INTERNATIONAL ENERGY AGENCY

Oil Crises & Climate Challenges

30 Years OF ENERGY USE IN IEA COUNTRIES

OECD

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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.*

ORGANISATION FOR
ECONOMIC CO-OPERATION
AND DEVELOPMENT

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

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

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

Foreword

As a result of the oil supply disruptions 30 years ago, many OECD countries took steps to reduce dependence on imported oil. One of these actions was to establish the International Energy Agency in 1974. Now, in the 30th anniversary year of the IEA, energy security remains a critical concern for our Member governments. Over the last three decades environmental issues also have been a growing concern. Greenhouse gas emissions from the energy sector present particular challenges that influence energy agendas.

The IEA's 30th anniversary is a timely occasion to take a look at how energy use has developed since 1973. Improved efficiency and a more diversified and clean energy mix have been fundamental building blocks in the IEA's work since the beginning. This publication helps to shed light on how these factors and others such as income, economic structure, climate, lifestyles and energy prices have shaped energy use and CO_2 emissions in our Member countries over the last three decades.

The analysis is based on a newly developed database that describes energy use and energy-using activities in the manufacturing, service, household, and transport sectors. We have organised the information into a series of graphs with accompanying analysis. Each sector is examined and there is also an economy-wide view, as well as a look at implications for CO_2 emissions.

There are many important policy messages. Compared to 1973, it now takes one third less energy to produce a unit of GDP in IEA economies. Oil continues to dominate in both primary supply and final energy demand, although its share has decreased in all sectors except transport. The fall in oil consumption was particularly strong in manufacturing, a result of both switching to other fuels and a strong decline in energy per unit of output. The gains in manufacturing resulted from improved energy efficiency and the growth in the shares of less energy - intensive products such as consumer electronics in total manufacturing output. Transport, especially the increased use of cars for passenger travel, continues to drive oil demand. While car engines have become more efficient over the years, cars have also become bigger, heavier and more powerful, which has limited improvements in average fuel efficiency.

Our analysis shows that significant energy savings have been achieved since 1973 in all sectors. However, one alarming message is that energy savings rates in IEA economies have slowed since 1990, as has the decline in CO_2 emissions relative to GDP. This shows that the oil price shocks in the 1970s and the resulting energy policies did considerably more to control growth in energy demand and CO_2 emissions than the energy efficiency and climate policies implemented in the 1990s.

The IEA has provided numerous energy policy publications to help our Member governments address the energy challenge more effectively. This book shows that there is an urgent need to consider ways to accelerate the decoupling of energy use and CO_2 emissions from economic growth. Examples of means to achieve this are given in the recent IEA books *Cool Appliances: Policy Strategies for Energy - Efficient Homes*, which demonstrates how energy efficiency can be improved at negative costs in household appliances and in *Saving Oil and Reducing CO_2 Emissions in Transport*.

This work is published under my authority as Executive Director of the IEA and does not necessarily reflect the views of the IEA Member countries.

Claude Mandil
Executive Director

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EXECUTIVE SUMMARY

This publication examines energy use developments in IEA Member countries since 1973. It draws on a database with detailed information on energy demand and energy demanding activities. From this information disaggregated measures – or indicators – are developed to help show how factors such as economic structure, lifestyle, climate, energy efficiency, and fuel mix have shaped patterns of energy use and CO_2 emissions.

The study assesses how energy use and CO_2 emissions trends have evolved in individual and groups of IEA countries from both economy-wide and sectoral perspectives. The analyses show, for example, an important shift from the direct burning of fossil fuels to the use of electricity in the 1970s and early 1980s, which was driven by changes in the activities and end-uses that make up total energy use. It also shows how fossil fuels were affected by price effects from the two oil crises, which resulted in significant fuel savings. Recent trends, however, indicate that both savings of fossil fuels and electricity have slowed despite efforts to combat climate change in IEA countries.

Economy-wide Results

Three decades of steady growth in IEA energy demand…

Energy demand in IEA countries has increased steadily since 1973, interrupted only by the oil price shocks in 1973-74 and 1979. Oil remains the dominant fuel in both the primary energy supply and final energy mix, although its share has declined. Oil use is down in all sectors except transport. Growth in the transport sector brought primary oil supply by 2000 back up to 1973 levels. Electricity has seen the strongest growth and in 1998 it overtook natural gas as the second largest share in the IEA final energy mix. Demand for electricity was led by the household and service sectors as more and more electric devices such as clothes-dryers, computers and air conditioners were installed and used.

Compared to 1973 it takes a third less energy to produce a unit of GDP…

Economic growth has far outpaced growth in IEA energy demand since 1973. Total primary energy supply (TPES) per unit of GDP fell by a third between 1973 and 2000. While this ratio fell in all IEA countries, the rate of decline varied significantly. Many factors influence this decline including improvements in energy efficiency and changes in the levels of energy services that consumers and businesses demand relative to GDP.

Big variations in energy per GDP levels across the IEA…

Differences in the development of energy service demands help to explain why the amount of energy used to produce a unit of GDP varies signifcantly among IEA countries. How much and what kind of energy service is demanded in a country depends on factors such as: climate; size of dwellings; number of people per dwelling; floor area of service sector buildings per unit of service sector output; share of energy-intensive products in manufacturing output; tonne-km of transported goods per GDP; average travel distance per capita; and the share of different modes used for transport activities.

While reducing energy intensities through improved energy efficiency is a key energy policy focus in IEA countries, affecting the factors that drive energy service demand is generally not. This study uses a decomposition approach to show how changes in energy service demand and energy intensity each have affected total energy use and energy per GDP trends.

Both changes in energy service demands and intensities helped reduce energy per GDP…

From 1973 to 1998, energy service demand grew less than GDP in most IEA countries, partly because production of energy-intensive goods became a smaller share of GDP, and building area and travel activity did not grow as fast as GDP. Therefore, the reduction in the energy per GDP ratio overestimates the improvements in energy efficiency. Indeed, for a group of eleven IEA countries (IEA-11)[1] the decline in energy services relative to GDP accounted for about one-fifth of the total 37% reduction in energy use per unit of GDP, with the rest being a result of declining end-use energy intensities.

Energy savings since 1973 have been substantial…

Between 1973 and 1998, the decline in these intensities resulted in energy savings corresponding to almost 50% of 1998 IEA-11 energy consumption levels. Therefore, absent these savings, energy use in 1998 would have been almost 50% higher. Economy-wide savings were similar in the United States, Japan and in a sub-group of eight European countries, but there were important differences at the sectoral level.

But rates of energy savings are slowing…

Reductions of energy end-use intensities have slowed in most IEA countries and sectors since the end of the 1980s. While the weighted sum of sub-sectoral energy intensities in the IEA-11 fell by 2% per year on average between 1973 and 1990, this intensity indicator declined by only 0.7% per year averaged over the 1990-1998 period.

Energy price developments offer some explanation for long-term trends…

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 prices fell after 1985 the incentive for maintaining energy savings rates weakened. The lower prices combined with the fact that energy intensities already were significantly reduced, resulted in considerably lower energy expenditures for both industry and private consumers from the mid 1980s.

Are recent trends impacted by the information economy?

The rate of decline in energy per GDP also slowed in most countries after 1990. However, recent trends in the United States and some other countries show that energy use per GDP is again falling rapidly. However, the reduction in the United States is not a result of improved energy efficiency. In fact, the decline in the US end-use energy intensities has been very modest since 1994. Instead most of the decline is due to shifts in economic structure. Less energy-intensive activities, such as the production of information technologies and

1. This group represents the countries for which the IEA has complete times series with detailed data for energy and energy consuming activities covering the period 1973 to 1998 and in some case to 2000 and 2001. The countries include; Australia, Denmark, Finland, France, Germany, Japan, Italy, Norway, Sweden, the United Kingdom and the United States. When their aggregate results are presented, the group is referred to as IEA-11. Together these countries accounted for 83% of IEA total final energy consumption in 2000.

electronic equipment, led the boom in the US economy during the last half of the 1990s. The growth in the output of these products far outpaced growth in the production of energy-intensive raw materials such as steel, which consequently reduced energy requirements per unit of GDP.

Manufacturing

Manufacturing energy use per unit of output has declined significantly since 1973…

IEA manufacturing energy use fell 15% between 1973 and 2000, while oil consumption dropped by as much as 62%. Nonetheless, manufacturing remains the most significant energy consuming end-use sector. The decline in energy demand was achieved even as manufacturing output increased almost 90%. Consequently, aggregate energy use per unit of output fell significantly.

Structural changes explain part of the decline, while the rest are due to energy savings…

The decline in aggregate manufacturing intensity is affected both by structural changes and by reduced energy intensities in each sub-sector. For the IEA-11 group, structural shifts toward less energy-intensive materials account for about a third of the decline in manufacturing energy use per unit of output between 1973 and 1998. The remaining reductions are related to energy intensity declines in individual sub-sectors. The impact of structural changes varies among countries: in most, the manufacturing structure has become less energy intensive, while in a few, structural changes have driven up energy use.

Recent trends show very little intensity decline, while structure is rapidly becoming less energy- intensive…

The impact of structural changes has increased since 1994. In most countries, the share of less energy-intensive products has increased, with rapid growth in electronic equipment industries leading the shift. On the other hand, the decline in sub-sectoral energy intensities in IEA-11 almost came to a halt after oil prices fell in 1986. Between 1973 and 1986 intensities fell 3.2% per year on average, while over the next twelve years the average annual decline was only 0.5%. The slower intensity reductions can be seen both across countries and across sub-sectors.

Energy has become less significant in total production costs…

Energy's share of manufacturing production costs have fallen substantially since 1973 as a result of reduced energy intensities and the decline in energy prices after 1986.

Households

Households have become more electricity intensive…

Today, households consume about 20% of total IEA final energy demand and about a third of the total end use of gas and electricity. For the IEA-11, household energy demand was up 17% between 1973 and 1998, with a doubling of electricity consumption and a 40% increase in natural gas use.

Space heating trends vary as home sizes and heating practices evolve ...

Strong growth in ownership and use of household appliances propelled the increase in electricity consumption. Yet, space heating remains the most significant residential energy end-use in almost all IEA countries. The demand for space heating has developed quite differently among countries. Bigger houses and fewer people per dwelling have put upward pressure on space heating demand in all countries, but to varying degrees. On the other hand, helping to restrain demand, the amount of heat demanded per unit of floor area fell in most countries, but the rates of decline vary dramatically. Partly this reflects differences in energy efficiency improvements, but also that some countries where heating levels were low in the early 1970s saw efficiency improvements offset as heating comfort levels (indoor temperature and proportion of dwelling heated) increased.

Energy savings have slowed in the 1990s...

Energy intensities in all residential end uses fell steadily until the early 1990s. Since then, the decline rates have slowed markedly, and even reversed in some countries. For IEA-11, household energy use would have been 56% higher in 1998, if intensities had remained at 1973 levels. Most of these savings occurred before 1990.

Heating prices vary much less than electricity prices...

There are significant variations in electricity prices among countries, which therefore provide different economic incentives for improving energy efficiency of electricity-specific uses such as lighting and appliances. The fuel-weighted price paid for space heating varies much less. This indicates that non-price factors such as building codes, climate and cultural aspects are important to explain the significant differences in the levels of space heating intensities among countries.

Energy savings have moderated the share of income spent on energy...

With the fuel price increases through the 1970s and early 1980s, IEA households spent an increasing share of income on energy. When energy prices fell, household energy expenditures declined relative to income. By 1998, the share of household income for energy expenditures was comparable to the share paid in 1973 in most countries. The increased share of electricity in the fuel mix contributed to higher energy expenditures as electricity is generally more expensive than fossil fuels. On the other hand, lower growth in energy consumption relative to income helped to reduce the significance of energy in the household budgets. Clearly, without the energy savings achieved between 1973 and 1998, IEA households would have seen much more of their incomes being spent on energy.

Service

Service sector has driven much of the increased demand for electricity...

The service (commercial and public) sector consumes 13% of total final energy use in IEA countries, and 31% of electricity demand. The proliferation of electric devices for cooling, ventilation, lighting, and an increasingly diverse array of office and network equipment have driven the 35% overall growth of energy demand in the sector between 1973 and 2000.

Energy use per floor area in service buildings fell significantly in all of the IEA-11 countries through 1990, but since then the rate of decline has slowed. The fall in energy per service sector value-added has been even stronger, and although the decline in this intensity also slowed after 1990, the most recent trends indicate that it is again falling noticeably.

Slower intensity reductions since 1990, but recent trends indicate new acceleration…

Energy expenditures relative to value-added in the service sector increased significantly in the years following the oil price hikes, but dropped as prices fell during the mid to late 1980s. Since then, relatively stable prices combined with a steady increase in the share of electricity and a slower decline in energy intensities accelerated the growth in energy expenditures. By 1998, energy expenditures relative to service sector value-added had risen significantly from 1973 levels in most countries despite the declines in energy intensities that occurred during the period.

Energy costs per output have increased since 1973 despite reduced intensities…

Passenger Transport

Growth in passenger transport has been the biggest contributor to increased oil demand in IEA countries. By 1998, passenger travel accounted for 53% of total final oil demand in IEA-11, which is up from a 38% share in 1973.

Travel is a key driver of IEA oil demand…

Cars and airplanes account for most of the increase. Air travel has increased at the fastest rate of any transport mode, and nearly tripled its share of total passenger travel between 1973 and 1998. Car ownership has doubled or more in many countries, though average annual travel per vehicle has remained fairly stable in most countries.

More and more travel by cars and airplanes…

Fuel intensities for all passenger transport modes have declined, but not nearly enough to offset the growth in travel activity and the shift to more energy intensive modes (i.e., increasing shares of cars and planes in total travel). The rate of decline in average fuel intensity for all travel modes slowed in the 1990s compared with the 1970s and 1980s. While the decline in car fleet fuel intensity generally also slowed, improvements in *new* car fuel intensity are evident since the mid 1990s in some countries, particularly in Europe and Japan. This lower intensity for new vehicles has begun to dampen the rate of increase in car fuel consumption in these countries.

Slowing fuel intensity declines have led to strong growth in fuel use in the 1990s…

Real gasoline prices peaked in the early 1980s and have generally fallen since then. In most European countries much of this decline was offset by increasing fuel taxes. Still real prices, including taxes, were lower in the late 1990s than in the early 1980s in almost all IEA countries. Since average car fuel intensity has declined in most countries, albeit moderately, the real cost per kilometre of driving has generally also fallen since 1973, and particularly since the early 1980s.

Declines in fuel intensities have helped reduce the cost of driving…

Freight Transport

Freight is the sector with the biggest increase in energy use…

Freight is the end use sector with the strongest relative growth in energy demand since 1973. Its share in total final oil demand for IEA-11 went up from 15% in 1973 to 26% in 1998. The 80% increase in freight fuel demand over the period came as a result of tonne-km haulage growing in line with GDP in most countries and a shift towards trucking, which is more energy intensive than rail and shipping.

Modest declines in fuel use per tonne-km, probably affected by changes in trucking loads…

This growth was accompanied by generally modest overall declines in fuel intensities. In most countries, it is likely that intensities of individual trucks have declined per truck-km, but it is also likely that this effect was offset to a large extent by generally smaller trucks and/or lower load factors. For example, in the United States, the average-weight truck shipment has declined, reflecting a trend towards moving lighter-weight products, which resulted in an increase in fuel use per tonne-kilometre shipped.

CO_2 Emissions from Energy Use

Wide variations in CO_2 emissions per GDP…

CO_2 emissions per unit of GDP vary considerably among IEA countries. These variations are due to a multitude of factors including differences in: the mix of fuels used at end use levels and for electricity generation; industry structure; climate and geography; demographics; lifestyles; and energy intensities.

High growth in emissions during the 1990s…

All countries within the IEA-11 group experienced significant reductions in CO_2 emissions per unit of GDP between 1973 and 1990, but after 1990 only a few saw a continued strong decoupling. While total IEA-11 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.

..mainly due to slowing declines in energy intensities…

Detailed data show that the primary reason for weaker decoupling of CO_2 emissions from GDP growth since 1990 is that energy intensity reductions in most sectors have slowed. This is a uniform trend among the IEA-11 countries. In addition, fuel switching towards less carbon-intensive fuels in electricity generation contributed less to overall CO_2 emission reduction in most countries after 1990 than before.

Shifts in manufacturing structure helped to bring down emissions…

Manufacturing is the only sector in the IEA-11 where CO_2 emissions fell between 1973 and 1998, yet it remains the sector with the highest emission levels.[2] CO_2 emissions per unit of output in manufacturing fell in all eleven countries, primarily due to strong declines in sub-sectoral energy intensities, augmented in most

2. In this study emissions from electricity and district heat generation are allocated to end-use sectors using average yearly CO_2 emission coefficients for electricity and district heat, respectively.

countries by reductions in the CO_2 intensity of electricity supply and a shift towards a less energy-intensive manufacturing structure. After 1990, however, the fall in energy intensities almost came to a halt and continued structural changes took over as the most important factor in restraining manufacturing CO_2 emissions.

Emissions from households on the rise…

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, CO_2 emissions from IEA-11 households would have accelerated even more.

Emissions from services also on the rise, especially where the electricity mix is carbon-intensive…

Service sector CO_2 emission growth rates accelerated significantly after 1990, as the decline in energy intensity slowed. Reduced CO_2 emissions per kWh of electricity generated have helped dampen the emission increase in most countries, although generally less so after 1990. On the other hand, the increased share of electricity in the service sector fuel mix 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.

Emissions from cars and airplanes on a steady increase…

Emissions from the passenger transport sector have increased steadily since 1973 driven by growth in travel activity and a shift towards more cars and airplanes in the modal mix. CO_2 emissions from passenger transport 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 helped to slow emission growth rates.

The rapid growth in freight emissions may be slowing…

Among all sectors, freight showed the highest relative growth in IEA-11 CO_2 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-km hauled. The very modest decline in fuel intensity did little to moderate emissions growth, but contrary to the trends seen in the other sectors, the average intensity for freight fell more rapidly after 1990 than before.

Chapter 1. INTRODUCTION

This publication examines energy end-use developments in IEA Member countries since 1973. The analysis draws on a newly developed database with detailed information on energy demand in the manufacturing, household, service and transport sectors. This information facilitates a better understanding of how factors such as income, prices, demography, economic structure, lifestyle, climate, energy efficiency and fuel mix have shaped patterns of energy use and CO_2 emissions.

The study uses quantitative measures to show how these factors drive or restrain energy use. These measures – or indicators – include: *activity* measures such as manufacturing output or heated-floor-area of homes; measures of *structural* developments such as changes in manufacturing output mix or changes in the mix of transport modes; and energy *intensity* measures – defined as energy use per unit of activity – for sub-sectors and end-uses.

The information used for the study represents the most detailed data available on a consistent basis across countries and sectors. This allows for developing energy indicators at fairly disaggregated levels. The study employs a decomposition approach to disentangle the impact of changes in activity, structure, and energy intensities 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 the energy intensity of individual sub-sectors in determining manufacturing energy use developments. 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.

The decomposition approach is also used to explain trends in CO_2 emissions. In this case, the energy decomposition is expanded with factors representing changes in end-use fuel mix and changes in emissions from the utility sector. A close examination of these measures helps to understand why CO_2 emission developments vary across countries and what factors are the most important for controlling growth in future energy demand and CO_2 emissions.

It should be kept in mind that changes in "energy intensity" are not quite the same as changes in "energy efficiency". Take gasoline consumed per vehicle kilometre driven as an example. This energy intensity measure has declined only moderately in most IEA countries since 1973. However, that does not mean that cars have not become much more efficient. On the contrary, important technical improvements have been made to engine and other vehicle components, but these have been largely offset by heavier, larger and more powerful cars. To accurately measure changes in vehicle *efficiency,* data must be analysed for each weight-class, engine volume, etc.

The data required to take all the factors that affect energy efficiency into account go beyond what is available on a consistent basis across countries. Consequently the energy *intensity* measures presented in this book for cars and other end uses provide a picture that reflects changes in technical as well as other factors such as behaviour. Thus, when reductions in energy intensities are discussed here they are not presented as equal to energy efficiency improvements.

A brief overview of the methodology and data employed, and the geographic coverage for the analysis is provided in the next chapter. Chapter 3 examines economy-wide trends and each subsequent chapter provides a sector-by-sector analysis that compares trends in aggregate indicators with those at a more disaggregated level using illustrative graphs with a brief explanation and a headline that spotlights the key message. Chapter 9 gives an overview of how the energy trends have affected the development of CO_2 emissions, while the final chapter summarises key findings and future implications. The appendix includes data and key results by country to provide additional details to the graphs presented in this book.

Chapter 2. METHODOLOGY AND DATA

Introduction

The methodology used in this study builds on the analytical framework developed under the IEA Energy Indicator Project, which in turn has drawn extensively on data and analysis developed by the Lawrence Berkeley National Laboratory in the United States. The project has been carried out in collaboration with governments and research institutions in a dozen IEA Member countries as well as with energy indicator projects organised by the European Commission. A thorough presentation of the IEA indicator work is available in *Indicators of Energy Use and Efficiency.*[1] There are also a number of journal publications that present the methodology and results of this work.[2]

The measures – or indicators – employed to analyse energy use are constructed by combining energy data with data that describe activities driving consumption in end-use sectors. From these data various types of energy intensities can be developed. Energy intensities are related to the inverse of energy efficiencies, but are not equivalent. The two are related in that the energy intensity of an activity or productive output summarises the relationship between an overall measure of output and the energy used for a variety of processes toward that end. Each process, e.g., heating, motive power, involves one or more transformation of energy that can be described in terms of efficiencies.

Since changes in intensities are also affected by factors other than energy efficiency, the IEA does not term them energy efficiency indicators. Still, changes in the intensities are related to changes in energy efficiency and thus analysing intensity trends provides important insights into how energy efficiency and other factors affect energy use.

IEA Methodology for Analysing Energy Use

The IEA methodology for analysing energy end-use trends distinguishes among three main components affecting energy use: (1) activity levels; (2) structure (the mix of activities within a sector); and (3) energy intensities (energy use per unit of sub-sectoral activity). Depending on the sector, *activity* is measured either as value-added, passenger-kilometres, tonne-kilometres, population, or built area. *Structure* divides activity further into industry sub-sectors, transportation modes, or measures of residential end-use activity. Table 2.1 gives an overview of the various measures applied for activity, structure and energy intensities in each sector.

