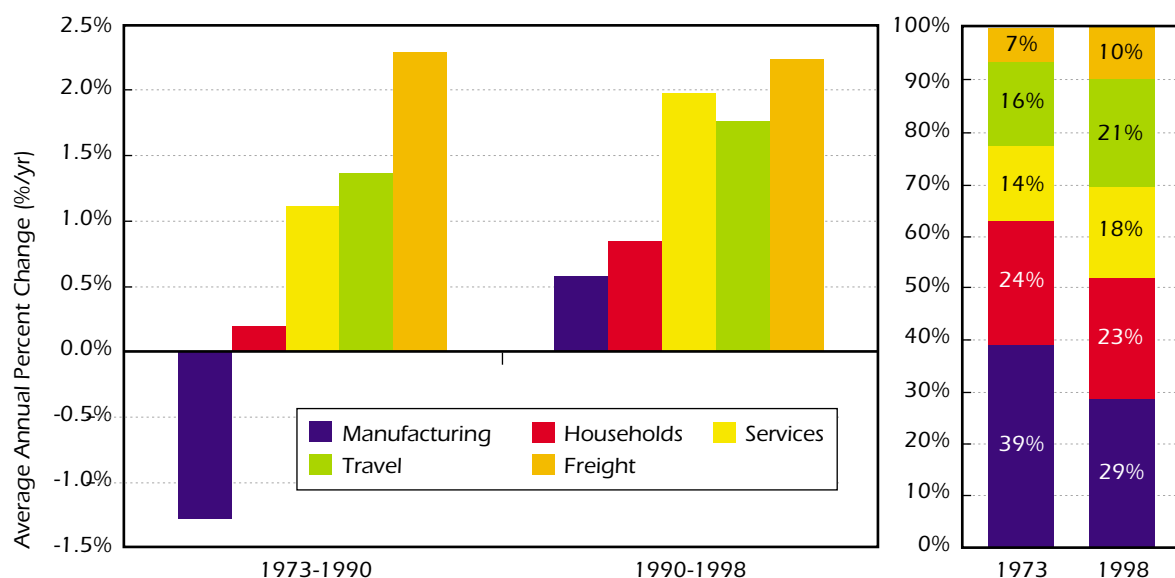
	1973-1990					1990-1998				
	Emissions	Energy Services	Energy Intensity	End-use Fuel Mix	Utility Intensity	Emissions	Energy Services	Energy Intensity	End-use Fuel Mix	Utility Intensity
Australia	2.5	3.2	-0.6	0.4	-0.4	2.4	2.4	-0.3	0.0	0.3
Denmark	0.1	1.5	-2.2	0.5	0.8	-1.2	1.5	-0.4	0.3	-2.3
Finland	1.4	3.1	-1.2	-0.4	-0.7	-0.3	2.1	-1.2	-0.6	-0.5
France	-1.4	2.4	-1.7	-0.9	-2.3	0.3	1.6	-0.7	-0.4	-0.2
Germany	-0.8	2.2	-2.2	0.1	-1.3	-0.4	1.5	-0.8	-0.4	-0.8
Italy	1.2	3.4	-3.4	0.2	0.2	0.3	1.8	-0.9	0.0	-0.5
Japan	0.8	3.7	-2.6	0.3	-1.0	1.2	1.1	0.9	0.1	-0.5
Norway	-0.9	1.9	-0.6	-2.2	0.0	1.6	2.2	-0.6	-0.2	0.0
Sweden	-2.2	1.4	-1.4	-1.9	-0.4	-1.5	1.2	-0.7	-0.2	-1.1
UK	-0.6	1.5	-1.7	0.0	-0.6	-1.3	1.2	-0.7	0.0	-1.7
US	0.4	2.2	-1.9	0.2	-0.3	2.0	2.8	-1.1	0.1	0.1
EU-7	-0.5	2.2	-2.2	-0.1	-1.0	0.1	1.5	-0.8	-0.2	-0.4
IEA-11	0.2	2.4	-2.0	0.1	-0.6	1.3	2.2	-0.7	0.0	-0.2