1. Indicators of Energy Use and Efficiency: Understanding the Link between Energy and Human Activity, *International Energy Agency, (OECD/IEA, Paris), 1997.*

2. Selected references include;

- *Schipper, L.; Unander, F.; Murtishaw, S. and Ting, M., Indicators of Energy Use and Carbon Emissions: Explaining the Energy Economy Link,* Annual Review of Energy and the Environment*, volume 26, 49-81, 2001.*
- *Unander, F.; Karbuz; S.; Schipper, L.; Khrushch, M. and Ting, M., Manufacturing Energy Use in OECD Countries: Decomposition of Long-term Trends.* Energy Policy *27 (13): 769-778, 2000.*
- *Schipper, L.; Murtishaw, S.; Unander, F., Analysing Differences in Carbon Emissions in IEA Countries.* The Energy Journal *22(2):35-75, 2001.*
- *Krackeler, T.; Schipper, L.; Sezgen, O., Carbon Dioxide Emissions in OECD Service Sectors: the Critical Role of Electricity Use.* Energy Policy. *26(15):1137-52, 1998.*
- *Unander, F.; Ettestøl, I.; Ting, M. and Schipper, L., Residential Energy Use: An International Perspective on Long-Term Trends in Denmark, Norway and Sweden,* Energy Policy *(forthcoming), 2004.*

Table 2.1

Summary of Variables Used in the IEA Energy Decomposition Methodology

Sector (i) **Sub-sector (j)**	**Activity (A)**	**Structure (Sj)**	**Intensity (Ij = Ej/Aj)**
Household			
Space Heating	Population	Floor area/capita	Heat[1]/floor area
Water Heating	"	Person/household	Energy/capita[2]
Cooking	"	Person/household	Energy/capita[2]
Lighting	"	Floor area/capita	Electricity/floor area
Appliances	"	Ownership[3]/capita	Energy/appliance[3]
Passenger Transport			
Car	Passenger-km	Share of total pass-km	Energy/pass-km
Bus	"	"	"
Rail	"	"	"
Domestic Air	"	"	"
Freight Transport			
Truck	Tonne-km	Share of total tonne-km	Energy/tonne-km
Rail	"	"	"
Domestic Shipping	"	"	"
Service			
Total Service	Value-added	(not defined)	Energy/value-added
Manufacturing			
Paper & Pulp	Value-added	Share of total value-added	Energy/ value-added
Chemicals	"	"	"
Non-metallic Minerals	"	"	"
Iron & Steel	"	"	"
Non-Ferrous Metals	"	"	"
Food and Beverages	"	"	"
Other Manufacturing	"	"	"
Other Industry[4]			
Agriculture & Fishing	Value-added	Share of total value-added	Energy/ value-added
Mining	"	"	"
Construction	"	"	"

1. Adjusted for climate variations and for changes in the share of dwellings with central heating systems.

2. Adjusted for dwelling occupancy (number of persons per household).

3. Includes ownership and electricity use for six major appliances.

4. Other industry is not included in this study.

Key Terms

- ***Final Energy:***
  Energy delivered, for example, to a building, factory or fuel tank and ultimately converted to heat, light, motion or other energy services, i.e., energy the consumer actually purchases. Transformation and distribution losses are not included.
- ***Primary Energy:***
  Final energy plus losses incurred in converting energy resources into delivered heat and electricity. Primary energy figures generally are not included in this study.
- ***Useful Energy:***
  Delivered energy minus losses estimated for boilers, furnaces, water heaters and other equipment; used for estimates of heat provided in space and water heating for buildings.
- ***Activity or Output:***
  Basic unit of accounting for which energy is used, e.g., in space heating, it is the area heated; in manufacturing, it is the production measured as value-added in real terms.
- ***Energy Intensity:***
  Energy "consumed" per unit of activity or output.
- ***Structure:***
  Refers to the mix of activities within a sector, e.g., modal mix (trucks, rail, ships) in travel, energy end uses in households, and the shares of each sub-sector to total manufacturing value-added.
- ***Energy Services:***
  Implies actual services for which energy is used: heating a given amount of space to a standard temperature for a period of time, etc. In this study, a quantitative measure of energy service demand in a sector is obtained from combined activity and structure measures.

The separation of impacts on energy use from changes in activity, structure and intensity is critical for policy analysis as most energy-related policies target energy intensities and efficiencies, often by promoting new technologies. Accurately tracking changes in intensities helps to measure the effects of these new technologies. To separate the effect of various components over time, the IEA uses a factoral decomposition where changes in energy use in a sector are analysed using the following equation:

$$E = A \sum_{j} S_j * I_j \qquad (1)$$

In this decomposition:

E represents total energy use in a sector;

A represents overall sectoral activity (e.g., value-added in manufacturing);

S_j represents sectoral structure or mix of activities within a sub-sector *j* (e.g., shares of output by manufacturing sub-sector *j*);

I_j represents the energy intensity of each sub-sector or end-use *j* (e.g., energy use/real US$ value-added).

If indices for the changes in each of these components over time are established, they can be thought of as "all else being equal" indices. They describe the evolution of energy use that would have taken place if all but one factor remained constant at their base year (*t=0*) values.[3] In this study 1990 is used as the base year for the decomposition analysis.

From this the ***activity effect*** can be calculated as the relative impact on energy use that would have occurred between year *t=0* and year *t* if the structure and energy intensities for a sector had remained fixed at base year values while aggregate activity had followed its actual development:

$$A_t / A_0 = A_t \sum_j S_{j,0} * I_{j,0} / E_0 \tag{2}$$

Similarly, the hypothetical change in energy use given constant aggregate activity and energy intensities but varying sectoral structure – the ***structure effect*** – is:

$$S_t / S_0 = A_0 \sum_j S_{j,t} * I_{j,0} / E_0 \tag{3}$$

and the proportional change in energy use given constant activity and structure but varying energy intensities – the ***intensity effect*** – is:

$$I_t / I_0 = A_0 \sum_j S_{i,0} * I_{j,t} / E_0 \tag{4}$$

Thus through calculating the relative impact on energy use from changes in each of these components the impacts on energy use related to improved end-use energy efficiency (reductions in energy intensities) can be isolated from changes derived from shifts in the activity and structure components.

Energy savings from reduced energy intensities can be defined as the difference between the hypothetical amount of energy that would have been used in a given year if energy intensities in each sector had remained at base-year values and the actual energy use, $\mathbf{E_t}$:

$$\textbf{Energy Savings in year t} = E_t / (I_t / I_0) - E_t \tag{5}$$

With the energy intensity effect, $\mathbf{I_t / I_0}$, defined by equation 4.

By introducing the dimension of fuel mix, the decomposition of energy use can be extended to address changes in CO_2 emissions. Fuel mix in this case represents both changes in fuel shares among end uses and changes in the utility CO_2 intensity (CO_2 emissions per unit of electricity or district heat produced). Changes in CO_2 emissions (**G**) in a sector then can be decomposed according to:

$$G = A \sum_j S_j * I_j * \sum_k F_{j,k} \tag{6}$$

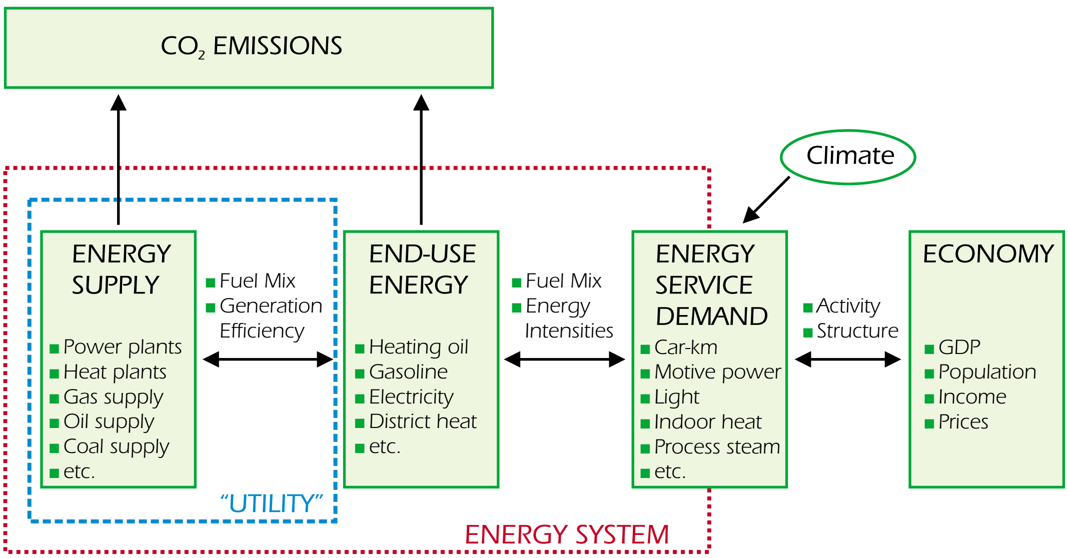
where **F** stands for the carbon content of each fuel (***k***) used in sub-sector (***j***). The ***k*** index represents two factors: changes in the utility CO_2 intensity (electricity and district heat production fuel mix and generation efficiency) and changes in the final fuel mix within each end-use sector.

3. There are different index-number techniques that permit analysing this relationship over time. In this book, the Laspeyeres indices approach is used. The Laspeyeres approach yields a residual term due to interaction among the factors in the decomposition. This means that the changes in the decomposition factors do not necessarily always add up exactly to the changes in energy use or CO_2 emissions. In most cases, the residual term is relatively small compared to the effects of the other factors and for simplicity has not been included in the figures or tables presented in this book.

Figure 2-1 summarises how the decomposition approach can be used to break down changes in energy use and CO_2 emissions into the different components included in the equations above. It illustrates the links between the general economy, consumer demand for different kinds of energy services, the energy system to supply these services and the resulting emissions. Demand for energy services is generated by the activity levels in the different sectors of the economy and the structure within each of these sectors. The driving factors behind the activity and structure developments are GDP, population, income distribution and prices, as well as geographic factors such as climate. The end-use energy required to satisfy the demand for energy service is then expressed as delivered, or final, energy per unit of activity – the energy intensity. By including supply-side losses for electricity and district heat generation and multiplying all fuels by their emission factor, the emissions resulting from each of the activities in the sectors can be calculated.

Figure 2-1

Model of Energy and CO_2 Emissions Decomposition



The resulting indices from each sector defined above can be combined further and weighted at base-year values of energy use to measure the impact of changes in energy intensities or activity and structure components on overall economy-wide energy use. The same approach can be applied to CO_2 emissions. With E and G in this case representing energy use and CO_2 emissions at a national level, the decomposition equations take the forms:

$$E = \sum_i A_i * \sum_j S_{i,j} * I_{i,j} \qquad (1b)$$

and

$$G = \sum_i A_i * \sum_j S_{i,j} * I_{i,j} * \sum_k F_{i,j,k} \qquad (6b)$$

where the index i denotes the sectors and the index j denotes sub-sectors or end uses within a sector as shown in Table 2-1.

By re-aggregating the decomposition terms to a national level, interesting comparisons can be made of developments in energy per GDP or CO_2 emissions per GDP. If both sides of equation 1b and 6b are divided by GDP, then:

$$E/GDP= ((\sum_i A_i * \sum_j S_{i,j}) / GDP) * \sum_{i,j} I_{i,j} \quad (1c)$$

and

$$G/GDP = ((\sum_i A_i *\sum_j S_{i,j})/GDP) * \sum_{i,j} I_{i,j} * \sum_{i,j,k} F_{i,j,k} \quad (6c)$$

The product of the activity effect (**A**) and the structure effect (**S**) can be defined as the *energy services* effect. Thus equation 1c helps explain how energy per GDP has changed due to shifts in the ratio of energy services to GDP and due to changes in end-use energy intensities. The first factor reflects that the structural evolution of economies and human activities can cause changes in demand for energy services and, therefore, consumption that enhances or offsets shifts caused by changes in energy intensities. For example, air travel measured as person-kilometres has grown faster than GDP in many countries, usually more than offsetting declines in air travel intensity (energy per person-kilometre), with an increase in energy use for air travel per unit GDP as a result. On the other hand, structural changes away from energy-intensive manufacturing industries have enhanced the effect of reduced sectoral intensities in many places and thus accelerated a decline in energy per GDP. Measuring the impact of these changes in the relationship between energy services and GDP is therefore crucial to understanding how the ratio of energy use to GDP changes over time.

Developments in the energy services per GDP indicator help to show how much of the change in energy per GDP is due to factors other than changes in energy intensities. The impact of intensities at the national level is instead captured by the energy intensity index at a national level (the **I** term in equation 1c and 6c). This is constructed through weighting the sectoral energy intensity effects (equation 4) at the base-year value of energy use.

Similarly, when assessing developments of CO_2 emissions per GDP, impacts from changes in the energy services to GDP ratio can be separated from the impacts of CO_2 intensity. The CO_2 intensity is defined as the product of the **I** and **F** terms in equation 6c.

The separation between energy services effects and energy or CO_2 intensity effects is important from a policy perspective since restraining energy service demand is seldom a policy objective. The decomposition approach used by the IEA allows for observing the impacts of the policy elements related to energy and CO_2 intensity separately from changes in the structural and activity components of energy use. This helps both to determine where policies can be most effective and to monitor progress once they have been implemented.

Sectors and Data Analysed

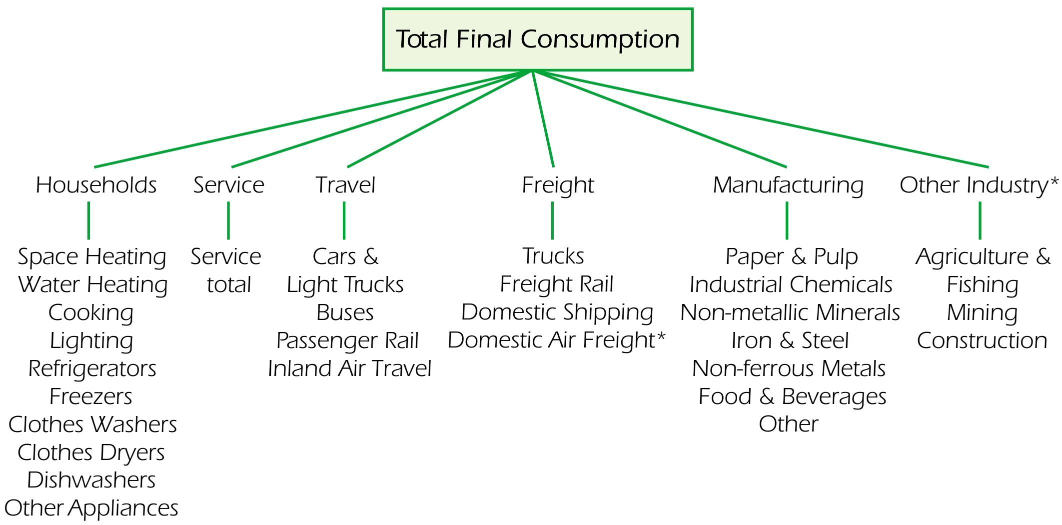
This study considers energy use in the manufacturing, household, service, passenger and freight transport sectors in the categories shown in Figure 2-2. It does not cover *other industries* as data for these activities are scarce.

Data definitions in this study are based on the methodology used in the IEA *Energy Balances of OECD Countries* although there are some important differences. In IEA statistics, coal transformation losses are included as energy transformation, while for the IEA indicator approach these losses are allocated to the manufacturing sub-sectors where the secondary coal products are consumed, notably in the iron and steel sub-sector. Petroleum products used as feedstocks for industrial chemicals are included in total final consumption (TFC) in the IEA statistics, while they are not considered in the indicator approach. Energy use for refining is included in the transformation sector in both approaches and thus is not part of TFC.

Excluded from this study are some categories of transportation such as natural gas pipelines, and fuel use for private boats and military vehicles. While both approaches exclude international marine bunkers from TFC, international air traffic is included in the IEA statistics but not in the indicator approach. As a result of these differences, TFC for IEA countries in 2000 is about 10% higher using the statistics approach than with the indicator approach.

Figure 2-2

Sectors, Sub-sectors, and End Uses in the IEA Indicator Approach



* Not included in this study.

Country Coverage

Detailed data required for time-series indicator analysis exist in many IEA countries, but not yet in all of them. Therefore, this study considers energy use only in IEA countries where consistent, detailed, long-term time series are available. This group, referred to as the IEA-11 in this analysis, includes: Australia, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, the United Kingdom, and the United States. Detailed data are also available for Canada and the Netherlands, although these data sets are either incomplete or cover shorter time series.

Consistent data series for Germany are difficult to obtain due to the reunification of east and west Germany in 1991. The IEA has indicator data for the former west Germany from 1970 through 1994. Detailed data are available for the unified Germany from 1991. For the long-term trend analysis presented here, the IEA has constructed time-series for unified Germany going back to 1970. This was done by taking real 1994 data for unified Germany and "back-casting" all data time-series to 1970 using indices based on the data for west Germany between 1970 and 1994. Thus relative trends for this "constructed" Germany reflect the development in west Germany through 1994 (although scaled-up to total Germany by multiplying the indices by the ratio of total Germany to west Germany in 1994) and the development in unified Germany after 1994.

Sections of this book discuss aggregate trends in energy use for all IEA countries based on data from IEA *Energy Balances of OECD Countries*. In such cases, the IEA is defined as those countries that were members of the OECD in 1974 when the IEA was established. This means that Korea, the Czech Republic and Hungary are not included in the IEA aggregates in this publication.

Data Sources

Due to the diverse nature of the data needed for the disaggregated indicator analysis, this study draws from a mix of national and international sources. Wherever possible, aggregate economic and activity data are taken from the OECD *National Accounts*. These data include population, employment, GDP, personal consumption expenditures, consumer price indices and producer price indices. Value-added data for manufacturing sub-sectors are drawn from the OECD STAN database, except for Australia where data are from the Australian Bureau of Statistics. Data on energy use for electricity and district heat production are from the IEA *Energy Balances of OECD Countries*. Energy price data are from the IEA quarterly publication, *Energy Prices and Taxes in OECD Countries*.

Energy data for the manufacturing and service sectors generally are from IEA *Energy Balances of OECD Countries*. Since this source does not provide data that separate the energy-extensive printing sector from the energy-intensive production of paper and pulp, printing data have been taken from national sources, where available.

The detailed energy and activity data for the remaining sectors (households, passenger travel and freight transport) come from national sources. In Australia, data are taken from the Australian Bureau of Agricultural and Resource Economics, the Australian Bureau of Statistics, the Australian Greenhouse Office and the Australian Bureau of Transportation and Regional Economics. In Canada, data are from Natural Resources Canada. In Japan, the detailed data are from the Ministry of Economy, Trade and Industry, the Ministry of Land, Infrastructure and Transport, and the Energy Data and Modelling Center. In the United States, detailed data are from the Department of Energy – Energy Information Administration and the Oak Ridge National Laboratory. Data for Norway are mostly from Statistics Norway. Detailed data for the European Union countries analysed here are principally from data developed within Eurostat's project on Energy Efficiency Indicators (see box). For the transport and household sectors, the Eurostat data are supplemented by data from the ODYSSEE project or from national teams within this project.[4]

4. The ODYSSEE national teams in the European countries covered in this study include; ADEME (France), AEAT (United Kingdom), DEA (Denmark), ECN (Netherlands), ENEA (Italy), FhG-ISI (Germany), IFE (Norway), MOTIVA (Finland), and STEM (Sweden).

Eurostat: Priority Energy Efficiency Indicators

To help measure energy efficiency progress in the European Union (EU) and in individual countries, the Energy Statistics Committee of Eurostat established a list of Priority Indicators in 2000. These indicators are based on regular Eurostat statistics, supplemented with data from the EU-SAVE sponsored ODYSSEE indicator project. The ODYSSEE network consists of expert teams in all EU countries and Norway that annually submit disaggregated energy indicator data to a central database. These data, however, have not been considered as official Eurostat data. Consequently Eurostat conducted a procedure to ask its member governments to check and approve the ODYSSEE data needed for the Priority Indicators so that they could be considered official Eurostat data.

Based on these data, the first official Energy Efficiency Indicators for the EU were presented to the Energy Statistics Committee in 2001. Following a second data collection in 2002, the indicators were updated and presented in a publication *Energy Efficiency Indicators (Data 1990-1999)*, released in December 2002. [ISBN 92-894-4886-5]

Chapter 3. ECONOMY-WIDE TRENDS IN ENERGY USE

Highlights

- Primary energy supply in IEA countries has increased steadily since 1973, interrupted only by the oil price shocks in 1973-74 and 1979. Oil remains the dominant fuel in both the primary energy supply and final energy mix. Yet the oil share has fallen. Oil use is down in electricity generation and all stationary end-use sectors (manufacturing, service and households). This decline offset growth in transportation oil use so that total primary oil supply levels in 2000 were the same as in 1973.

- Electricity demand has increased strongly since 1973. It was one-fifth of IEA total final energy consumption in 2000, up from only 12% in 1973. The household and service sectors led the growth in electricity consumption as more and more electric devices such as clothes-dryers, computers and air conditioners were installed and used.

- Economic growth far outpaced the growth in IEA energy demand: total primary energy supply (TPES) per unit of GDP fell by a third between 1973 and 2000. While this ratio fell in all countries, the rate of decline varied significantly. The country differences are related to the development of sub-sectoral energy intensities (intensity effect) and of energy service demand relative to GDP. In most countries, energy service demand grew less than GDP and thus boosted the decline in energy per unit of GDP. This happened as key activities that drive the need for energy services fell relative to GDP, such as output from energy-intensive manufacturing, house size and, to some extent, travel activity.

- For those countries where a decoupling of energy services and GDP is observed, using the decline in the energy per GDP ratio as an indicator of energy efficiency developments would overestimate the improvements. Indeed, for a group of eleven IEA countries (IEA-11) (together accounting for 83% of IEA total final energy consumption (TFC) in 2000), the decline in energy services to GDP was about one-fifth of the total 37% reduction in TFC/GDP between 1973 and 1998.

- All countries included in this study have seen reductions in energy intensities. However, in most countries the rate of decline has slowed in all sectors since the end of the 1980s. While the weighted sum of sub-sectoral energy intensities in the IEA-11 fell by 2% per year on average between 1973 and 1990, this intensity indicator only declined by 0.7% per year averaged over the 1990-1998 period.

- This slowing rate of decline can also be discerned in the energy per unit of GDP ratio in most countries. However, in some, most notably in the United States, the fall in the energy per unit of GDP ratio has accelerated since 1994. Most of the decline in the United States is due to structural shift. Less energy-intensive activities, such as the production of information technologies and electronics equipment, led the boom in the US economy during the last half of the 1990s, far outpacing the growth in production of energy-intensive raw materials such as steel. This trend reduced energy requirements per unit of GDP in the manufacturing sector. This reduction, therefore, is not a result of improved energy efficiency. In fact, the decline in the US end-use energy intensities has been very modest since 1994.

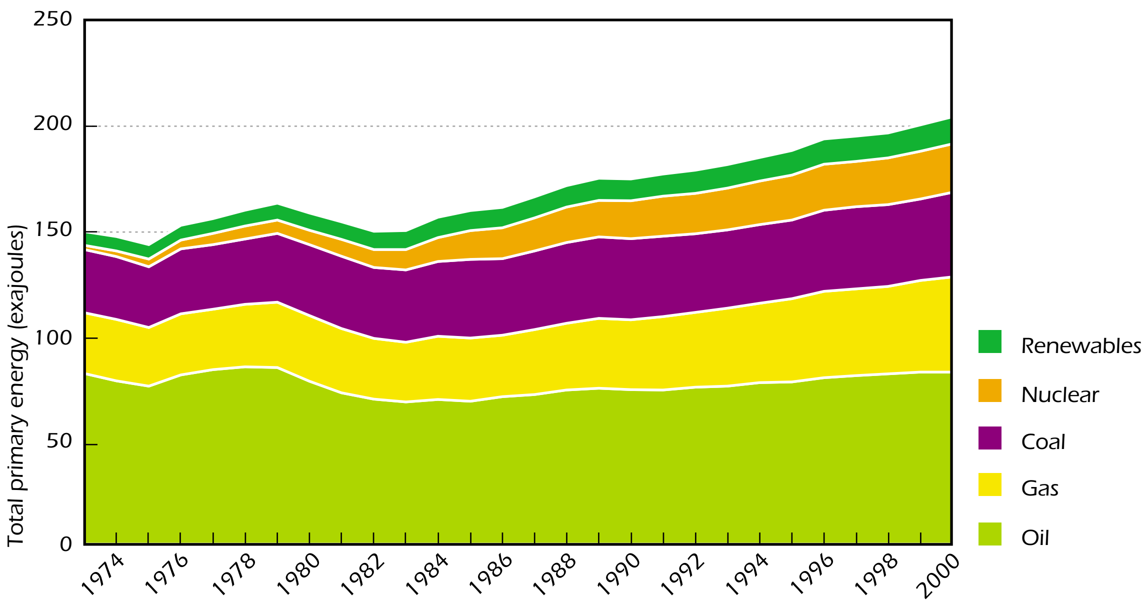
- Despite the slowdown of intensity declines in recent years, reductions in energy intensities led to considerable energy savings. The savings accrued between 1973 and 1998 for the IEA-11 correspond to almost 50% of 1998 energy consumption levels, i.e., energy use in 1998 would have been about 50% higher without the reductions in energy intensities that took place over the period. Comparing the developments in the United States, Japan and a group of eight European countries shows that economy-wide savings were of a similar magnitude, but that there are important differences in savings rates at the sectoral level. These differences are examined in the subsequent sectoral chapters.

Primary Energy Supply by Fuel

Primary energy supply has been growing since 1973 and oil continues to be the dominant fuel

Figure 3-1

Total Primary Energy Supply by Fuel, IEA Countries[1]



Total primary energy supply (TPES) in IEA countries increased 37% between 1973 and 2000, a compound growth rate of 1.2% per year. The growth was fairly steady except in 1974-1975 and in the early 1980s as a consequence of the two oil price shocks. The decline in these two periods lowered IEA energy demand in 1983 to 1973 levels. Since then, the IEA's primary energy supply has grown relatively smoothly at about 1.7% per year.

Oil, by far, remains the major contributor to supply, though its share of TPES declined from 55% in 1973 to 40% in 2000. Oil demand peaked in 1978 and then fell by 20% from 1979 to 1983. Since then, oil demand has increased continuously, returning to 1973 levels in 2000.

Natural gas overtook coal as the second largest contributor to the energy supply after 1994. In 2000, natural gas accounted for 22% and coal for 20% of TPES for IEA countries.

Nuclear generation has experienced the largest growth in both absolute and relative terms. Nuclear electricity production increased ten-fold between 1973 and 2000 and contributed 11% of total supply in 2000.

The share of renewable energies expanded from 4% in 1973 to 6% in 2000. This share is dominated by combustible renewables (55%), hydro (36%) and geothermal (7%). Wind and solar were the fastest growing renewables, yet only accounted for 2% of total renewable supply in 2000.

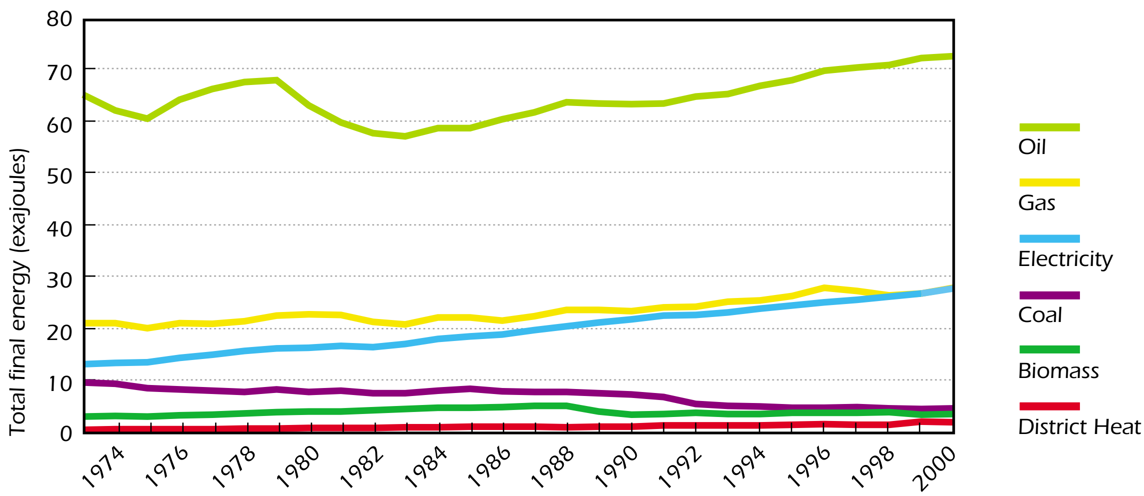
1. IEA in aggregate figures in this publication refers to those countries that were members of the OECD in1974, and therefore does not include the newer Member countries – Czech Republic, Hungary and Korea.

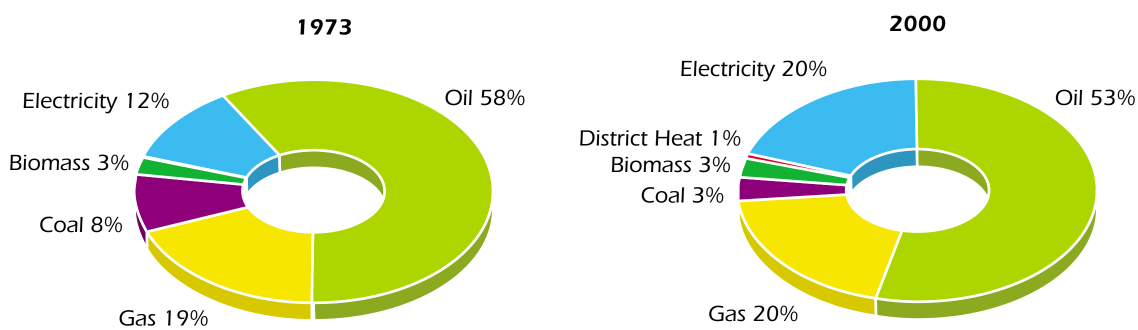
Final Energy Consumption by Fuel

Oil dominates final energy consumption, but electricity is growing the strongest

Figure 3-2

Total Final Energy Consumption by Fuel, IEA Countries





Total final energy consumption (TFC) for IEA countries is even more dominated by oil than TPES. In 2000 oil accounted for 53% of consumption, down from 58% in 1973. The decline is related to the oil price shocks. After 1983, oil use increased steadily at about the same rate as TFC, approximately 1.4% per year.

Electricity caught up with natural gas as the second most important fuel in the final energy mix in 1998. Since then, both have grown at the same rate and each constituted 20% of final demand in 2000. Overall, electricity has grown the fastest, averaging almost 3% per year since 1973. Coal, on the other hand, declined at about the same rate as electricity increased. Coal only had a 3% share of IEA TFC in 2000, the same as biomass.[2]

2. Coal use is concentrated in the power generation sector which is accounted for in TPES but not in TFC. In 2000 only 11% of IEA total coal supply was consumed in the end-use sectors, which compares to almost 90% of the oil supply and 62% of the gas supply.

Energy Use by Sector

Manufacturing is the only sector with a net decline in energy consumption since 1973, but it is still the main energy user

Figure 3-3

Total Final Energy Consumption by Sector, IEA-11[3]

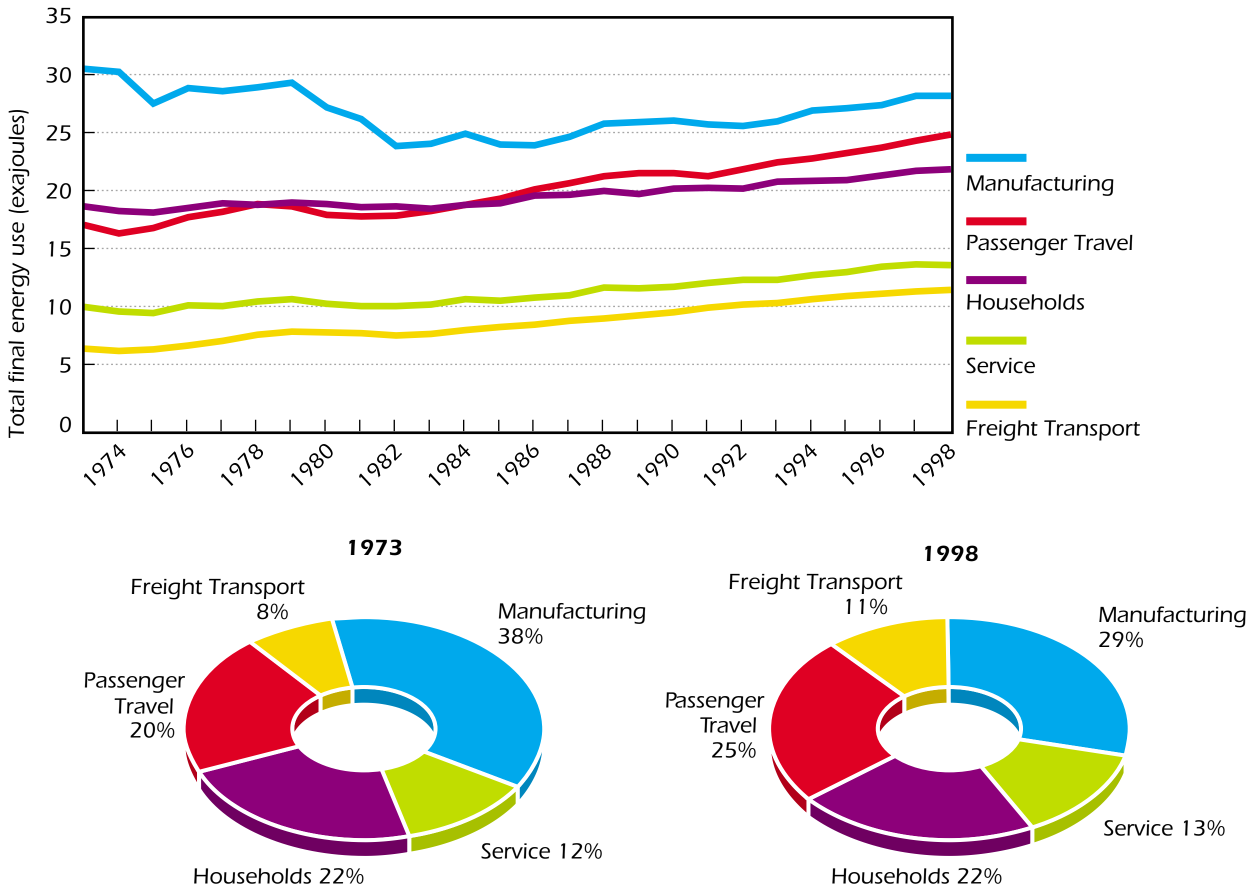


Figure 3-3 shows the development of energy consumption by sector for a group of eleven IEA countries. Both within this group and for the total IEA, manufacturing industries remain the main energy user, though the sector's energy use in 2000 was lower than in 1973.

Except for manufacturing, energy consumption increased in all sectors within the IEA-11. The strongest relative growth was in freight transport where demand increased by 2.3% per year on average. Still the share of freight in IEA-11 energy consumption only went up from 8% to 11% between 1973 and 1998.

3. This group represents the countries for which the IEA has complete times series with detailed data for energy and energy consuming activities covering the period 1973 to 1998 and in some cases to 2000 and 2001. The countries include; Australia, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, the United Kingdom and the United States. Together these countries accounted for 83% of IEA Member country total final energy consumption in 2000.

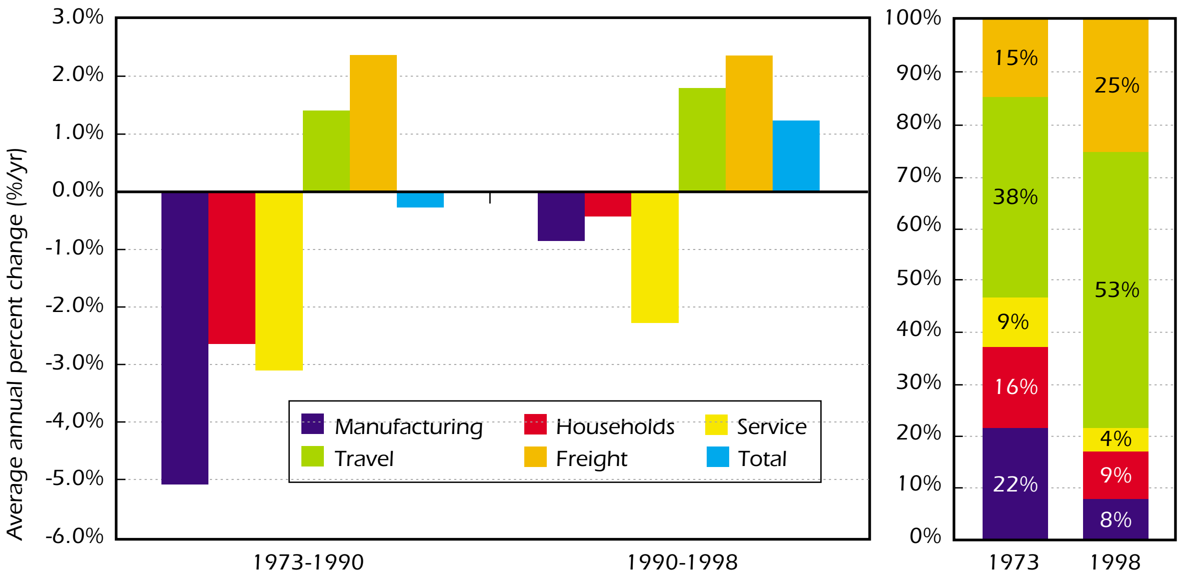
Energy consumption in the household and passenger travel sectors each accounted for about 20% of IEA-11 consumption in 1973. These two sectors, both dominated by private consumers, grew at roughly the same rate to 1983. Since then passenger travel energy use has accelerated and today is the second largest energy consuming sector. The average annual growth rate for passenger transport energy use between 1973 and 1998 was 1.5%, which compares to 1.2% for the service sector and 0.8% for the household sector. As a consequence, the combined share of the two transport sectors grew from 28% in 1973 to 36% in 1998, close to a mirror-image of the decline in the share of manufacturing.

Oil Demand by Sector

Declines in stationary oil use have largely offset growth in transport

Figure 3-4

Oil Demand by Sector, IEA-11



Growth in transport put pressure on oil demand. An important driver of the increased demand was car travel where annual car use increased much more rapidly than car fuel intensities fell across the IEA-11 countries. Similarly for freight transportation, haulage by trucks increased rapidly while there were only small reductions in truck fuel intensities in most IEA-11 countries.

Conversely, oil use fell significantly in all three stationary (non transport) sectors. In manufacturing this came as a result of three factors: (1) reductions in energy intensities; (2) structural changes towards less oil-intensive sub-sectors; and (3) direct substitution of oil by other fuels. The extent of the contribution from each of these factors to the decline in oil use varies from country to country. The total effect for IEA-11 was that manufacturing oil use fell much more than total manufacturing energy did (60% versus 8% between 1973 and 1998).

Oil use in residential and service sector buildings also fell considerably, 40% and 50% respectively, between 1973 and 1998. This decline is primarily a result of shifts from oil to other heating alternatives and a general reduction in space heating intensities.

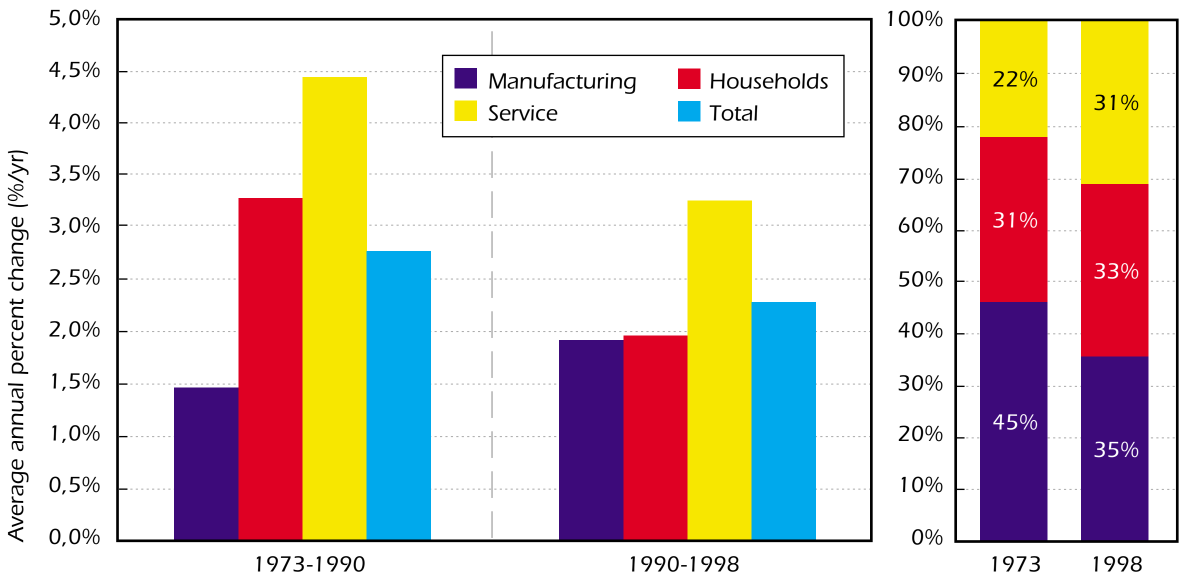
The share of oil use for all three stationary sectors fell from almost half of total final oil demand in 1973 to only a fifth in 1998. Clearly, oil use in the IEA-11 has become concentrated in transportation.

Electricity Demand by Sector

Strong growth in electricity demand in all stationary sectors

Figure 3-5

Electricity Demand by Sector, IEA-11



Electricity demand has increased rapidly in all stationary sectors.[4] Residential electricity demand growth primarily has been driven by increased ownership and use of electric appliances. Traditional "big appliances" such as dishwashers and refrigerators dominated the growth to the early 1980s, while much of the recent growth is due to the use of "miscellaneous" appliances e. g., home electronics and small kitchen gadgets. In the service sector much of the strong growth is due to the proliferation of electric-based end uses such as cooling, ventilation, lighting, and various kinds of office and network equipment.

While manufacturing had lower electricity demand growth than the other two sectors, this needs to be seen in the context that total manufacturing energy use actually declined between 1973 and 1998. Therefore the importance of electricity in the manufacturing energy mix has increased significantly, though the share of manufacturing in total electricity demand has fallen and today the three sectors constitute roughly a third each of IEA-11 electricity demand.

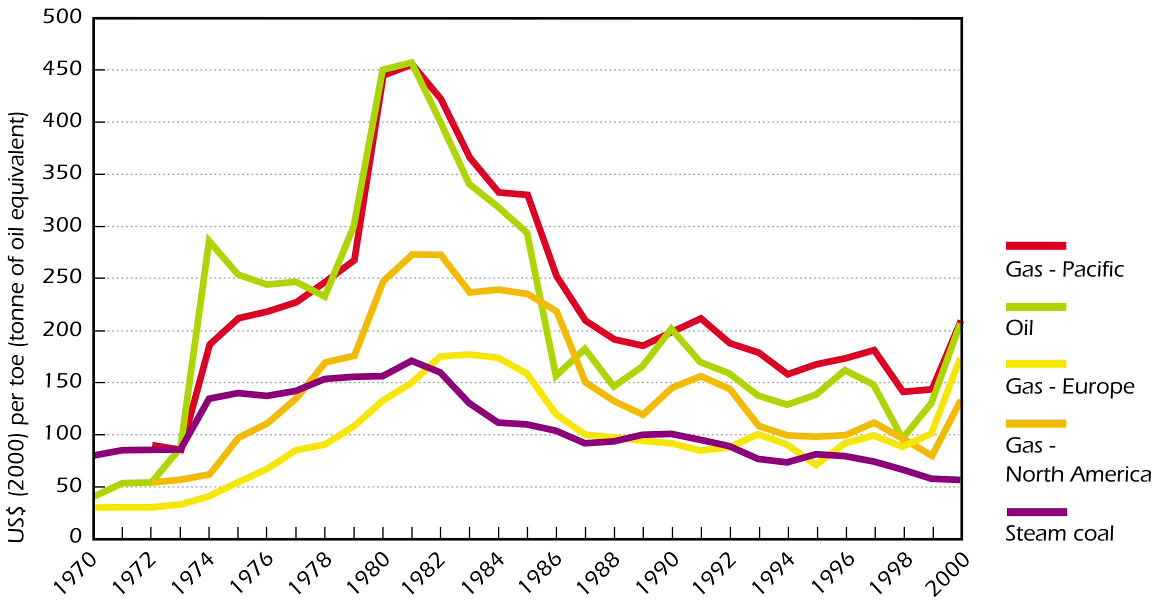
4. The electricity use in transport is very small compared to the stationary sectors and thus has not been included in Figure 3-5.

Energy Prices

Fossil fuel prices fell from 1982 to the end of the 1990s

Figure 3-6

Fossil Fuel Prices in Real Terms



The 1973 Arab oil embargo caused oil prices to rise dramatically. For example, Arabian Light prices increased from US$1.85/barrel in 1972 to $11.58 in 1974 (nominal prices). The next price peak came in 1981, in the wake of the Iranian revolution, when prices rose to an all-time high of nearly $40/barrel.

After 1982 oil prices began dropping and fell considerably in 1986 when Saudi Arabia substantially increased its oil production. After ten years of relative stability, crude oil prices started to decline again in 1997 due to OPEC's over production in the face of the Asian financial crises. By early 1999, prices had reached the lowest level since 1973. However, over the next two years they doubled on tighter OPEC discipline. (Since mid-2000 oil prices have fluctuated, with a recent peak during the Iraq war in 2003.)

Crude oil prices in real terms were on a declining trend between 1982 and 1999. In fact, the price in early 1999 was less than a quarter of prices in 1982 measured in 2000 US dollars.

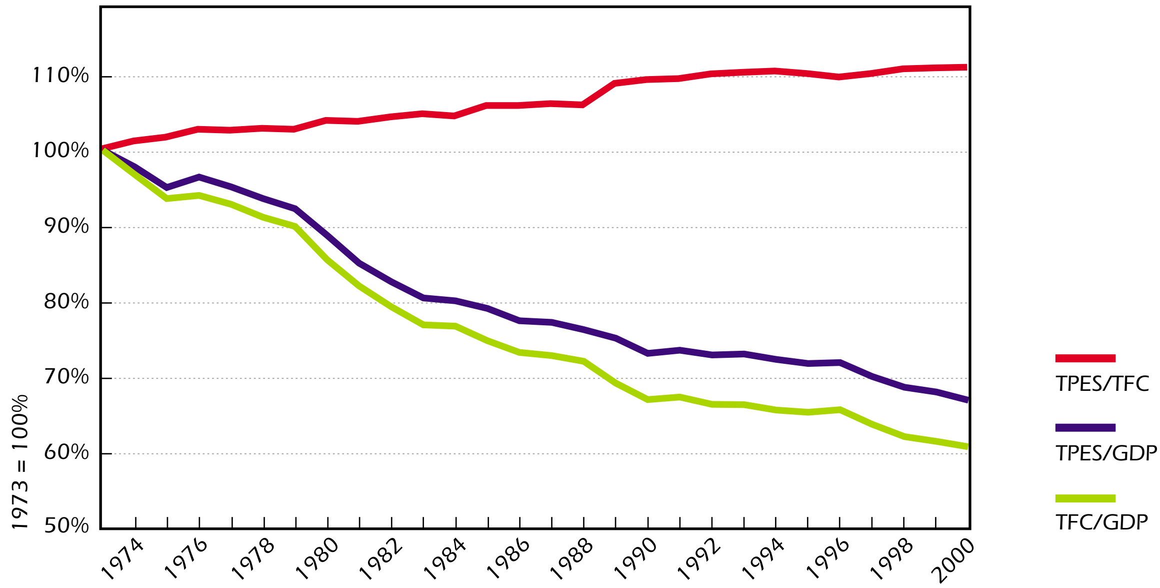
Real prices for natural gas and to some extent coal have more or less followed oil price developments; although with less strong fluctuations (except for LNG prices in Japan which have been closely linked to oil prices).