Changes in CO₂ Emissions by Sector

Emissions growth has accelerated since 1990 in all sectors

Figure 7

Changes in CO₂ Emissions by Sector, IEA-11 and Emission Shares by Sector



Manufacturing was the only sector where CO₂ emissions fell between 1973 and 1990. The decline was considerable, as much as 20% of 1973 emissions had been reduced by 1990, even though the manufacturing output grew by 50% over the same period. Important reasons for the reductions are a shift away from coal in the fuel mix, changes in manufacturing structure towards less energy-intensive products and lower energy intensities. Despite the emissions reductions manufacturing was in 1998 still the sector with the highest share of total IEA-11 emissions.

The household sector maintained its share of roughly 25% of total emissions between 1973 and 1998, despite a very modest growth in emissions before 1990. This development is a result of several factors partly offsetting each other: the increased use of electricity drove up households emissions in countries where the power sector is dominated by fossil fuels and helped reduce emissions in countries where hydro-power and nuclear are important; the growth in energy services demand pushed up emissions everywhere, but to a varying degree; and the decline in energy intensities helped bring down emissions in most countries, but again with great variations from country to country.

The share of service sector in total emissions has increased significantly since 1973, driven primarily by more use of electricity and strong growth in both value-added and building area. Also the share of the travel sector emissions has increased over this period. Growth in passenger travel activity and a shift towards more energy-intensive air and car travel drove up IEA-11 emissions from this sector. An even stronger growth in emissions came in the freight sector as tonne-km transported grew rapidly and trucks became the dominant mode.

After 1990, CO₂ emissions grew at a higher rate than in previous periods in all sectors, except freight where emissions kept growing at the same high average rate.

Manufacturing CO₂ Emissions per Value-Added

Emissions per output fell in all countries, although the rate of decline and absolute levels vary greatly