Energy Use and GDP

IEA countries have steadily reduced the need for energy to fuel economic growth

Figure 3-7

TPES per GDP, TFC per GDP and TPES per TFC, IEA Countries



TPES per unit of GDP has fallen sharply in IEA countries since the first oil price shock. Today IEA economies use a third less primary energy to generate a unit of GDP than in 1973.

The TPES/GDP ratio fell most rapidly immediately after the two oil price shocks. Between 1973 and 1983 the fall in primary energy intensity averaged 2.2% per year. After 1983 and until 1990, the decline in TPES/GDP was steady, although at a more modest average rate of 1.3% per year. After 1990 the decline slowed considerably until 1996 when the decline in IEA primary energy intensity accelerated again, averaging a rate of 1.8% per year between 1997 and 2000.

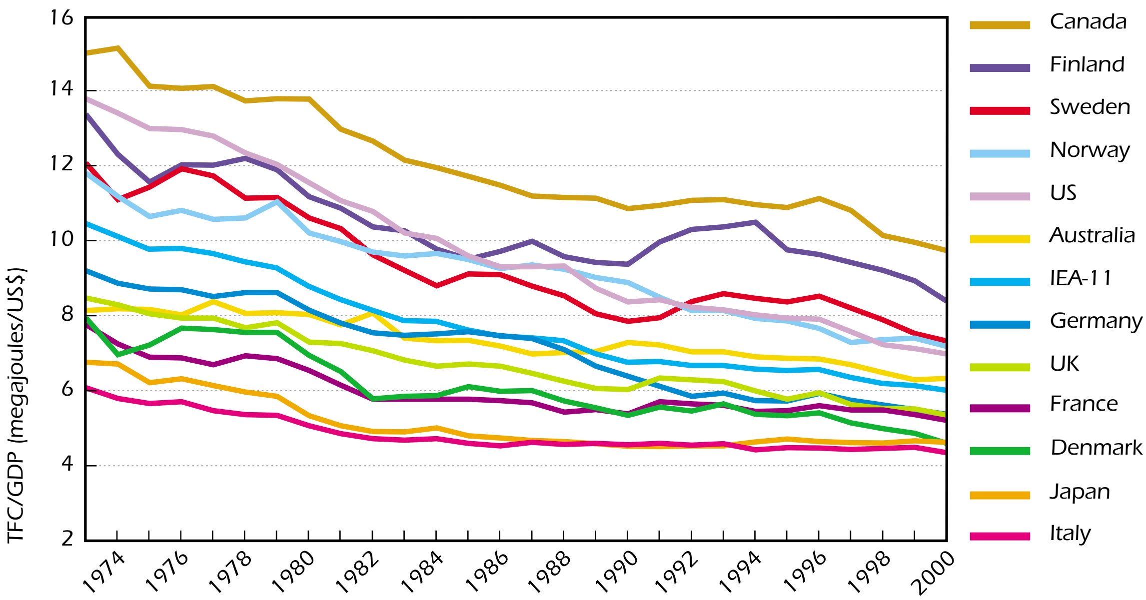
The decline in primary energy per unit of GDP has been driven by improved energy efficiency in key end uses, shifts in fuel mix and changes in the structure of human and economic activities. Changes in the mix and efficiency of energy supply have also affected this ratio. This is illustrated by the line showing the development of TPES/TFC in Figure 3-7. In 2000 this ratio was 11% higher than in 1973, i.e., losses and consumption in the energy sector per unit of final energy delivered to end-use consumers had increased 11%. The main reason is the increased share of electricity in final demand. Electricity has a high end-use efficiency compared to direct fuel-fired applications, but often significant losses in generation. Thus the increased share of electricity "moved" losses from the demand side to supply side, which more than offset the improvements in supply side efficiency achieved during the period. Consequently TFC per GDP fell more than TPES/GDP. By 2000, TFC per GDP was only 60% of the 1973 level.

Energy Use per GDP by Country

Big variations in energy per GDP ratios across countries

Figure 3-8

TFC per Unit of GDP



Energy consumption per unit of GDP has declined in all IEA countries since 1973, but the rate at which it has fallen varies. The United States had the strongest decline among the countries shown in Figure 3-8 - TFC/GDP fell almost 50% between 1973 and 2000. At the other end of the scale, Australia had a 22% decline. The reduction in the United States was relatively steady while other countries experienced strong variations over time. In Japan, for example, TFC/GDP fell at about the same rate as in the United States until the end of the 1980s, it then levelled off and even increased as a result of economic recession.

Large differences in levels of energy consumption per unit of GDP are also evident in Figure 3-8. For example, Canada consumed more than twice as much energy per GDP in 2000 as Japan, Italy and Denmark, while the consumption per GDP in the United States was about 50% higher than in Japan, down from twice as high in 1973.

Why are energy consumption levels per unit of economic output so different when these countries are at similar stages of economic development? Part of the difference reflects variations in energy efficiency. However, it would be very misleading to rank energy efficiency performance according to a country's energy per GDP measure as that ratio is affected by many non-energy factors such as climate, geography, travel distance, home size and manufacturing structure.

Key Factors Affecting Energy Use

Key factors affecting energy demand vary widely

Figure 3-9

Minimum and Maximum versus IEA –13 Average Values for Key Factors Affecting Energy Use[5]

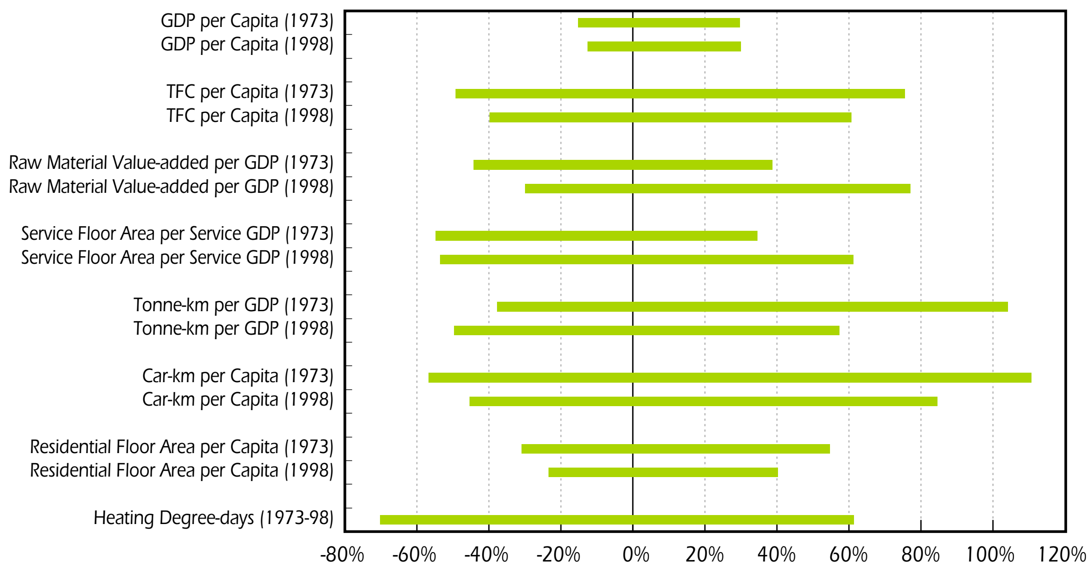


Figure 3-9 illustrates the wide spread in some key factors that are important for understanding differences in energy per unit of GDP levels. Most of the factors are independent of GDP itself and thus help explain the significant variations among IEA countries.

Note that the spread in GDP per capita basically did not change while the spread in TFC per capita decreased from 1973 to 1998. This helps to explain why the variations in TFC/GDP in 1998 are lower than in 1973 (Figure 3-8).

The proportion of energy-intensive raw materials manufacturing in GDP is significant for energy use levels in an economy: some products like steel and aluminium require 10 to 20 times the energy per value-added than producing less energy-intensive products such as electronics. Compared to generating GDP in the service sector, the difference is even higher, often more than a factor of 30. The spread in the raw material share of GDP has increased since 1973. It varied by a factor of 2.5 among the countries in 1998, indicating that differences in industry structure are still a crucial factor behind differences in energy per GDP levels.

The range in another key factor, the building area per unit of value-added in the service sector, has also increased since 1973. The larger area-per-dollar-generated, the more demand for energy for heating, cooling and lighting and the higher contribution to the energy per GDP ratio. In 1998 this varied by a factor of 3.5 among the thirteen IEA countries included in the figure.

5. IEA-11 countries plus the Netherlands and Canada, denoted as IEA-13.

Clearly in freight transportation, the more goods moved around at a given level of GDP, the higher the freight energy use in an economy. Tonne-km per GDP in 1998 varied by more than a factor of three among the IEA-13 countries, to a large extent due to differences in country size. Geography also explains to some degree the differences in automobile use per capita, which in 1998 ranged from more than 13 000 km/year in the United States to 3 900 km/year in Japan.

Household area per capita also impacts a country's energy use. The variation in this ratio fell from 1973 to 1998, but there was still a difference of almost a factor of 2 between the highest value (United States) and lowest (Japan).

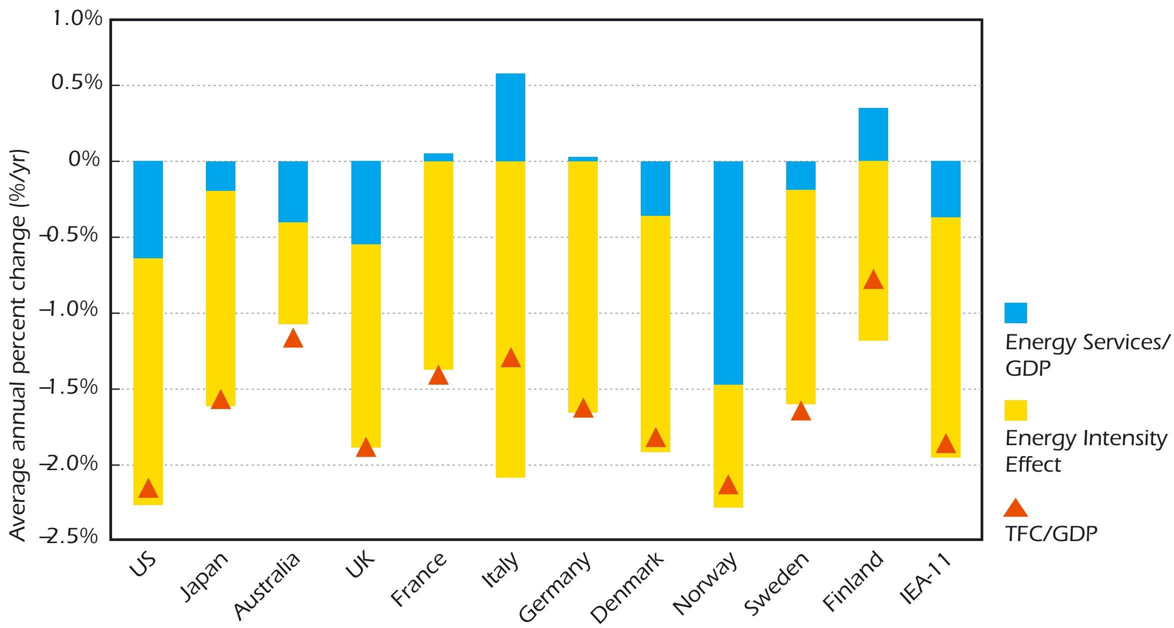
Climate is a key determinant for energy use in buildings. IEA countries cover a wide range of winter climates with 30-year average heating-degree days (base 18 degree C) varying from 900 in Australia and 1800 in Japan to more than 4 500 in Canada and Finland.

Decomposition of Energy per GDP Trends

Evolution of sub-sectoral intensities and energy service demand explain variations in energy per GDP decline rates

Figure 3-10

Changes in TFC/GDP Decomposed into Changes in Energy Services/GDP and Intensity Effect[6], 1973 - 1998



Large divergences in how much energy (TFC) per unit of GDP has fallen over time are shown in Figure 3-8. To what extent does this reflect differences in energy efficiency developments? To answer this, the impact on energy use from changes in sub-sectoral energy intensities, which are more closely related to energy efficiency, are separated from the impacts of changes in economic structure and other factors that affect the demand for energy, but which are not measured directly by GDP. Variations in some of these factors across countries are depicted in Figure 3-9.

Increased demand for energy services – reflecting increased ownership levels of electric household appliances, bigger houses, more personal travel by car, and so on – drives energy use and energy use per GDP. Therefore, it is useful to examine how changes in the ratio of energy services to GDP and in end-use intensities such as energy used to heat a square metre of floor space or to ship a tonne of freight a kilometre affect the energy per GDP ratio. This is done using the index decomposition method described in Chapter 2.

6. The data used in this decomposition analysis are described in Chapter 2. The following sectors are included: manufacturing, service/commercial, households, passenger travel and freight transport. Energy consumption in agriculture, mining and construction are normally included in the definition of TFC. However, since it is difficult to define activity levels in these sectors based on good-quality data, they have been excluded from the sector analysis in this book. The agriculture, mining and construction sectors together account for less than 10% of TFC in the IEA and thus the TFC/GDP ratio analysed in the remainder of this chapter is close to the "complete" TFC/GDP ratio shown in the preceding figures. In Figure 3-10 and all the following figures in this chapter, energy use for heating residential buildings has been corrected for year-to-year variations in climate (see Chapter 5).

Figure 3-10 shows how changes in energy consumption per GDP can be attributed to changes in the ratio of energy services to GDP and changes in sub-sector energy intensities (for more than two dozen end uses). The intensity effect for the whole economy shown in the figure is calculated as the sum of all sectoral intensity measures, weighted at 1990 energy use shares.[7]

Energy per unit of GDP fell by between 1 and 2% per year on average since 1973, except in the United States where it fell more and Finland where it fell less. In almost all countries, lower growth in energy services than in GDP, i.e., energy services to GDP fell, helped reduce the energy per GDP ratio. The countries with the strongest reduction in energy per GDP (United States, United Kingdom and Norway) are also the countries where energy services declined the most relative to GDP. In the United States this was because energy service levels in the early 1970s were already relatively high. In Norway and the United Kingdom rapid expansion of offshore oil and gas production led to strong GDP growth without increasing the demand for land-based energy services at the same rate.[8]

In the countries where demand for energy services grew less than GDP, energy per GDP declined faster than what was attributable to the effect of falling sub-sectoral intensities. This means that using energy per GDP as a measure for energy efficiency developments would overestimate the improvements. On the other hand, in Italy and Finland, where growth in energy services outpaced economic growth, the effect of declining intensities is stronger than what the energy per GDP ratio would imply.

7. In the Laspeyres index decomposition used here the sum of the annual percentage changes in energy services per GDP and energy intensities does not always add up to the changes in TFC/GDP due to a residual interaction term. (See Chapter 2.) This explains why the triangles representing TFC/GDP do not exactly match the sum of the two other components for some countries.

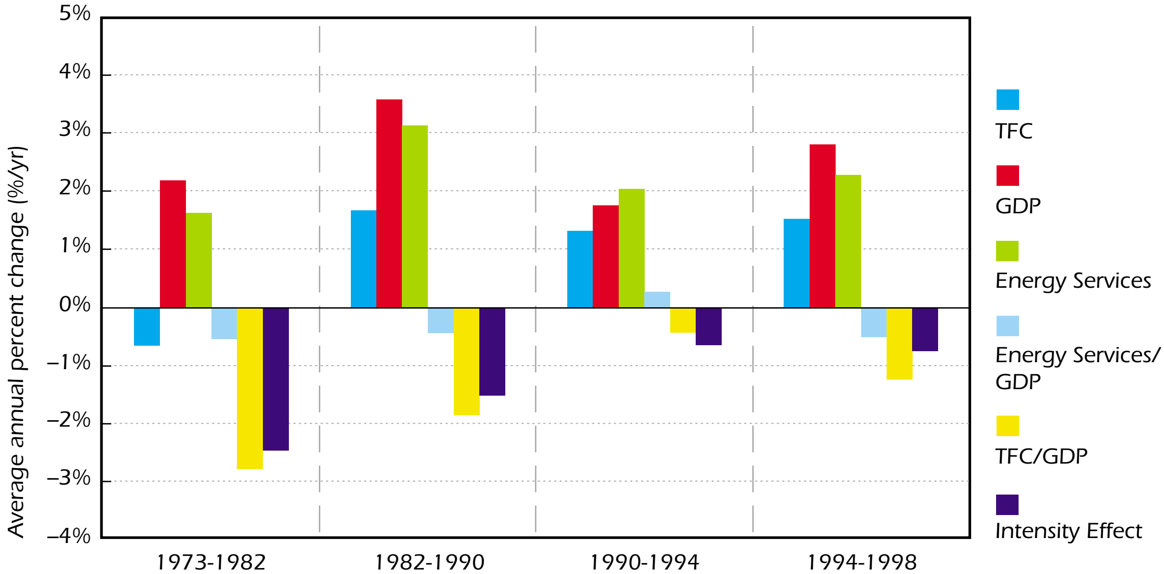
8. Energy use in oil and gas production is accounted for in the energy sector and is thus not part of TFC.

Energy Use, Energy Service Demand and Intensities

Decoupling of energy services to GDP continues, but reductions in energy intensities have slowed

Figure 3-11

Changes in TFC, GDP, Energy Service Demand and Intensities, IEA-11



The decline in energy per unit of GDP between 1973 and 1982 for the aggregate IEA-11 was strong enough to lead to a net decline in final energy consumption. The most significant impact came from declines in sub-sectoral energy intensities, though growth in energy service demand lagged GDP during this period and thus also contributed to the decline in energy per GDP.

GDP grew rapidly between 1982 and 1990, but with a more moderate decline in energy per GDP than the previous period. Since energy services per GDP also fell, the main reason for the slower decline in energy per GDP was less impact from reduced end-use intensities.

Between 1990 and 1994, GDP growth in IEA-11 was moderate as several IEA economies went through recession and energy service demands increased faster than GDP. This is one explanation of why energy per GDP only fell by 0.3% per year on average. It is also because the decline in sub-sectoral energy intensities slowed significantly compared to the earlier periods.

After 1994, the slow decline in intensities continued, but was then augmented by a decline in the ratio of energy services to GDP. The decline in this ratio contributed almost as much as the decline in intensities to the 1.2% annual average reduction in energy per GDP between 1994 and 1998.

Impact of Changes in Energy Service Demand and Intensities

Declines in sub-sectoral energy intensities account for about 80% of the total 37% reduction in TFC/GDP

Figure 3-12

TFC per GDP, and Impacts from Changes in Energy Services per GDP and Energy Intensities, IEA-11

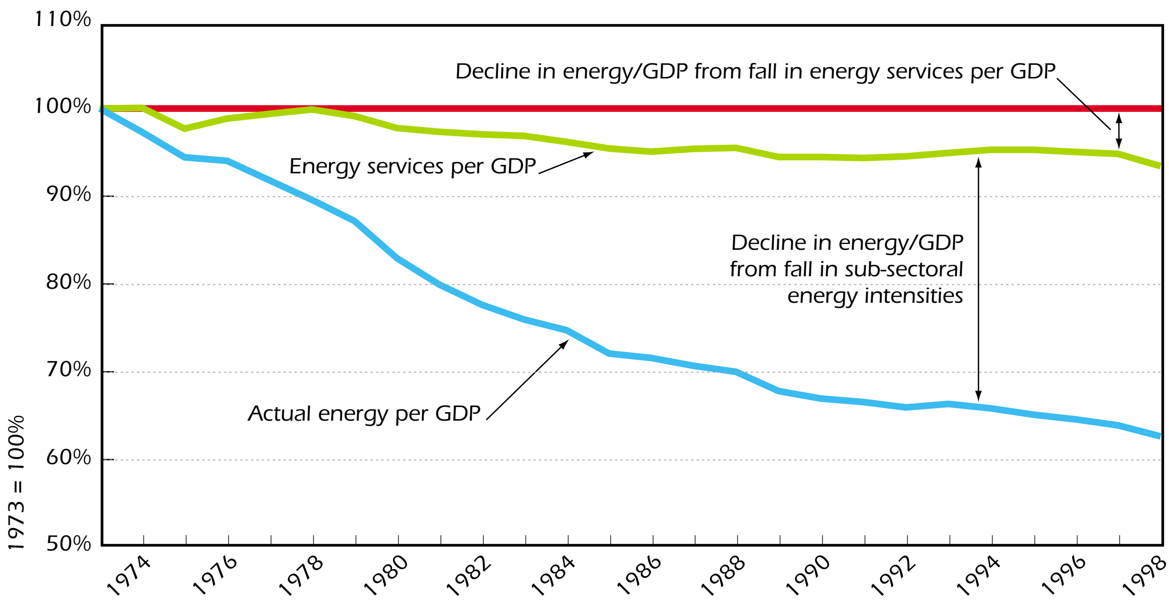


Figure 3-12 illustrates how both the reductions from the energy intensity effect and from the decoupling of energy service demand and GDP led to reduced energy consumption per unit of GDP. As seen in Figure 3-11, until the most recent years the intensity effect was by far more important than the energy services per GDP ratio in driving down energy per GDP. The decline in the latter ratio only accounted for one fifth of the 37% decline in energy per GDP since 1973.

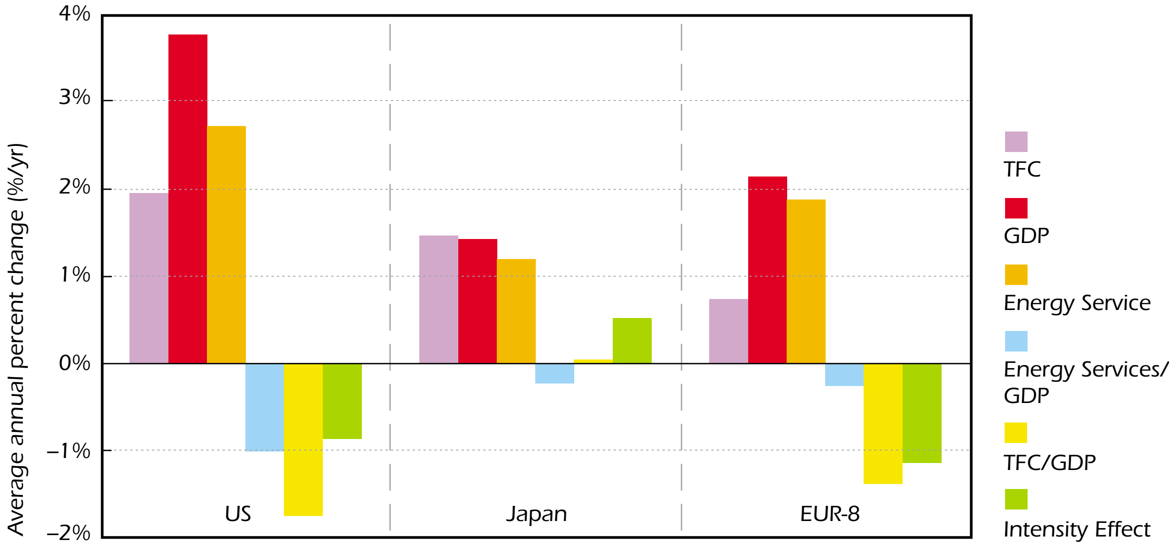
In summary, four important observations can be made from Figure 3-11 and 3-12 for the IEA-11 countries: first, there seems to be a tendency for energy service demand to increase less than GDP except in recession periods; second, the decline in energy per GDP slowed gradually from the first half of the 1980s to the mid-1990s when it again accelerated somewhat; third, the decline in energy per GDP between 1973 and 1994 can mostly be attributed to falling sub-sectoral intensities, closely related to energy efficiency improvements; fourth, recent trends indicate that falling energy service levels relative to GDP are almost as important as improved energy efficiency in reducing energy demand per unit of GDP.

Energy per GDP and Intensities: A Closer Look at Recent Trends

Declines in US energy per GDP resulted from reduced energy service demand per GDP, while in Europe they resulted from intensity declines

Figure 3-13

Changes in TFC, GDP, TFC/GDP, Energy Services/GDP, and Intensity Effect, 1994-1998



As illustrated in Figure 3-11 decoupling energy service demand from GDP growth has been almost as significant as declining energy intensities to reduce energy per unit of GDP for IEA-11 after 1994. This trend was more prominent in the United States than in Japan or Europe, as seen in Figure 3-13. In the United States, more than half of the 1.8% average annual reduction in energy per GDP between 1994 and 1998 can be ascribed to the rapid growth in GDP relative to the demand for energy services, with the rest being the result of falling sub-sectoral energy intensities.

Energy intensities actually increased in Japan between 1994 and 1998 but thanks to a small decrease in the energy service demand to GDP ratio, energy per GDP remained almost unchanged. Among a group of eight European countries, energy per GDP fell at almost the same rate as in the United States, but here most of the decrease came as a result of declining sub-sectoral energy intensities.[9]

Developments since 1994 show that in both the United States and the group of eight European countries, energy per GDP has fallen more in recent years than seen since the mid 1980s. While most of the decline in the United States is related to strong economic growth relative to energy service demand, the decline in Europe came more as a result of improvements in sub-sectoral energy intensities. In Japan, energy services lagged behind the very modest growth in GDP, but nevertheless energy per GDP did not fall.

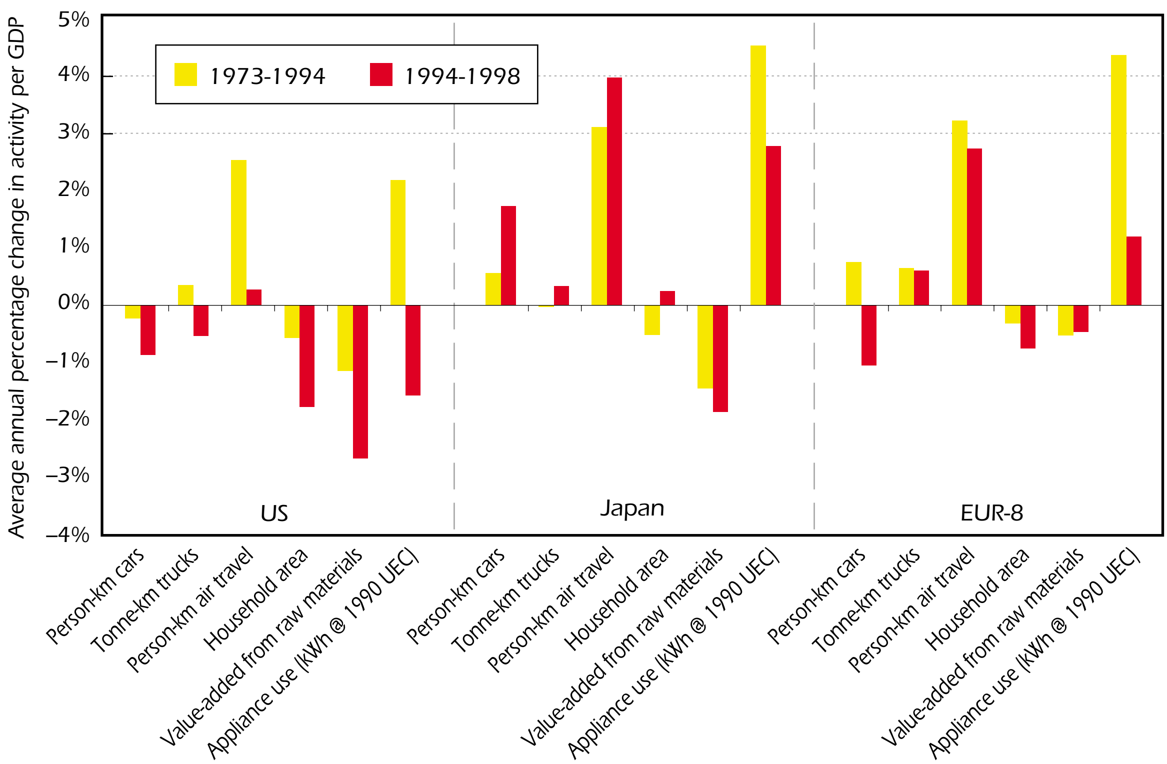
9. The eight European countries of the IEA-11 group; Denmark, Finland, France, Germany, Italy, Norway, Sweden and the United Kingdom, here denoted EUR-8.

Changes in Key Activities Driving Energy Service Demand

Most key energy demanding activities in the United States have grown less than GDP since 1994

Figure 3-14

Changes in the Ratio of Key Sub-sectoral Activity Levels to GDP



What caused the lag in energy service levels relative to GDP to accelerate in the United States after the mid-1990s while it was not seen to the same extent in Japan and EUR-8? To answer this, it is interesting to investigate the rate of growth in key activities that drive demand for energy services relative to GDP. Altogether changes in the activities shown in Figure 3-14 comprise most of the changes in the energy service effect discussed in the previous figures.

When one of these factors grows slower than GDP it will contribute to reducing the energy service to GDP ratio and thus energy per GDP. For example, if the share of GDP from the production of energy-intensive raw materials declines, it will drive down energy consumption per GDP. This has been the case for the United States, Japan and the EUR-8 since 1973. Similarly, growth in household floor area has lagged GDP increases, except for recent trends in Japan, and thus eased the demand for energy per unit of GDP.

Averaged over the 1973-1994 period, the main activities that grew faster than GDP in all regions were air-travel, use of electric appliances and, to some extent, truck freight haulage. In Japan and Europe, increased car travel relative to GDP also contributed to driving up energy demand. Still the energy services to GDP ratio fell in each region, which mostly is due to structural changes in manufacturing and reduced household area per unit of GDP.

The growth rates for all activities in Japan after 1994 did not slow as much as GDP, except the production of raw materials. While in Europe, the strong growth in air travel continued, and although to a lesser extent than before, the ownership and use of appliances still led the growth in GDP.

All activity indicators in the United States fell relative to the rather strong growth in GDP after 1994, with a small exception for air travel. Travel by car was lower than GDP growth by almost 1% per year and growth in household floor area by almost 2%. But the most important factor lowering the energy service per GDP ratio was the decline in the raw material share of GDP. This decline was to a large extent driven by increased shares of other types of manufacturing, most notably the production of electronics and communication equipment. This can be related to the development of the so-called "information economy", which may have important impacts on future energy use (see box).

Energy Impacts of the Information Economy

Growth of information and communication technology in an economy can affect energy demand in several ways:

- *Improved overall productivity and the relative productivity of different sectors*. This will boost economic growth and possibly alter the relative prices of goods and services and thus affect both the level and pattern of energy use.
- *Structural effects.* Both the production and use of information and communication technology may lead to structural changes. For example, the production of electronics requires much less energy per value-added than the average for manufacturing so an increased share of electronics production would lead to lower aggregate energy intensity in manufacturing, and thus contribute to lower energy per GDP.
- *Changes in activity levels that drive demand for energy services.* Increased use of electronic commerce can reduce the need for building area for storage and shops and thus the requirements for heating and lighting. On the other hand, freight transport activity, especially for non-bulk items sent by air or trucks, may increase as more consumer products are ordered via the Internet. Increased telecommuting may reduce work-related travel in the short-term, but can in a longer perspective also increase travel distances as people move farther away from city centres when they do not need to be in the office every day.

The acceleration in the decline of energy consumption per GDP in the United States since the mid-1990s started a debate about whether this could be explained by impacts from the development of the "information economy". If this was the case certain end-uses would be expected to rise or fall relative to others. As indicated by Figure 3-14, this did happen to some extent: information and electronics technologies played an important role in the strong manufacturing sector growth in the United States, which reduced the importance of energy intensive raw materials and thus the need for energy services per value-added.

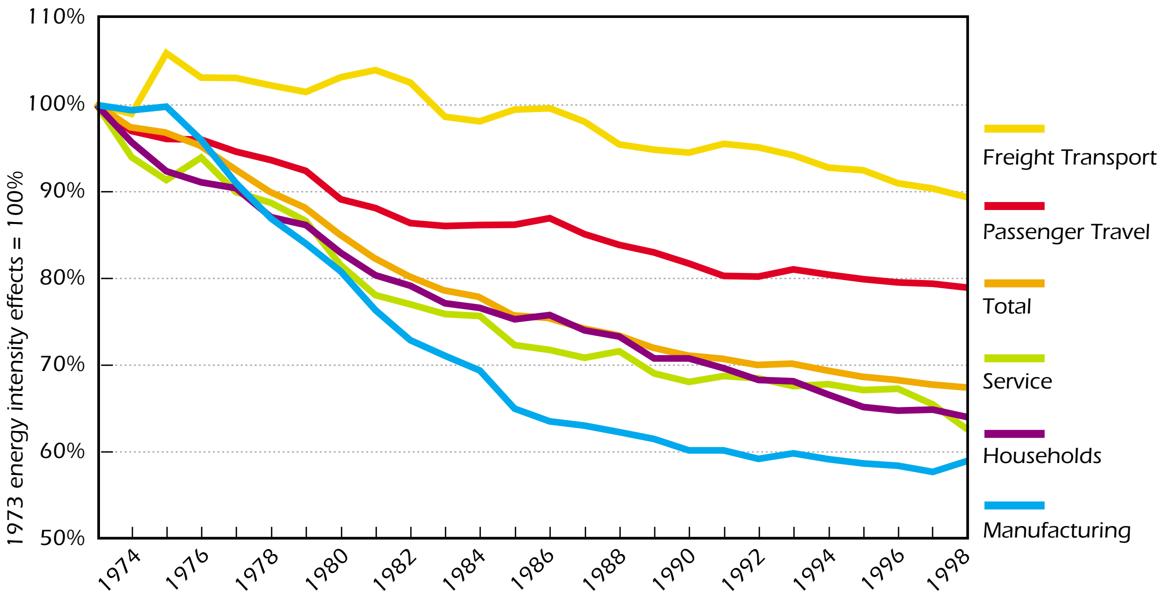
This development has nothing to do with energy efficiency improvements. In fact, the decline in sub-sectoral energy intensities was very modest, which contrasts with earlier periods when intensity changes accounted for most of the drop in energy per GDP in the United States.

Energy Intensities by Sector

Energy intensity declines have slowed in all sectors since the late 1980s

Figure 3-15

Sector Intensities and Total Economy Effect, IEA-11



Declining end-use intensities have been responsible for most of the drop in the energy/GDP ratio during most of the 1973 to 1998 period. But notably, the rate of decline has slowed since the mid to late 1980s. The intensity effect for the whole economy, which is calculated as the sum of all sectoral intensity measures, weighted at 1990 energy use shares, declined by as much as 2.5% per year on average between 1973 and 1982. Over the next eight years there was still a significant decline, although at a somewhat lower average annual rate of 1.5%. After 1990, the decline rate was down to only 0.7% per year, averaged over the 1990 to 1998 period. (See also Figure 3-11.)

This slowing rate of intensity decline trend is seen in most sectors. It is most prominent in the manufacturing sector: intensity (corrected for changes in structure) fell by 41% over the 1973 to 1998 period, but it had already declined 36% by 1986. This corresponds to an average annual rate of decline of 3.5% between 1973 and 1986 and only 0.6% per year for the next twelve years.

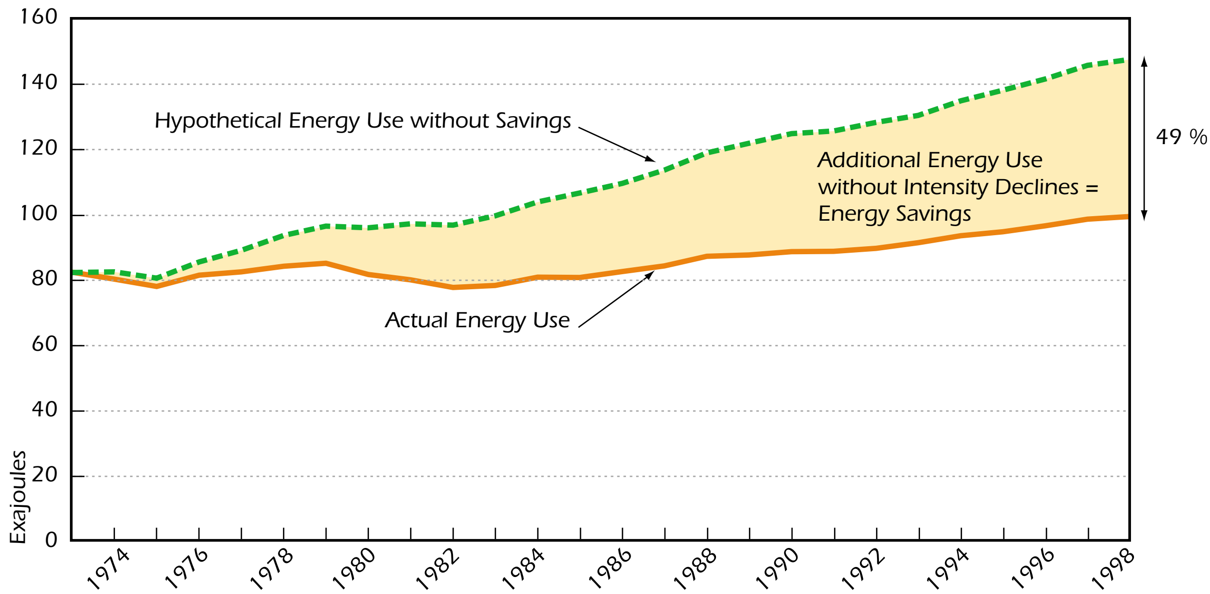
The service and household sectors trailed manufacturing in terms of total intensity reductions. Interestingly, the decline rates in these two sectors have followed each other closely throughout most of the period, with slightly stronger reductions than average for the whole economy. Passenger and freight transport have pulled up the average economy-wide intensity effect. While the passenger travel intensity fell at almost the same average rate before and after 1986 (about 1% per year on average), the freight intensity in 1986 was at about the same level as in 1973 (both intensities calculated holding the modal mix constant). Since 1986, the freight intensity has declined at about the same rate as the passenger travel intensity.

Energy Savings

Without 25 years of energy savings, energy consumption would have been almost 50% higher

Figure 3-16

Actual Energy Use and Hypothetical Energy Use without Intensity Reductions, IEA-11



How much did falling energy intensities in the various sectors reduce total energy use in IEA-11 between 1973 and 1998? In Figure 3-16 the lower line shows actual climate-corrected energy use, which includes the effect of changes in energy intensities. The upper line represents the hypothetical energy use that would have occurred if energy intensities had remained at the 1973-level in all sectors.[10] Energy savings due to falling intensities are then calculated as the difference between the hypothetical energy use without savings and actual energy use (see equation 5 in Chapter 2).[11]

Relatively steady declines in energy intensities resulted in energy savings, although the savings rates have slowed somewhat over recent years (see Figures 3-11 and 3-15). By 1998 the savings amounted to 48.2 EJ, which corresponds to 49% of 1998 energy use level. In other words, IEA-11 energy use would have been 49% higher in 1998 if intensities of the different sub-sectors and end-uses had remained at 1973 level.

10. Since this book uses a Laspeyres index decomposition with base-year 1990 both the intensity effect in 1973 and in any other year are weighted using 1990-structure in each sector. The hypothetical energy use described by the upper line is the same as the energy service demand, except for a residual term that occurs due to interaction effects (refer to Chapter 2).

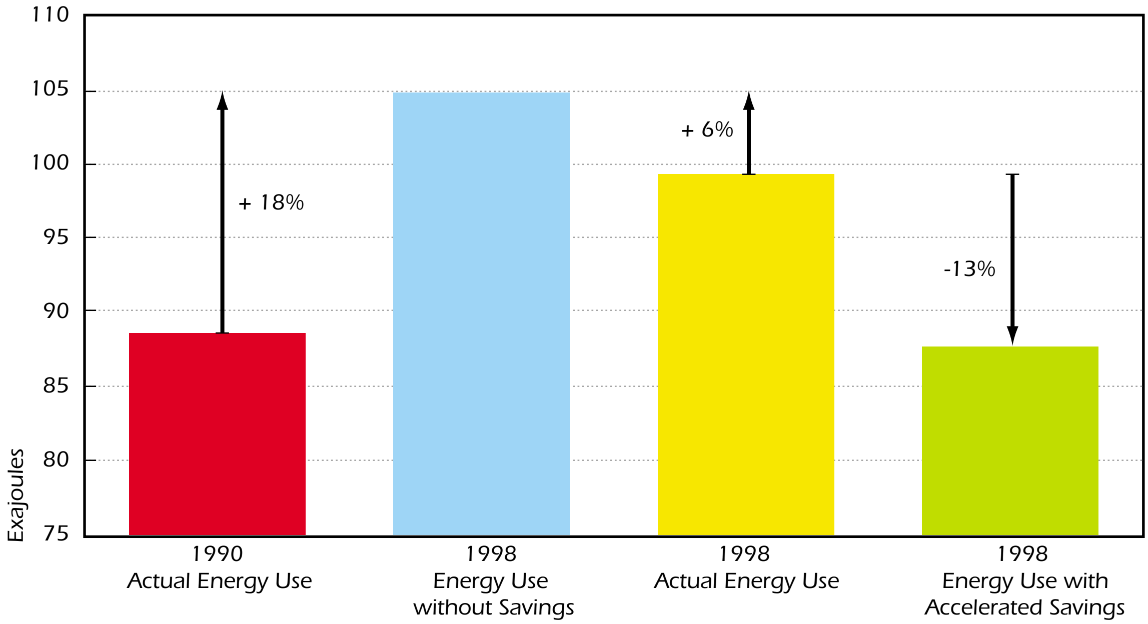
11. Using this method the savings in a given year reflect the impact of the decline in intensities between 1973 and the given year. As a consequence, subtracting the savings in a year, say 1998, from another, say 1990, does not necessarily yield the savings resulting from the decline in intensities between 1990 and 1998. If savings due to changes in intensities between 1990 and 1998 are to be calculated correctly, the upper curve needs to be rebased to 1990-level.

Accelerated Energy Savings Case

If savings rates had followed "the second best" IEA-11 could have saved 13% more energy between 1990 and 1998

Figure 3-17

Actual Energy Use in 1990 and 1998 and Two Hypothetical Energy Savings Cases, IEA-11



How much more energy could have been saved if each of the IEA-11 countries had reduced their end-use intensities at the same rate as the country with the strongest intensity reduction in each end-use?

Before answering the question it is important to keep in mind that many countries had very different starting points for some of these intensities. Looking back to 1973, for example, the fuel intensity of cars in the United States was much higher than in Europe and Japan where cars were smaller, lighter and had less powerful engines. This means that there was more room for US cars to reduce fuel intensity throughout the 1970s and 1980s. Similarly, in 1973 Japan had a low space heating intensity due to both efficient heating practices and lower heating comfort levels. Thus, it would be unrealistic to expect the same rate of intensity reductions in Japan as in countries where heating comfort levels already were high.

By 1990 these differences among countries were less significant which makes end-use comparisons of intensity developments for recent years more meaningful. In Figure 3-17 the bar labelled "1998 energy use with accelerated savings" illustrates what energy use in 1998 would have been if each IEA-11 country's own intensity decline was substituted end-use by end-use (listed in Figure 2-2 in Chapter 2) by the decline rate of the country with the second strongest intensity reduction between 1990 and 1998, and keeping the country's own activity and structural development. (The second "best performance" was chosen to avoid the impact of extreme cases, which in some cases could be a result of data uncertainties.)

The results of these calculations across all IEA-11 countries show that in the accelerated savings case, energy use would have been 13% lower than the actual energy use in 1998. By comparison, if each country's intensity had remained at 1990 levels, energy use would have been 6% higher in 1998 (bar labelled "1998 energy use without savings" in Figure 3-17).[12]

The case without savings would have resulted in an 18% increase in energy use between 1990 and 1998. In the accelerated savings case, energy use in 1998 would have been virtually the same as the 1990 level. This compares with the 12% increase that energy use actually grew from 1990 to 1998.

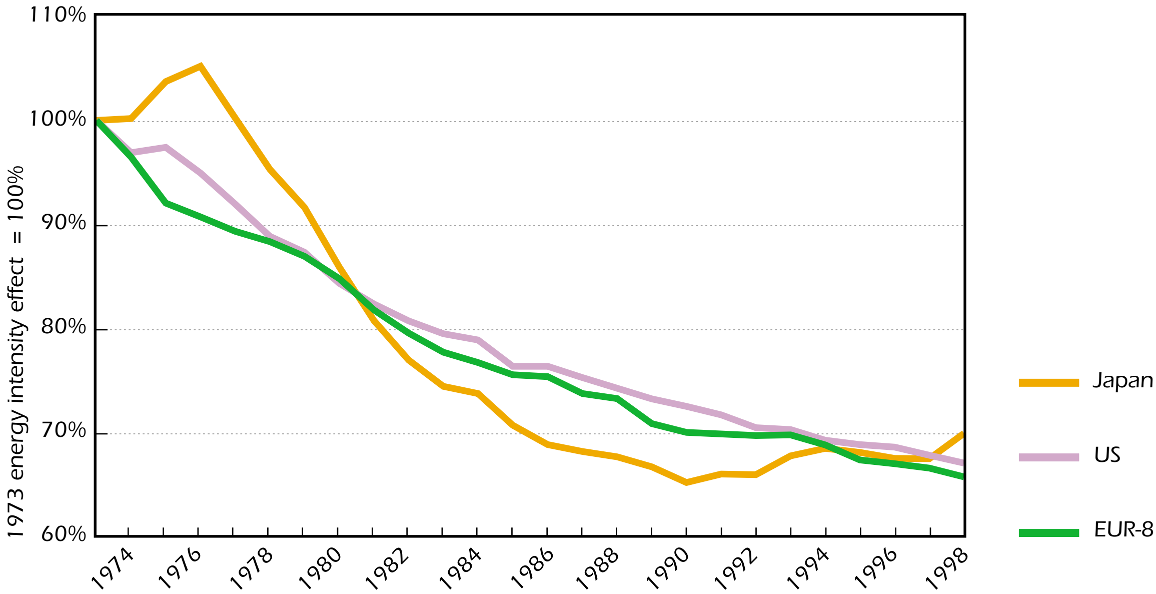
12. Calculated in the same manner as the hypothetical energy use without savings in Figure 3-16.

Energy Intensity Effect

Economy-wide intensity effect fell by about 30% in each region

Figure 3-18

Changes in Economy-wide Energy Intensity Effect



The economy-wide energy intensity effect declined by almost the same amount in each region between 1973 and 1998: 30% in Japan, and 34% in the United States and EUR-8.

The development of the EUR-8 and the Unites States' intensity effect closely followed each other through 1998, but it was very different in Japan. Intensity rose between 1973 and 1977 in Japan largely due to increased energy per value-added in key manufacturing industries. After 1977, falling intensities in these industries led the very dramatic decline in the Japanese intensity effect until the mid-1980s. This decline is stronger than seen in any period in any other country studied by the IEA.