Figure 8

CO₂ Emissions per Total Value-added

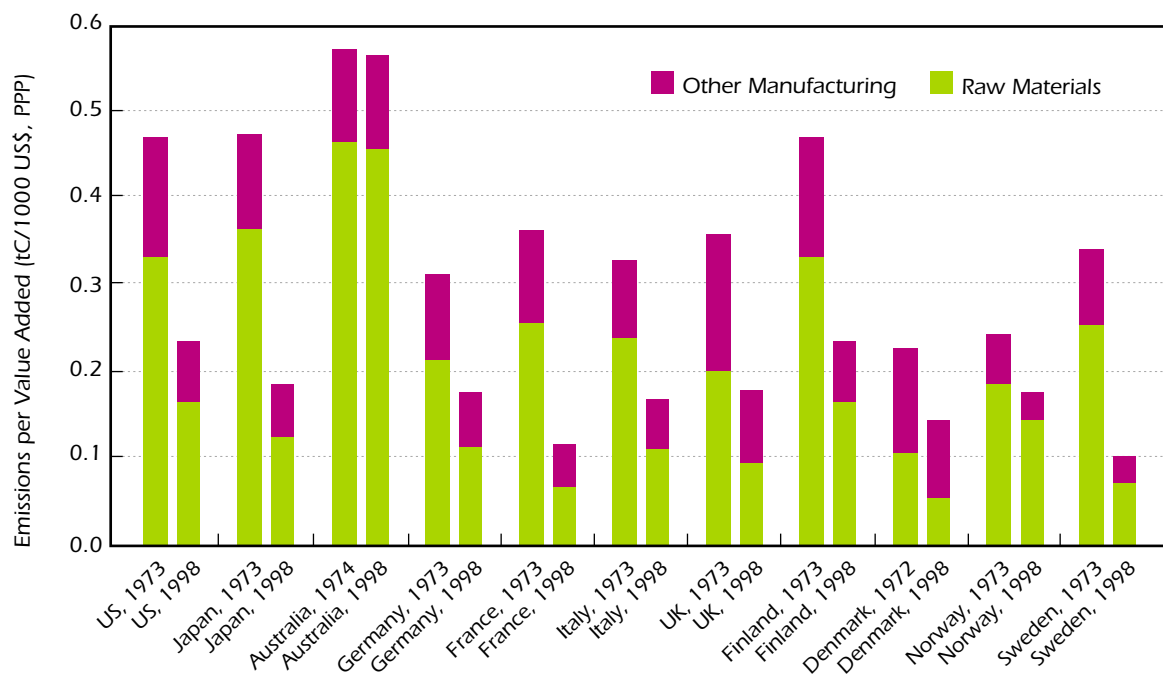


Figure 8 shows considerable variation in manufacturing sector CO₂ emission levels across countries. Interestingly, emission levels showed more variation among the extreme high and low in 1998 than in 1973. In 1973 there was a factor of 2.5 between Denmark at the low end and Australia at the high, while in 1998 this variation had increased to a factor of more than 5 between Sweden and Australia. However, while Australia's manufacturing emissions in 1973 were only somewhat higher than the United States, Japan and Finland, it was much more of an outlier in 1998 when the United States, as the country with second highest emissions among these countries, was more than 50% lower than the Australian level. In fact, outside of Australia, emissions per value-added fell by 30% or more between 1973 and 1998.

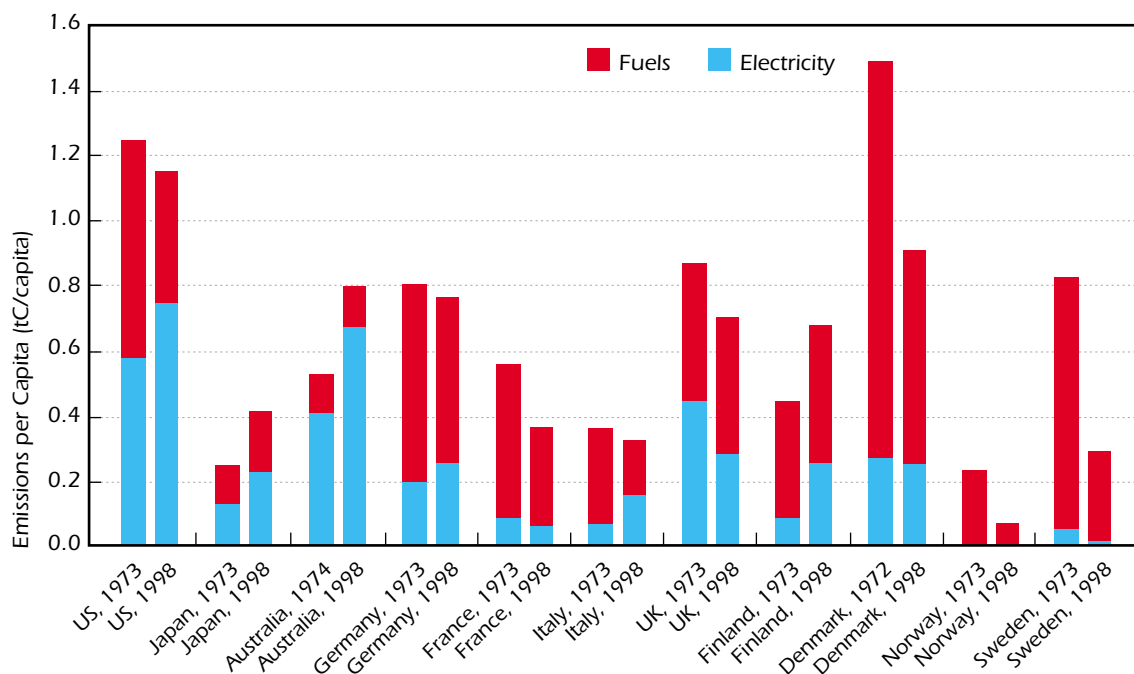
Why are there such big variations in emissions in both absolute levels and over time? Differences in fuel mix play an important role. In some countries the manufacturing end-use fuel mix has a high share of coal. Furthermore, CO₂ emissions from electricity generation vary from the hydro-based system in Norway to the coal-dominated system in Australia. Both these countries expanded their electricity-intensive metal manufacturing industries between 1973 and 1998. However, while this development did not increase emissions much in Norway, it had a very strong impact on emissions in Australia and offers an important explanation of the lack of emission reductions per value added in this country. Australia and Norway are also among the countries with the highest share of emissions from the production of raw materials, indicating an energy-intensive structure. The final factor affecting emission levels per value-added is energy intensities in the various manufacturing sub-sectors. This factor varies greatly across countries both in levels and in how it has developed over time.