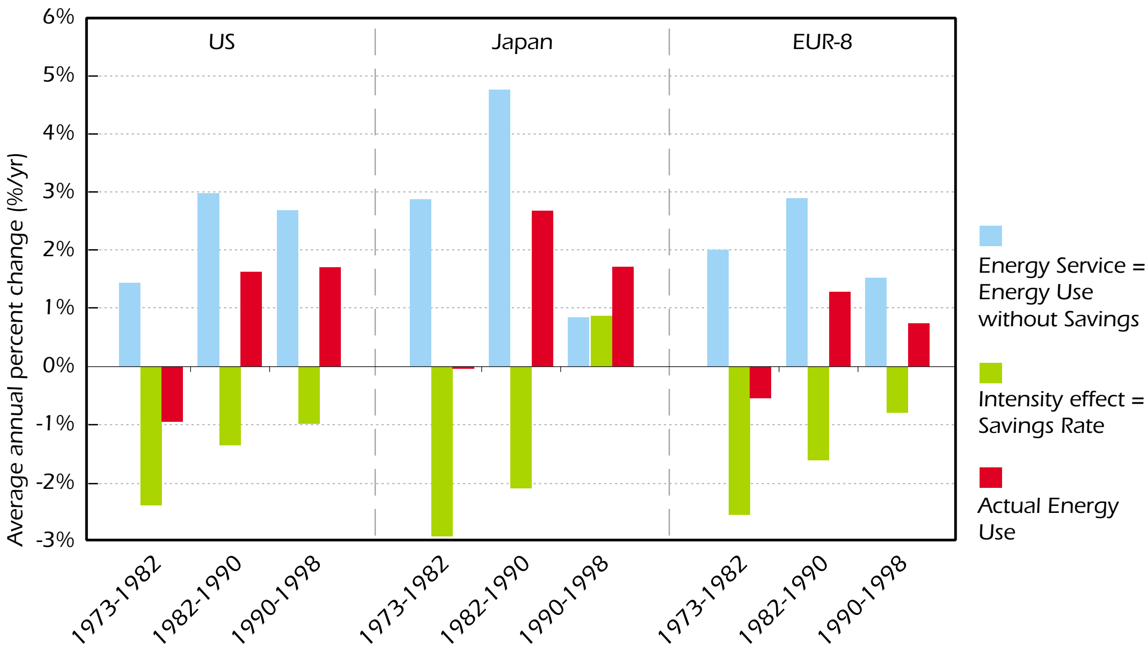
As Japan slipped into recession after 1990, the economy-wide energy intensity effect shifted and started to increase. This gave the United States and EUR-8 a chance to catch up, and by 1994 intensities had fallen by just over 30% since 1973 in all three regions. After 1994, the decline in Japan more or less followed the trends in the United States and EUR-8 until 1998 when the Japanese economy-wide intensity jumped due to increased intensities in the manufacturing and service sectors.

Energy Intensity and Savings

The rate of energy savings has slowed

Figure 3-19

Changes in Energy Service Demand, Intensity Effect and Actual Energy Use



Without the reductions in energy intensities, energy demand would have grown considerably in the United States, Japan and the EUR-8. This is illustrated in Figure 3-19 where the first bar represents the hypothetical development if intensities had not changed and energy use had followed growth in energy service demand. The second bar shows the impact of energy intensities, while the third bar gives the changes in actual energy use. The average annual percentage change in actual energy use is equal to the difference between the two first bars.

Before 1982 energy intensity declines were strong, leading to enough savings to avoid increased energy demand in all three regions. In the United States and EUR-8 actual energy use fell considerably between 1973 and 1982 due to the intensity reductions. On the other hand, Japan had the highest savings rate but also the strongest growth in energy service demand. The two factors exactly offset each other with the result that energy consumption in 1982 was at the same level as in 1973.

From 1982 to 1990 IEA economies generally enjoyed strong economic growth accompanied by rapidly increasing energy service demand. Absent changes in energy intensities, energy consumption would have increased by 3% per year on average in the United States and EUR-8 and almost 5% per year in Japan. Although intensities declined at a lower rate than previous periods, energy savings were still significant, but not enough to avoid a net increase in total energy consumption.

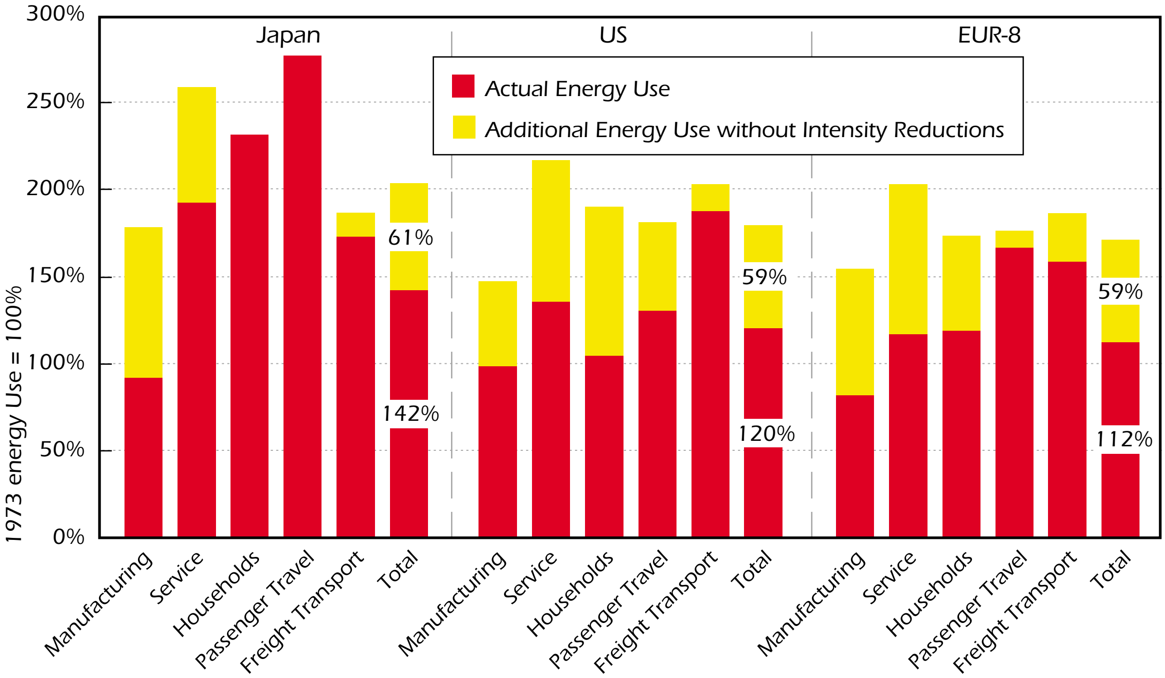
After 1990 the decline in energy intensities slowed in the United States and EUR-8, which led to only modest savings. Energy intensities actually increased in Japan, clearly a result of economic recession. However, due to relative modest growth in energy service demand in the EUR-8 and Japan, energy use still grew less than in the 1982 to 1990 period, while energy use growth in the United States was only marginally higher than in the pervious period.

Energy Savings by Sector

Total energy savings across the three regions are similar, but there are important differences by sector

Figure 3-20

Actual Energy Use and Energy Savings



The decline in energy intensities between 1973 and 1998 led to considerable energy savings in all three regions. By 1998 the total savings in amounted to 61% of 1973 energy use in Japan, and 59% in the United States and EUR-8.

Japanese energy consumption in 1998 was up 42% from the 1973-level, but would have been a factor two higher without the savings from reduced energy intensities. Similarly, in the United States a potential total growth in energy use of 79% between 1973 and 1998 was reduced to 20% due to savings, while in the EUR-8 the modest 12% increase in energy demand would have been 71% if energy intensities had remained at 1973-levels. Without these savings energy use in 1998 would have been 43% higher in Japan, 49% in the United States and 53% in the EUR-8.

Total savings among the three regions are similar, but they were achieved through different sector developments. In Japan, the intensity declines in the manufacturing and service sectors led the savings, while there were only modest reductions in the freight sector. In Japan's household and passenger travel sectors, energy intensities actually increased over the period and thus led to "negative savings" (not shown in the figure).[13] In the EUR-8, manufacturing had the strongest intensity decline, followed by the service and household sectors. There were relatively similar reduction rates in the three stationary energy use sectors in the United States, while it was the only place where important intensity declines were experienced in the passenger travel sector.

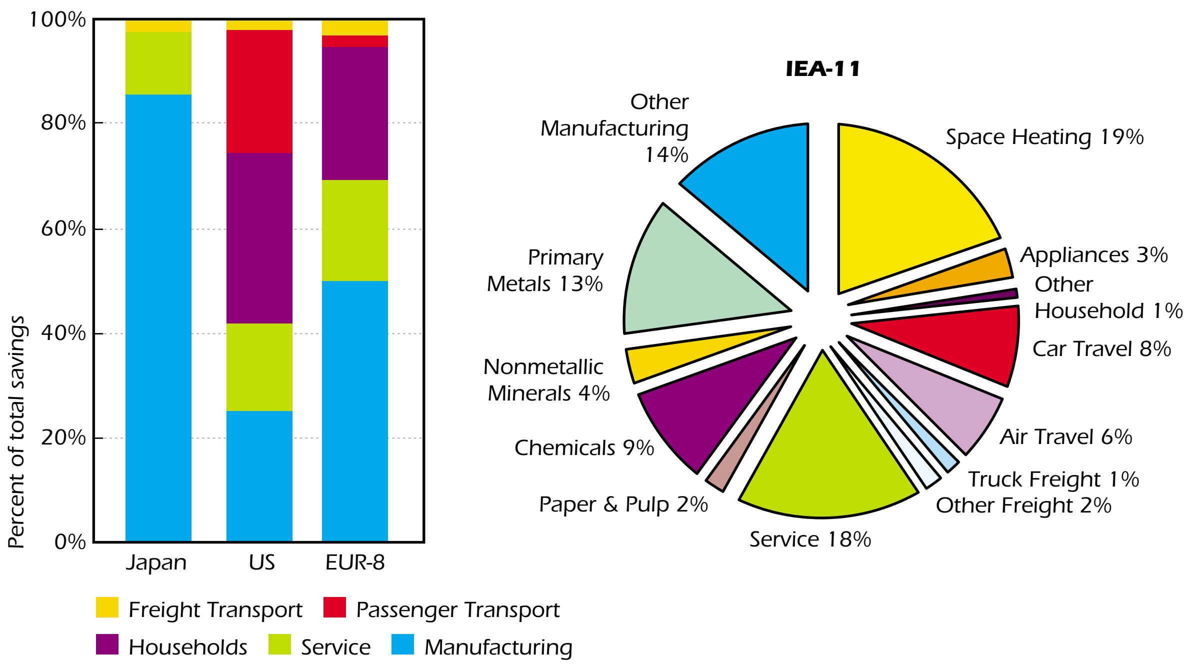
13. This development is not necessarily due to lack of energy efficiency improvements, but rather to the fact that Japan in the 1970s had a low degree of space heating comfort and relatively small cars compared to other countries (refer to Chapter 5 and 7).

Contribution to Energy Savings by Sector

Outside the United States, transport has contributed little to overall savings

Figure 3-21

Contribution to Energy Savings from Sectors and End Uses



The savings rates in Figure 3-20 do not give a clear picture of the contribution of each sector to the overall savings since the relative weight of the sectors varies. For example, in Japan manufacturing by far is the most important sector in terms of energy use, while in the United States, passenger travel that has the highest share of energy consumption. In the EUR-8, the household and manufacturing sectors share first place as the most important energy end-use sectors.

These relative weights help to explain why more than 80% of the total energy savings in Japan came in the manufacturing sector, while manufacturing only accounted for a quarter of the savings in the United States and about half the savings in EUR-8 (see left-hand part of Figure 3-21). Only 5% of the savings in the EUR-8 came from the two transport sectors while household and service sectors contributed 25% and 20%, respectively. The highest share of the savings in the United States was in households (30%), while passenger travel matched the 25% share of the manufacturing sector with the service sector just behind at 18%.

Sectoral savings came as energy efficiency improved in the myriad of energy-using technologies and processes. Examining each one in detail is beyond the scope of this study. Instead intensity developments are analysed for some two dozen sub-sectors and end uses. The contribution from some of these to total IEA-11 savings between 1973 and 1998 are shown in the right-hand part of Figure 3-21. Although the contributions vary significantly across countries, it shows that for IEA-11 reduced space heating intensities were a very important contributor to overall savings. Surprising perhaps is the small contribution made from important energy users in the transport sectors - car travel and truck freight.

The subsequent chapters discuss these sectoral developments in more detail.

Chapter 4. MANUFACTURING

Highlights

- In 2000 the manufacturing sector accounted for 27% of total IEA final energy consumption, down markedly from 36% in 1973. The decline in this share is due to a 15% reduction in manufacturing energy use between 1973 and 2000 and by increased energy use in other sectors. The drop in manufacturing energy use was driven by a 62% decline in oil consumption, which more than offset the increased use of natural gas and electricity.
- Analysing data for a group of eleven IEA countries (IEA-11), together accounting for almost 90% of IEA total manufacturing energy use, shows that energy consumption declined, even with an 88% increase in manufacturing output between 1973 and 2000. Consequently, aggregate energy use per unit of output fell significantly.
- This decline in aggregate intensity is affected by both structural changes and reductions in individual energy intensities in each manufacturing sub-sector. Structural changes impact energy use when the proportion of energy-intensive products such as steel and chemicals in total manufacturing production increases or decreases. Although the overall share of energy-intensive raw materials in IEA-11 manufacturing output did not fall significantly between 1973 and 1998, the mix of raw material products did change, which led to a less energy-intensive manufacturing structure.
- For IEA-11 these structural changes explain about a third of the decline in manufacturing energy use per unit of output between 1973 and 1998. The rest of the reductions are related to declining energy intensities in individual manufacturing sub-sectors. However, the impact of structural changes varies among countries: in most, the structure became less energy intensive, while in a few countries structural changes drove up energy use. Hence, accounting for structural changes is important to explain variations in the evolution of manufacturing energy use among countries.
- The impact of structural change has increased since 1994. In almost all countries the share of less energy-intensive products increased. Rapid output in electronics and electronic equipment industries led the shift in most places.
- On the other hand, the decline in energy intensities for the IEA-11 group almost came to a halt after 1994. This follows a period marked with only modest reductions in intensities after oil prices fell in 1986. In fact, while sub-sectoral intensities declined on average by 3.2% annually between 1973 and 1986, the average decline was down to 0.5% per year for the next twelve years. The trend of slowing intensity reductions can be seen both across countries and across sub-sectors. Examining fuel price and consumption data shows that this slowdown came after a significant reduction in energy's share in manufacturing production costs. This results from both the successful reduction in intensities throughout the 1970s and early 1980s and the fall in energy prices after the mid 1980s.
- Even if structural changes driven by the expansion of the "information economy" have helped reduce manufacturing energy use in recent years, this analysis shows a gloomy picture of recent energy efficiency developments. IEA countries may face strong growth in manufacturing energy use unless energy efficiency improvements resume.

Definitions, Methodology and Data Used in this Chapter

Sectors

This analysis disaggregates the manufacturing sector into seven sub-sectors as defined by the International Standard Industrial Classification (ISIC), revision 2:

- paper and pulp (ISIC 341);
- chemicals (ISIC 351 and 352);
- non-metallic minerals (ISIC 36);
- ferrous metals (ISIC 371);
- non-ferrous metals (ISIC 372);
- food and kindred products (ISIC 31);
- "other manufacturing" – all remaining manufacturing sub-sectors, excluding oil refining.

The first five sub-sectors refer to the production of raw materials. For some countries, value-added data separating ferrous and non-ferrous metals are not available and thus, for these countries, the aggregate of the two sectors, termed primary metals, is used in the analysis.

Energy

Measured as final (delivered) energy. Data are generally from IEA *Energy Balances of OECD Countries*. Since this source does not provide data that separate the energy-extensive printing sector from the energy-intensive production of paper and pulp, printing data have been taken from national sources, where available.

Activity

Contribution to GDP from each sub-sector, here termed value-added, measured in real terms (1995) and converted to US dollars using purchasing power parities. Value-added data are taken from the OECD STAN database, except for Australia where data are from the Australian Bureau of Statistics.

Structure

Mix of manufacturing output, measured as relative shares of value-added among the sub-sectors.

Intensity

Final energy use per activity. Energy intensity is measured in terms of economic output (value-added) because of the daunting problem of representing manufacturing output by a few well-defined products for which data on energy use and physical output are known.

Energy Prices

Energy prices are taken from IEA *Energy Prices & Taxes, Quarterly Statistics.*

Decomposition

Changes in manufacturing energy use are decomposed into impacts from changes in activity, structure and energy intensities using the method described in Chapter 2.

Country Coverage

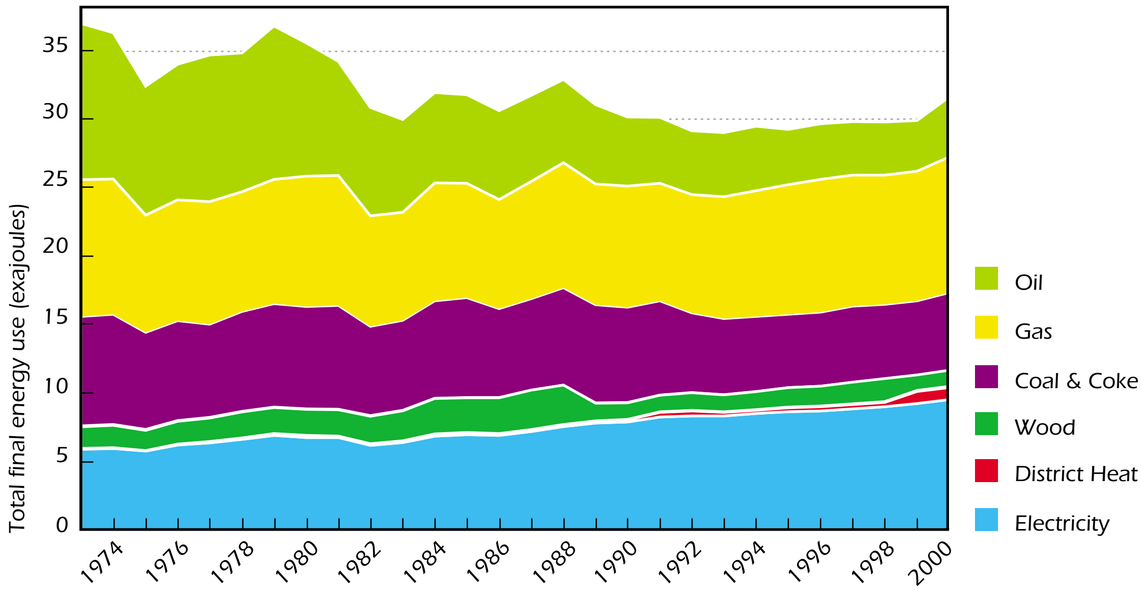
IEA has consistent time series with energy and value-added data from 1973 or 1974 through 1998 and in some cases 1999 and 2000 for eleven IEA countries. This includes Australia, Denmark, Finland, France, Germany, Japan, Italy, Norway, Sweden, the United Kingdom, and the United States. When the aggregate results of this group are presented, the group is referred to as IEA-11. Together these countries accounted for 88% of total IEA manufacturing energy use in 1998. The group of eight European countries within IEA-11 is sometimes referred to as EUR-8. In addition, IEA has complete time series with manufacturing data from 1979 for the Netherlands and 1981 for Canada.

Energy Use in Manufacturing by Fuel

Manufacturing energy use is 15% lower than in 1973, driven by a 62% decrease in oil use

Figure 4-1

Manufacturing Energy Use by Fuel, IEA Countries



Total manufacturing energy demand in IEA countries fell by 15% between 1973 and 2000. From 1973 to 1975, demand fell in response to the oil price shock to a level that was about the same as in 2000. Then, demand increased through the mid 1970s, so that by 1979 energy use was back up at the 1973 level. Similarly the oil price hike in 1979 sparked a significant decline in manufacturing energy use that lasted until 1983, when demand reached its lowest level (20% lower than in 1973). Since 1983, the variations in manufacturing energy use have been less significant, however, demand rose 5% from 1999 to 2000.

Oil use in manufacturing has declined significantly. It was 62% lower in 2000 than in 1973. This drop reflects the oil price increases in 1973-1974 and 1979, but also a move away from oil even after 1986 when oil prices fell and remained relatively stable. Coal and coke use fell 29% and natural gas use increased only marginally in the 1973-2000 period. Electricity use expanded by 65% and is now the most important energy carrier in the manufacturing sector. Electricity's share increased from 15% in 1973 to 31% in 2000, a mirror image of the decline in oil from 31% in 1973 to 15% in 2000. Coal and coke, and natural gas each accounted for 25% of the shares of manufacturing energy use in 1973, but while gas had picked up 5% market share by 2000, coal and coke lost 5%.

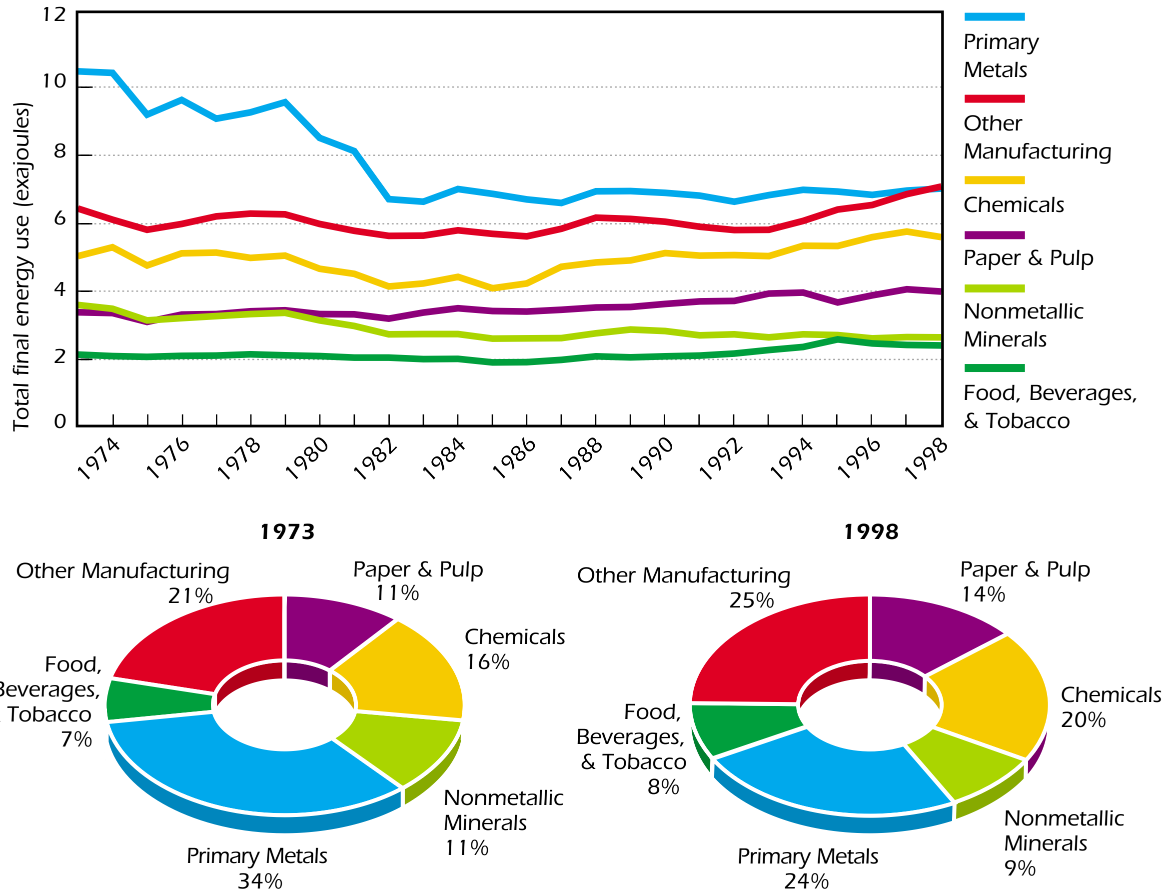
Some of the observed changes in fuel mix may be attributed to substitution driven by changes in relative fuel prices. In addition, shifts in industry structure and processes contributed to changes in the fuel mix. The increased share of electricity in the manufacturing end-use fuel mix has important consequences for CO_2 emissions since many IEA countries rely on fossil fuels for electricity generation.