Household CO₂ Emissions per Capita

Wide variations in per capita emissions are due mostly to differences in electricity-related emissions

Figure 9

Household Sector per Capita CO₂ Emissions from Fuels and Electricity



CO₂ emissions per capita in IEA-11 households vary substantially. The low emission levels in some countries are related to low or no emissions from electricity generation, as elaborated for the manufacturing sector. Thus the high emissions from electricity use in Australia should be seen in light of the high share of coal in the electricity mix. The United States also has relatively high emissions per kWh of electricity, which combined with the high electricity consumption per capita, puts it at the highest per capita CO₂ emissions from residential electricity use within the IEA-11.

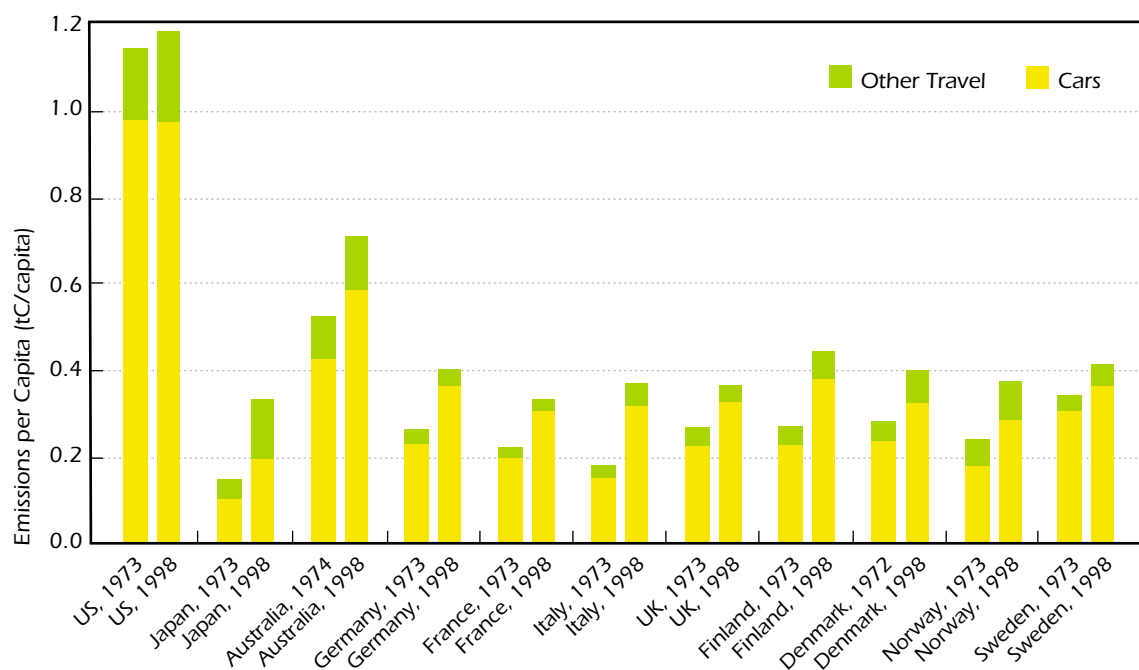
Most of the fuel use in households is for space heating. So countries with relatively cold climates and a low share of electricity in the space heating mix can be expected to have high CO₂ emission levels from fuels. Countries such as Germany, the United Kingdom and Denmark fall into this category. In Denmark, district-heating systems from combined heat and power plants fuelled by natural gas have an important share of the heating market. In Norway, the very high share of carbon-free electricity supplemented by wood results in low CO₂ emission from space heating, despite a cold winter climate. Sweden is in a similar situation, although the electricity share of space heating is lower than in Norway. On the other hand, district heat from biomass is now common in Sweden, which helps moderate emissions from fuel use.