Energy Use by Manufacturing Sub-sector

Energy use is still concentrated in the production of raw materials

Figure 4-2

Energy Use by Manufacturing Sub-sector, IEA-11



About two-thirds of energy use in manufacturing in 1998 was to produce raw materials; metals, minerals, chemicals and paper and pulp for the group of eleven IEA countries (IEA-11).[1] In 1973, these industries accounted for an even higher share at 73% of energy demand. This decline results from a significant drop in energy needed for primary metals production throughout the 1970s and early 1980s and a more modest decline for the production of non-metallic minerals. Energy demand increased in all other sectors. The largest increase was in the category "other manufacturing" where by 1998 it had taken over from primary metals as the manufacturing sub-sector with the highest energy consumption.

Just looking at consumption, however, gives no information about whether the observed changes in energy use since 1973 are a result of changes in energy efficiency or changes in manufacturing output, or both. To assess the trends, energy consumption in each sub-sector needs to be linked to the development of manufacturing output in that sub-sector.

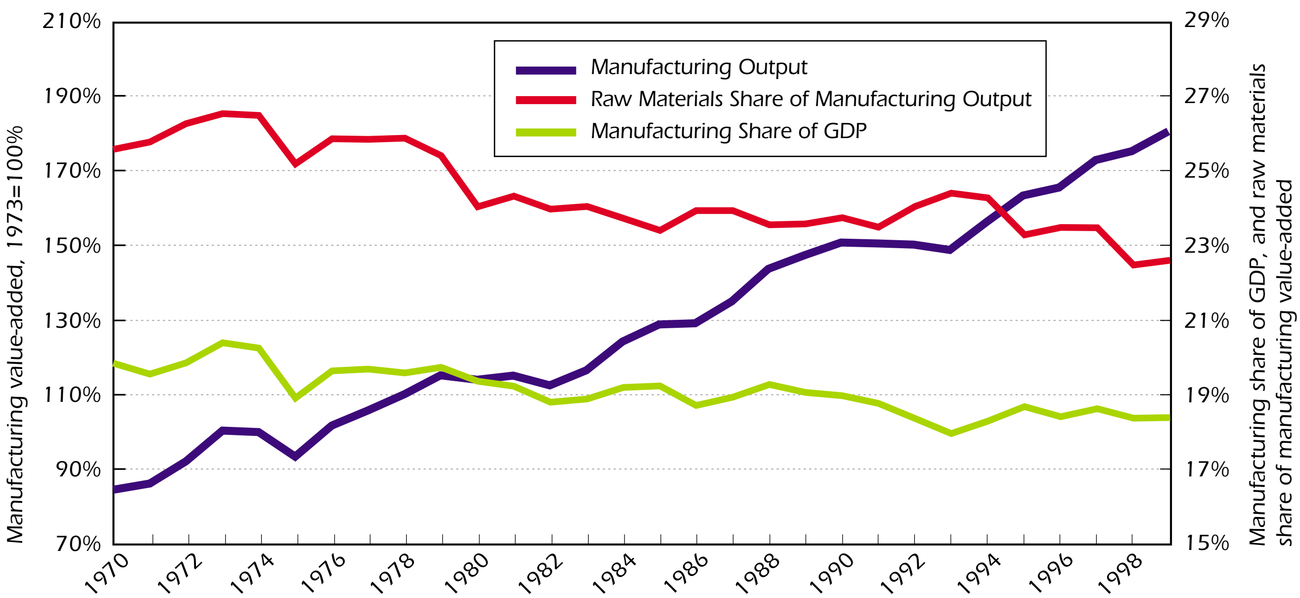
1. The IEA-11 and other country groupings are defined in the box at the beginning of this chapter.

Manufacturing Output

Manufacturing maintains its productive role in IEA economies

Figure 4-3

Manufacturing Output, Shares of Manufacturing in GDP and of Raw Materials in Manufacturing Output, IEA-11



For the IEA-11, manufacturing output (value-added) increased by 88% between 1973 and 2000, at an average rate of 2.3% per year. But the growth was not steady; it was interrupted by three periods of economic recession (1973-75, 1979-82, and 1990-93). For most countries, the recessions affected manufacturing relatively harder than other sectors, as illustrated by the drop in manufacturing share of GDP in these periods.

In the recovery periods of 1975-79 and 1982-90, growth in manufacturing usually exceeded growth in the overall economy. All countries examined here experienced reductions in their manufacturing GDP shares in the years following 1990, which confirms the trend seen for previous recessions. Since 1993, manufacturing's share of GDP has increased slightly, and in 2000 was only about one percentage point under the level in 1970. Thus, for this group of countries there is no evidence that manufacturing production has become significantly less important in generating economic growth.

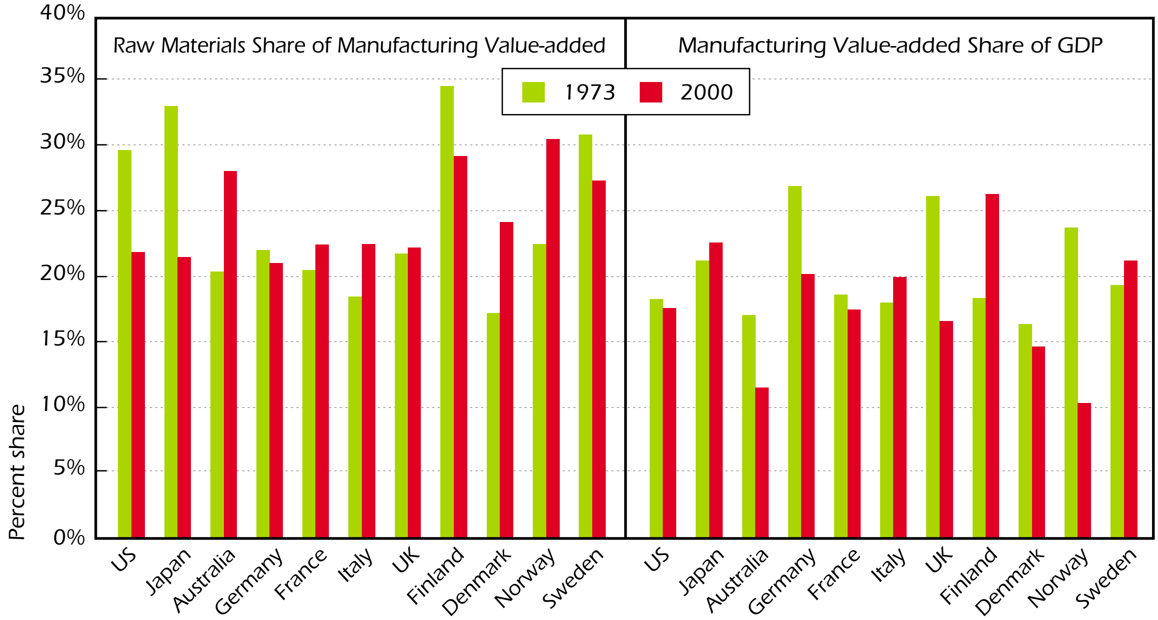
The share of energy-intensive raw materials in manufacturing output had a similar development. It also fell after both oil price shocks and recovered, or at least stabilised, in the years just after the recessions. However, after the recession of the early 1990s, production of raw materials actually increased relative to the lighter industries. Since 1994 the share of raw materials in manufacturing has declined by two percentage points, which accounts for roughly half of the total decline in this share between 1973 and 1998. This reduction represents only a modest long-term reduction in the importance of energy-intensive manufacturing.

Country Trends in Manufacturing Output

The importance of energy-intensive raw materials in manufacturing production has been reduced in only a few countries

Figure 4-4

Shares of Manufacturing Value-added in Total GDP and Raw Materials in Total Manufacturing Value-added



Data for individual countries confirm the development seen for the aggregate group. Figure 4-4 shows that only in Japan and the United States, and to some extent Finland and Sweden, was the share of energy-intensive raw materials in total manufacturing significantly lower in 2000 than in 1973. Thus, except for these countries, IEA economies have not become significantly less dependent on raw materials in their manufacturing production since 1973.

The data also indicate relatively large variations in the raw materials production shares among the IEA-11. In 1973, Denmark was at the low end of the range (17%) and Finland at the high end with almost 35% of manufacturing production concentrated in the production of raw materials. In 2000, the variation was moderated, with Norway at the high end with a 30% share and Japan at the low end with about 21% of its manufacturing value-added coming from raw materials.

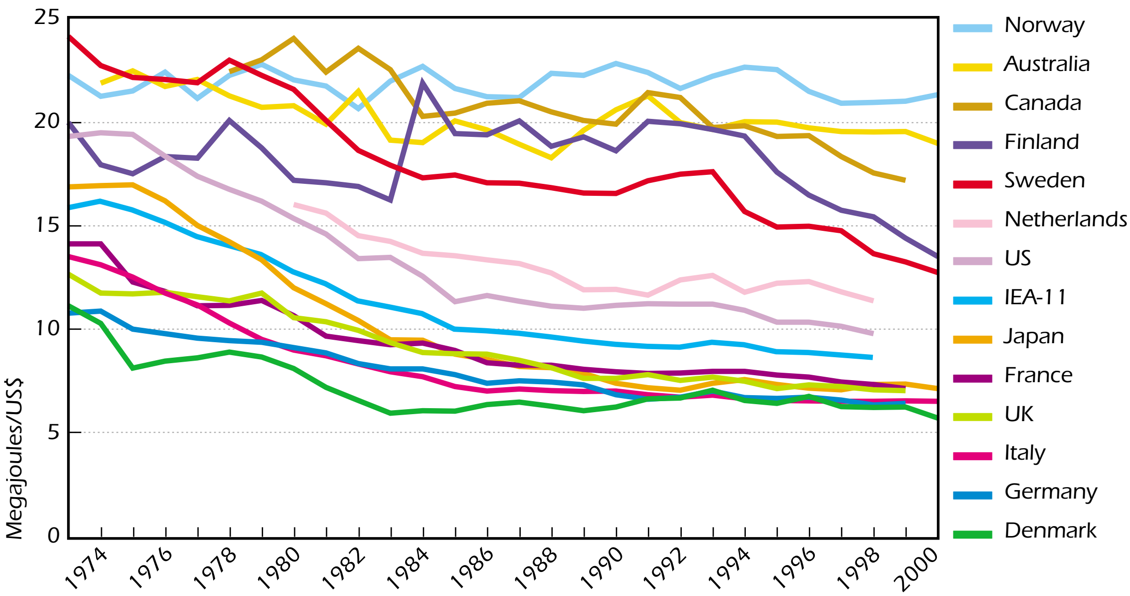
Only Australia, Germany, Norway and the United Kingdom saw a significant decline in the manufacturing share of GDP. In Norway, and to some extent the United Kingdom, the decline in this share is related to the rapid expansion of off-shore petroleum production that drained labour and capital resources from the development of land-based manufacturing industries. The figures for Germany are affected by the reunification. Other than these countries, there is no indication of a significant long-term trend towards de-industrialisation, but rather that manufacturing production is broadly following the development of overall GDP.

Aggregate Energy per Unit of Output

In the aggregate, the energy intensity of IEA manufacturing production is only about half of what it was in 1973

Figure 4-5

Energy Use per Unit of Manufacturing Value-added



A measure of aggregate manufacturing energy intensity is obtained by dividing total manufacturing energy use by total manufacturing value-added as shown in Figure 4-5. For the IEA-11 this intensity fell by 46% between 1973 and 1998, at an average rate of 2.4% per year. For the eight European countries within the IEA-11, the decline was a little less at 43% and in the United States a little more at 50%. In Japan energy per value-added fell by 57%, the strongest decline observed among the group. At the other end of the scale is Norway where the aggregate intensity hardly fell between 1973 and 1998 and Australia where it declined by only 10%.

The figure also indicates a large difference in energy intensity among the countries. Three groups of countries can be defined based on manufacturing energy intensity: the high-intensity countries (Norway, Australia, and Canada), the medium-intensity countries (Finland, Sweden, the Netherlands and the United States), and the low energy intensity countries (Denmark, France, Germany, Italy, Japan, and the United Kingdom).

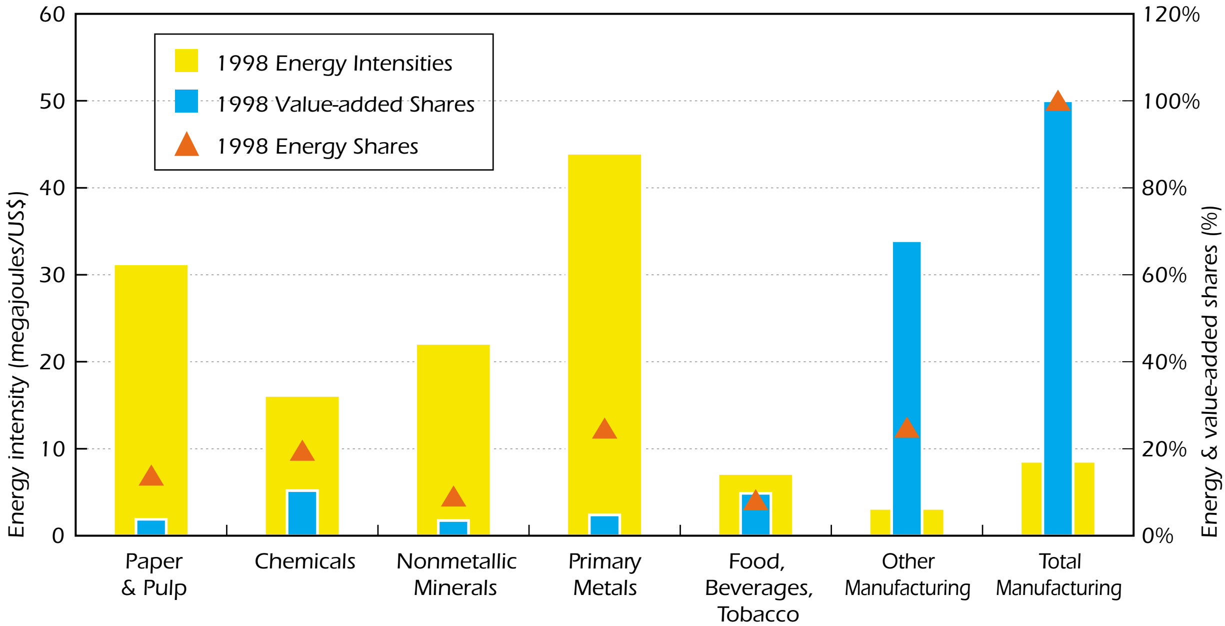
The variations in energy intensity are mostly due to differences in the mix of manufacturing products (structure) among the countries. These structural differences affect both the absolute levels and the rates of decline of the aggregate intensities. However, as the next figure illustrates, energy and value-added data at the sub-sector level are needed to quantify the importance of structural changes.

A Closer Look at Intensity and Structure in 1998

Energy-intensive sub-sectors contribute little to overall manufacturing output, but account for a large share of energy consumption

Figure 4-6

Sub-sector Energy Intensities, Value-added and Energy Shares, IEA-11



Manufacturing energy use is typically concentrated in a few energy-intensive sub-sectors that are responsible for a small fraction of total output. The most energy-intensive sub-sector in the IEA-11 is the production of primary metals. Its energy intensity was more than ten times higher than the category "other manufacturing" in 1998. The output from the primary metals sub-sector, however, constituted only 4% of total manufacturing value-added, compared to more than 65% from "other manufacturing". Each of these sub-sectors accounted for about a quarter of 1998 IEA-11 manufacturing energy use, despite the large differences in their shares of total output.

Clearly, changes in output shares can have large impacts on manufacturing energy use. The larger the difference in energy intensities among different sub-sectors, the greater the impact of shifts in output on energy use. Consider what happens when value-added from "other manufacturing" grows faster than that from primary metals. Since each dollar generated in "other manufacturing" requires one-tenth or less of the energy input required for metals, a small reduction in the share of metal production will yield a significant reduction in the aggregate manufacturing energy intensity. The impact on manufacturing energy use from these kinds of structural shifts and comparing them to impacts induced by changes in sub-sector energy intensities are an important focus for the remainder of this chapter.

Impact of Changes in Intensity and Structure by Country

Structural changes explain some of the country differences in aggregate intensity development

Figure 4-7

Decomposition of Changes in Manufacturing Energy Use, 1973-1998

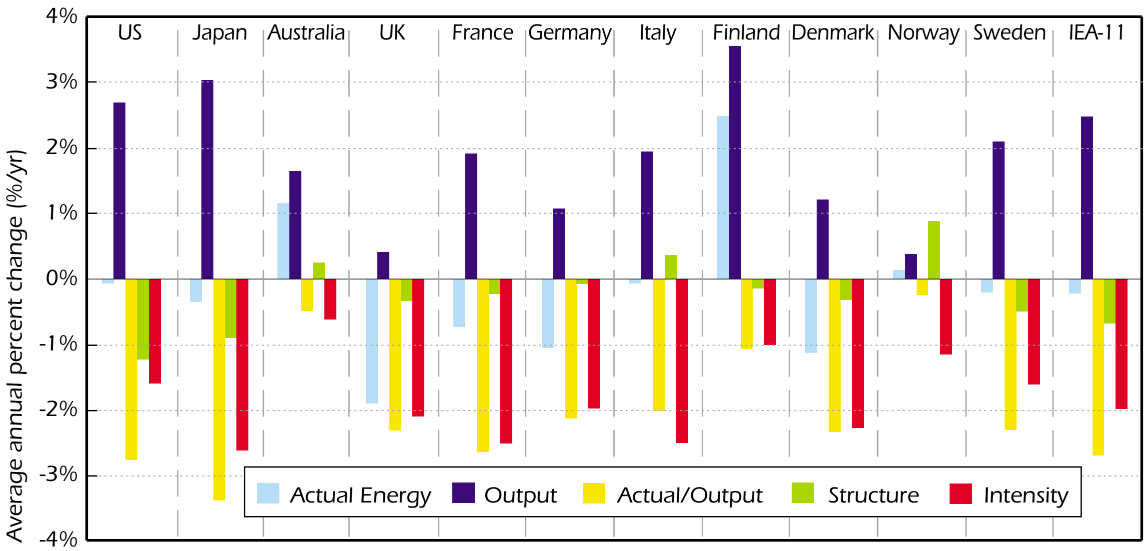


Figure 4-7 shows the average annual percentage change in actual manufacturing energy use and value-added (output) between 1973 and 1998. All countries experienced growth in value-added. Still, energy use fell in many countries indicating significant declines in aggregate intensities ("actual/output").

To what extent is this development driven by energy efficiency improvements and to what extent is it a result of structural changes? Applying the decomposition approach (explained in Chapter 2) helps to answer this question. In Figure 4-7 the fourth bar represents the impact of structural changes, while the fifth bar shows the effect of changes in energy intensities, adjusted for these structural changes.

The results indicate that structural changes have had an important impact on manufacturing energy use in Japan, the United States and Norway. In the United States and Japan, structural changes reduced energy use by about 1% per year on average, while in Norway the industry moved towards a more energy-intensive structure, which drove up energy demand by almost 1% per year. If the structural changes are accounted for, the energy intensity effect reduced manufacturing energy use by a little more than 2.5% per year in Japan, 1.6% per year in the United States, and 1.2% in Norway. Although the impact of structural changes was less in the other countries, adjusting for structure reduces the spread in decline rates across countries compared to only considering aggregate intensity. The countries with the strongest decline in aggregate intensity also had the greatest "help" from structural changes and vice-versa for the countries with the least decline in aggregate intensity. This demonstrates that only using aggregated data can be misleading when comparing energy efficiency developments among countries.

Impact of Changes in Intensity and Structure, IEA-11

Recent trends show that structural changes are reducing manufacturing energy use even more than during the high oil-price era

Figure 4-8

Decomposition of Changes in Manufacturing Energy Use, IEA-11

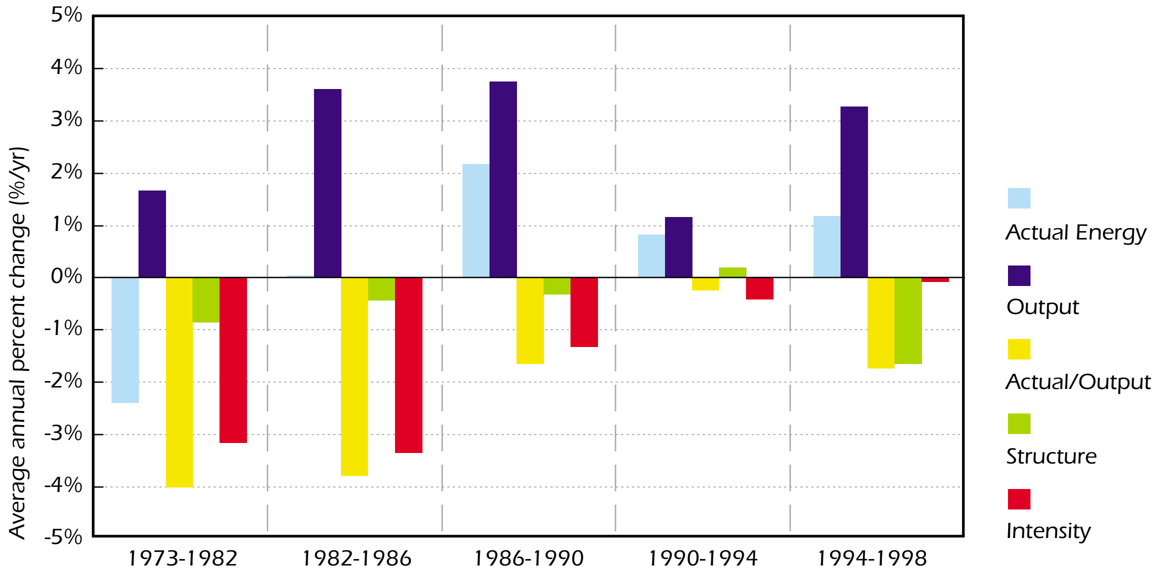


Figure 4-8 shows that the impact of structural changes has not been constant over time. Between 1973 and 1982 actual energy use fell by about 2.4% per year, while value-added averaged a 1.7% annual growth. This led to a decline in aggregate intensity of 4% per year, but since manufacturing structure as a whole became less energy intensive, the structure-adjusted intensities fell by less, about 3.2% per year on average.