Passenger Transport CO₂ Emissions per Capita

Per capita emission levels from passenger travel are converging outside of the United States and Australia

Figure 10

Passenger Transport CO₂ Emissions per Capita from Cars and other Modes



The United States has by far the highest per capita CO₂ emissions from passenger travel; both emissions from cars and other modes of travel are much higher than other countries. The United States saw per capita emissions increase from other modes, mainly due to increased air travel, a trend also observed in most other countries. On the other hand, the United States per capita emissions from car use decreased, albeit only slightly, between 1973 and 1998. This is in contrast to the trends seen for all the other countries, where per capita emissions increased considerably, up to 100%, over this period. The increase in CO₂ emissions from cars came as strong growth in travel activity, driven by increased car ownership, more than offset the mostly very modest reductions in fuel intensity. In the United States the development came as a combination of rapidly decreasing fuel intensities in the decade after 1973, combined with slower growth in per capita car travel activity than in most other countries. It should be noted, however, that the United States car fuel intensity and car travel levels in 1973 were much higher than all other countries.

Per capita fuel use, and thus CO₂ emissions, varied much less in 1998 than in 1973. In fact, among the European countries and Japan, per capita emissions levels from both total travel and from cars are surprisingly similar. Compared to the United States levels, big differences remain, although much less than in 1973. Comparing 1973 car CO₂ emission levels in Japan with those in the United States shows a factor of 10 difference, which was down to a factor of 4 in 1998.

Highlights from the Sectoral Analysis of CO₂ Emissions Trends

The preceding four figures are examples of the sectoral analysis that are included in the forthcoming IEA publication "From Oil Crisis to Climate Challenge: 30 Years of Energy Use in IEA Countries". The book provides a thorough analysis of how energy use patterns have evolved in each main sector and also how these developments have affected CO₂ emissions. Below are some main findings from the sectoral analysis of CO₂ emission trends.

- Manufacturing is the only sector in IEA-11 where the absolute emission level has fallen since 1973. Yet, manufacturing remains the sector with the highest emission levels. The decline in emissions per unit of manufacturing output came as sub-sectoral energy intensities fell in all countries, augmented in most countries by reductions in the CO₂-intensity of electricity supply and a shift to a less energy-intensive structure. However, after 1990, the fall in energy intensities almost came to a halt and continued structural changes took over as the most important factor in restraining manufacturing CO₂ emissions.
- Growth in CO₂ emissions from the service sector has accelerated significantly since 1990 as the rate of decline in energy intensities slowed. Since the service sector uses a lot of electricity, reduced CO₂ emissions from electricity generation have helped slow the emissions increase in most countries, but generally less so after 1990. On the other hand, the increasing share of electricity inserted an upward pressure on emissions in countries with primarily fossil fuel-based electricity generation, in many cases offsetting the effect of reduced emissions per kWh in the utility sector.
- For the IEA-11 group emissions from households did not increase much between 1973 and 1990. After 1990 emission growth rates accelerated, although the trends in individual countries vary. Some countries saw continued reductions in emissions from declines in energy intensities, and in some changes in the fuel mix also helped to maintain emission reduction rates. In all countries the growth in energy services demand slowed somewhat after 1990 mainly due to lower growth in dwelling area and in the ownership of some electric appliances. Thus if demand for energy services had grown at the same rate as before 1990, CO₂ emissions from IEA-11 households would have accelerated even more.
- CO₂ emissions from the passenger transport sector have increased steadily since 1973 driven by increased travel activity and a shift towards more cars and aircraft in the modal mix. Emission growth accelerated in the United States and Japan after 1990, as the decline in fuel intensities slowed. In Europe, a somewhat more rapid decrease in intensities after 1990 led to lower CO₂ emissions growth rates.
- Freight transport, among all sectors in the IEA-11 countries, showed the highest relative growth in CO₂ emissions since 1973. Emissions increased as freight activity grew in line with GDP and with energy intensive trucking taking a larger share of total tonne-kilometre hauled. The very modest decline in energy intensity did little to moderate emissions growth, but contrary to the trends seen in the other sectors, the average intensity for freight transport did fall more rapidly after 1990 than before.