A similar pattern emerges between 1982 and 1986. However, during this period increasing output offset the downward effect on energy use stemming from intensity and structural changes, with no net change in energy use as a result. Over the following four years, the rate of decline in energy intensities fell to 1.3%, while the effects of structural change were small. Thus strong growth in output led to an increase in energy consumption averaging 2.2% per year.

Between 1990 and 1994 energy consumption was restrained primarily by economic recession. Energy use and output moved almost in parallel at about 1% per year. Adjusted for the very modest impact from structural changes, the fall in energy intensity averaged only 0.4% per year.

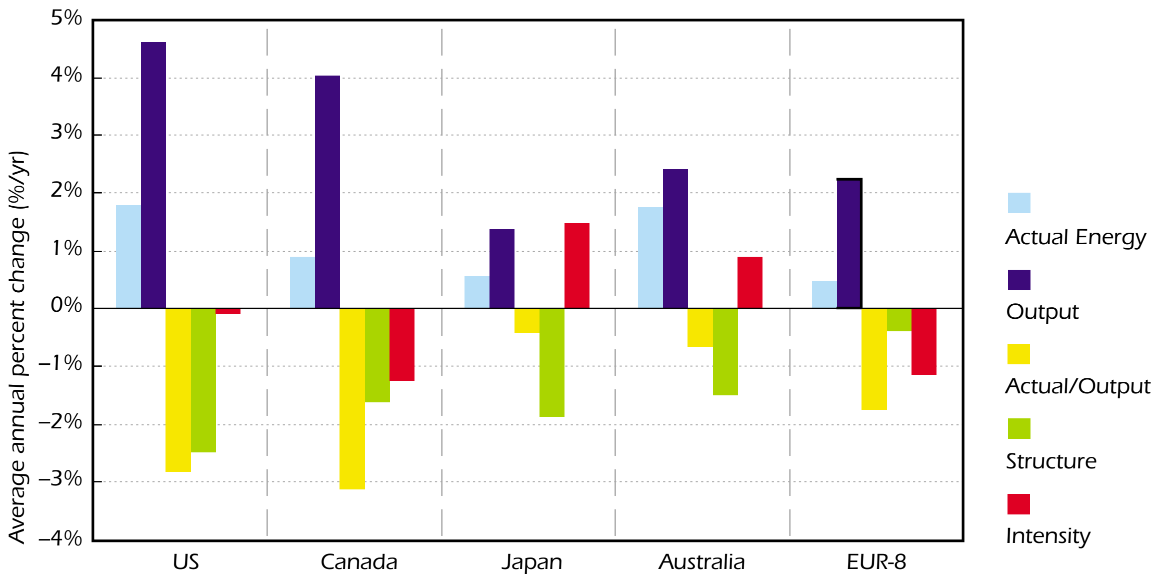
From 1994 to 1998 the picture changed as manufacturing production picked up and grew at an average annual rate of 3.3%, while energy use increased by only 1.2% per year. However, as most of the manufacturing growth came in less energy-intensive industries, the industry structure became significantly less energy intensive during this period. This structural change affected energy use in the IEA-11 even more than structural changes did during the 1973-1982 period. In fact, all the decoupling between energy use and output during 1994 and 1998 can be explained by structural changes while reductions due to the energy intensity effect were close to zero.

Recent Trends in Intensity and Structure

Since 1994 structural changes and not efficiency improvements have driven declines in manufacturing energy per output

Figure 4-9

Decomposition of Changes in Manufacturing Energy Use, 1994-1998



The previous figure showed that for the IEA-11 the decline in aggregate manufacturing energy use per unit of economic output since 1994 is more a result of structural change than of reduced sub-sector intensities. This trend holds for all non-European countries shown in Figure 4-9, while for a group of eight European countries (EUR-8) the intensity impact was more important. All of the countries, except Japan, experienced relatively strong growth in output between 1994 and 1998, while energy use grew less than output, i.e., aggregate intensity fell. However, in almost every country, the structure became less energy intensive. The only exceptions to this trend were Denmark and Germany (not shown separately in Figure 4-9). Still for the EUR-8 group, the overall effect was a structural shift away from energy-intensive industries.

The decline in the structure-adjusted intensity was modest for most countries. It even increased in Japan and Australia. (The increase in this intensity for Japan was influenced by the economic recession during this period; see discussion of Figure 4-10). Extending the analysis to 1999 or 2000 for those countries with available data confirms the trend towards an increasing concentration of manufacturing production in less energy-intensive industries and the slow decline rate of the structure-adjusted energy intensity.

Rapid growth in the output of electronics and electronic equipment industries led the shift in manufacturing structure in many countries. These shifts represent more production of information-intensive goods, with lower energy requirements per unit of value-added than both raw materials and more traditional manufactured products, such as white goods or cars.

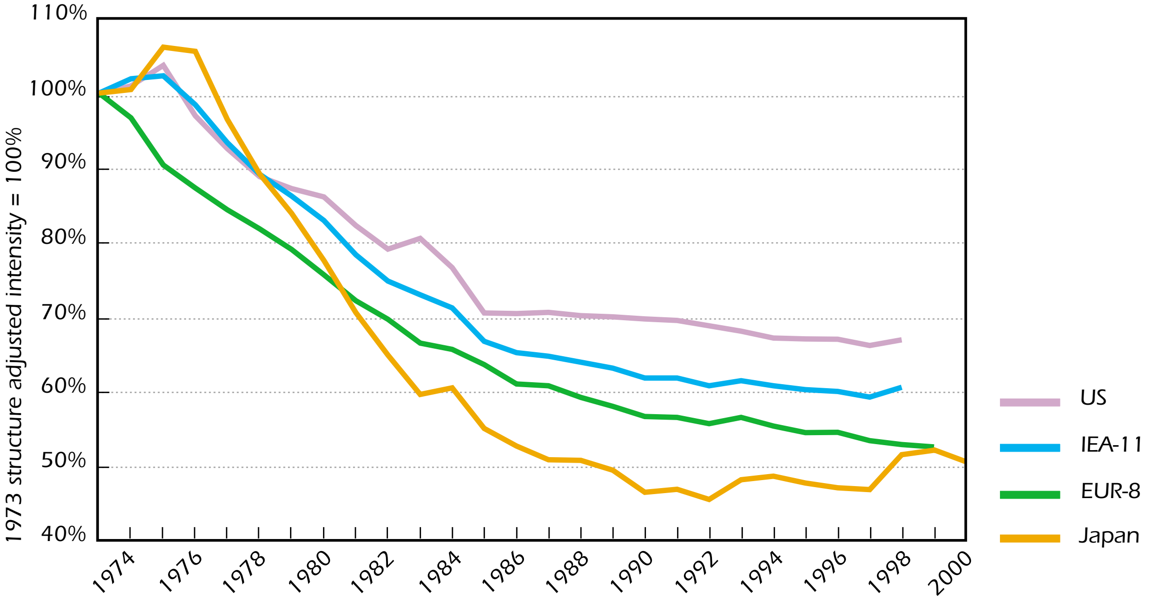
While the "information economy" effect has helped reduce manufacturing energy use, this analysis paints a gloomy picture of recent energy efficiency developments. Indeed, at an aggregate level the reduction resulting from these structural changes masks a lack of recent progress in reducing sub-sector energy intensities. Since it cannot be expected that future structural changes will favour less energy-intensive industries to the degree experienced recently, IEA countries may face strong growth in manufacturing energy use unless the negative trends in sub-sector energy intensities are reversed.

Long-term Energy Intensity Trends

Declines in energy intensities slowed markedly after 1986

Figure 4-10

Manufacturing Energy Intensity Adjusted for Structural Changes



The intensity bars in Figure 4-8 clearly indicate a trend of slowing intensity reductions for the IEA-11 group. Results for individual countries show the same trend. Figure 4-10 compares the development of structure-corrected energy intensity for the United States, Japan and EUR-8 with the IEA-11. This intensity fell significantly through 1986 for all countries. The decline was especially strong in Japan where the intensity had fallen 50% by 1987. Except for the United States, the intensities continued to decline though the late 1980s, though at lower rates than before 1986.

After 1990 the structure-adjusted intensity in Japan started to increase while reductions elsewhere were very modest compared to earlier periods. The development in Japan is at least partly due to the serious economic recession after 1990, when many industries did not produce at full capacity. This may have led to less efficient use of energy and other production factors. (Similar effects can be observed in the United States and Japan following the economic downturns in 1974-1975 and 1982-1983). Economic recession may also make the financial conditions for investments in energy efficient equipment more difficult. It is important to note that Japan was leading all other countries in intensities reductions before 1990, which could indicate that Japanese industries already were quite efficient and that it thus had less potential for additional improvements.[2]

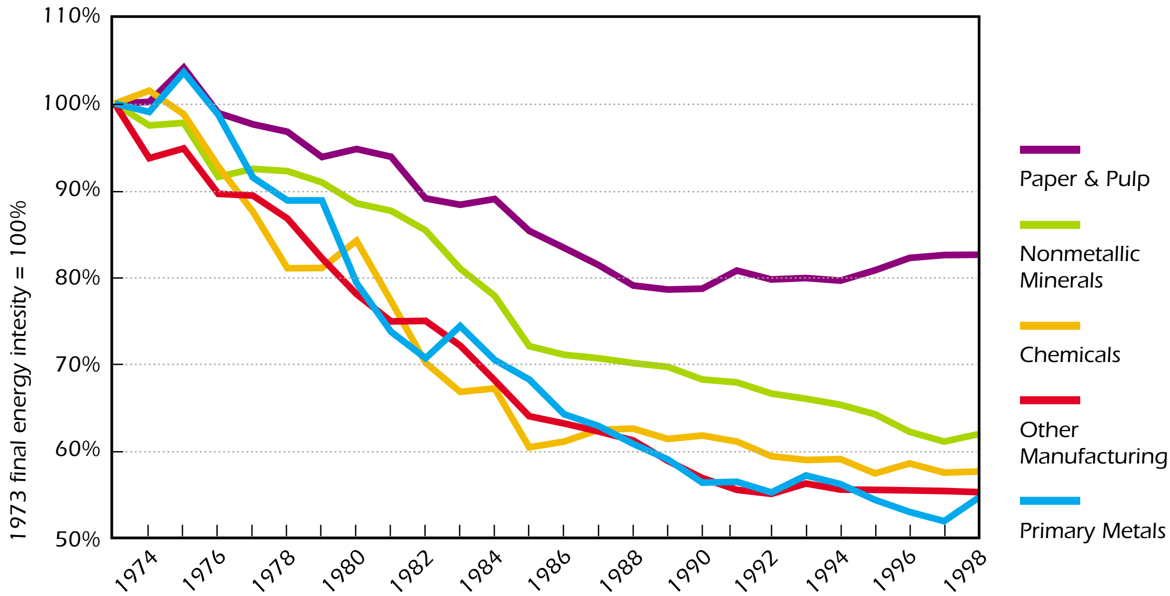
2. What may also have contributed to the intensity development in Japan after 1990, especially in the metals manufacturing sub-sector, are changes in the product mix within the specific sub-sector, e.g., a higher share of energy-intensive thin steel panel products, which is more energy intensive than the average product mix of Japan's metal manufacturing sector.

Development of Sub-sector Intensities

The decline in energy intensities has slowed since 1986 in all sub-sectors

Figure 4-11

Evolution of Sub-sector Energy Intensities, IEA-11



The sub-sector energy intensities for IEA-11 generally show the same development as seen for the structure-corrected total manufacturing intensity. Strong declines in energy intensities through the mid 1980s were followed by a significant slow down, and even a reversal in some cases.

Industrial chemical production achieved the strongest reduction in energy intensity until 1986 (down 38% from the 1973 level) followed by "other manufacturing" (down 36%). Yet, while intensity in chemicals changed very little over the next twelve years, the intensity in "other manufacturing" and primary metals (both ferrous and non-ferrous) continued to decline at a pace such that these two sectors had the most significant overall decline (45%) in the period since 1973.

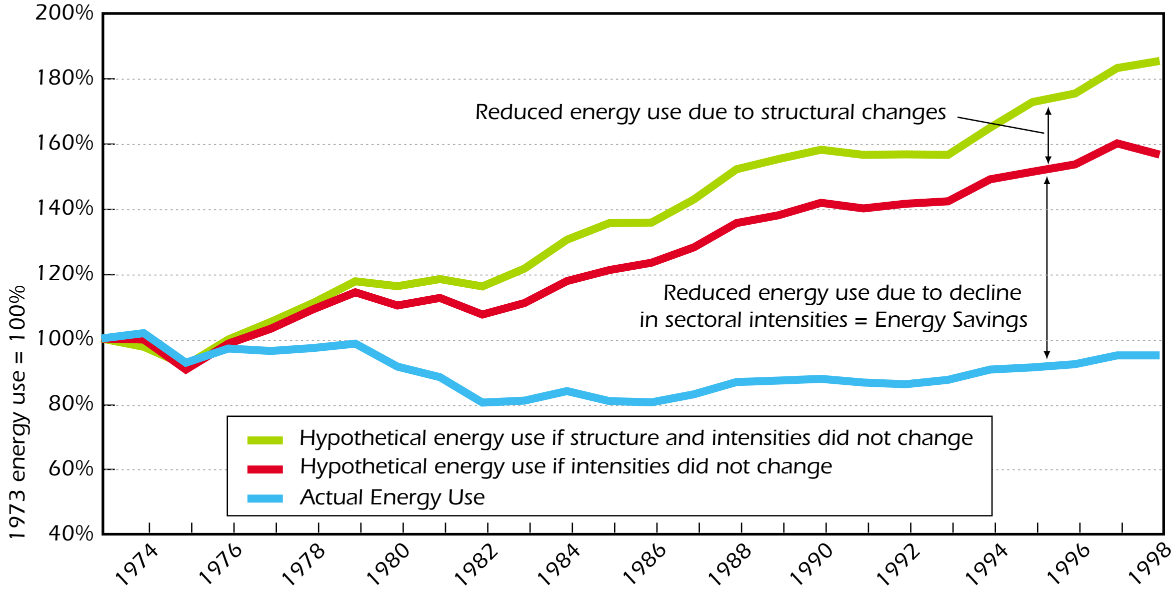
Given the high energy intensity of primary metals production compared to other sub-sectors (see Figure 4-6), the strong intensity decline in this sector had an important impact on overall manufacturing energy use between 1973 and 1998. On the other hand, paper and pulp which is also relatively energy intensive only saw a modest 16% intensity decline over this period.

Energy Savings and Structural Changes

Without energy savings and structural changes, 1998 energy use would have been twice as high

Figure 4-12

Reduction in Energy Use from Changes in Structure and Intensities, IEA-11



How much did structural change and declining energy intensities reduce manufacturing energy use in the IEA-11? In Figure 4-12 the lower curve represents actual IEA-11 energy use, including the effect of changes in both structure and energy intensities. The middle curve is calculated by adding the energy savings from changes in energy intensities for each year to actual energy use (see equation 5 in Chapter 2 and Chapter 3, Figure 3-16). The upper curve represents the hypothetical energy use that would have occurred if no changes in structure or energy intensities had taken place. This curve is calculated by adding the changes in energy use from structural changes for each year to the level of the second curve.

The difference between the upper and the middle curve illustrates the reduction in manufacturing energy use due to structural changes. As also shown in Figure 4-8, the IEA-11 structure gradually became less energy intensive until the end of the 1980s. At the same time, significant energy savings from reduced energy intensities were achieved.

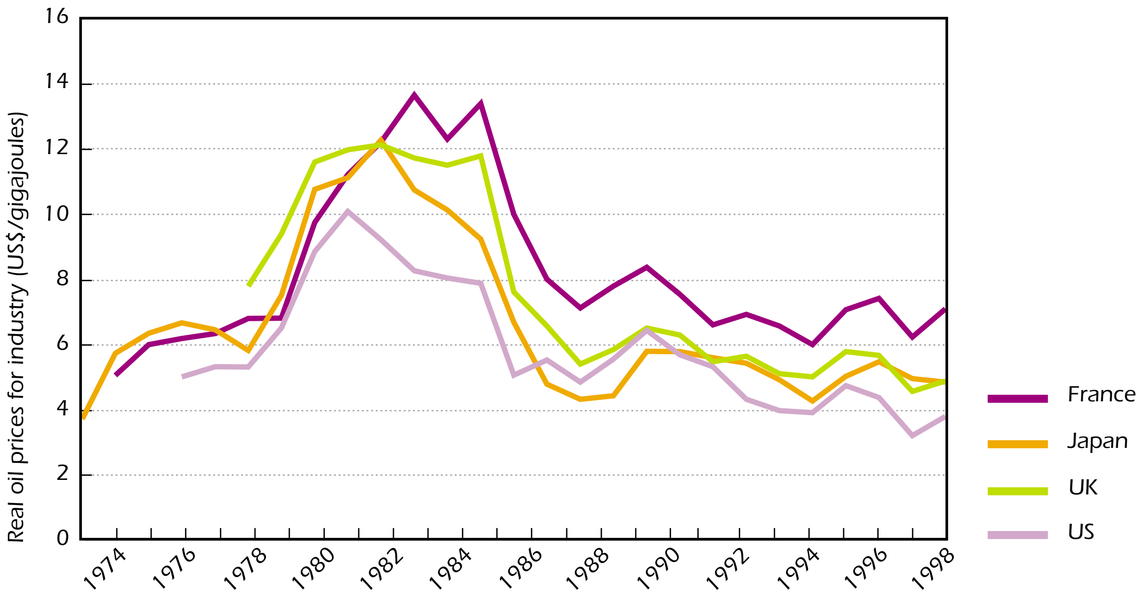
After 1990, and particularly after 1994, the rate of energy savings slowed as the decline in energy intensities more or less came to a halt. Instead, structural changes led to significantly reduced energy use. By 1998, the reduction in energy use from structural changes corresponded to roughly 30% of 1998 actual energy use. In comparison, energy savings from reduced energy intensities corresponded to 66% of 1998 energy use. Thus if both the sub-sectoral energy intensities and the share of output from each sub-sector had remained as they were in 1973, energy use in 1998 would have been about twice its actual level. Almost a third of the reduction from this hypothetical energy use was from structural change and the rest was from declines in energy intensities.

Energy Prices

The end of the high fossil fuel price era in 1986 offers an important explanation for the slow-down in energy intensity declines

Figure 4-13

Real Prices for Industrial Light Fuel Oil



Oil prices shot up in the wake of the embargo in 1973-4 and were further exacerbated by supply disruptions induced by the Iran-Iraq war in 1979. (See also Figure 3-4.) As indicated in Figure 4-13, the manufacturing sector faced significant price hikes: in the late 1970s and early 1980s industrial oil prices skyrocketed by 200 - 300% before falling back almost to the 1973 level by 1987. Since prices dropped in the mid-1980s, there have been only relatively small price fluctuations until the late 1990s. Natural gas and coal went through similar developments in most IEA countries.

It is hard not to attribute part of the decline in energy intensities observed before 1986 to higher energy prices. This stimulated the application of energy-saving technologies. Other factors also affected the rate of energy intensity decline. As discussed in connection with Figure 4-10, the rate of growth in manufacturing output influences the rate of investment in new technology and the utilisation of production factors, including energy. Thus both prices and the rate of economic growth are important determinants for how manufacturing energy intensities change over time.

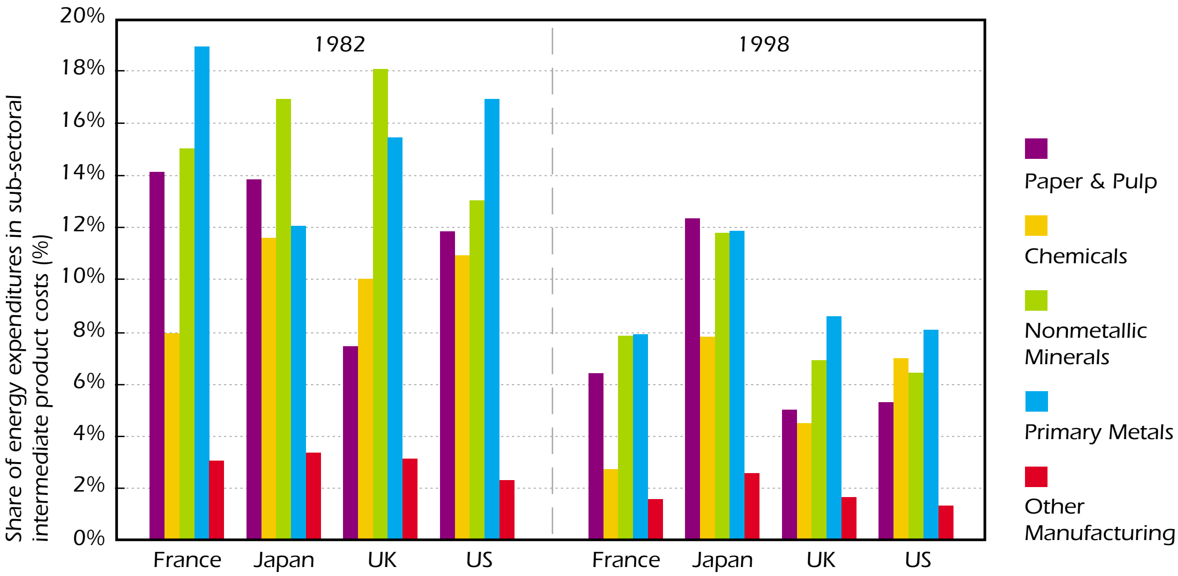
Shifts in the production processes themselves have also lowered manufacturing energy intensities. Examples include increased use of recycled feedstocks (e.g., scrap metal, recycled paper) and shifts from primary to secondary production, i.e., shifts away from raw steel and aluminium production to secondary and from raw paper to recycled paper production. These shifts represent structural changes within sub-sectors. To isolate the effects of these "micro" structural changes requires more disaggregated data than what are generally available on an internationally consistent basis.

Energy Costs as Share of Total Production Cost

The share of energy in total production costs varies significantly across countries and sub-sectors, but has fallen everywhere

Figure 4-14

Share of Energy Expenditures in Sub-sector Intermediate Product Costs[3]



The cost of energy for manufacturing depends on the energy intensity of the products produced, the mix of fuels used and the price of those fuels. For energy-intensive industries, energy costs constitute a significant share of total production costs (Figure 4-14).[4] Yet there are relatively large differences in this share among the countries included in this figure. Some of these differences are due to variations in the level of sub-sector energy intensities. Differences in fuel prices also play a role, although higher intensities, especially in energy-intensive industries, tend to be related to lower prices. Access to cheap energy is often a stimulant for the production of energy-intensive materials. For example, in Australia and Norway, where energy has been relatively inexpensive, the production of aluminium - a very energy intensive process - constitutes an important share of the production of primary metals and thus drives up the average intensity for this sector.

In France, the United Kingdom and United States, the energy cost share fell significantly between 1982 and 1998 in all sectors. Most sectors in Japan also saw a reduction in this share, but less than in the three other countries, even though Japanese industries reduced energy intensities at a faster rate than most other countries through the 1980s. A closer examination

3. Intermediate consumption is used as a measure of total production cost. It consists of the value of the goods (such as energy, materials, machinery and equipment) and services consumed as inputs by a process of production; the goods or services may be either transformed or used up in the production process.

4. The costs presented in Figure 4-14 are calculated assuming the same fuel prices in all sub-sectors. Thus the cost share differences across the sub-sectors are probably overestimated since the energy-intensive sectors often have access to cheaper energy through various forms of subsidies, for example guaranteed long-term low price contracts for electricity.

of the data for intermediate production cost and value-added, shows that value-added increased relative to product costs in Japanese industries. This indicates that the use of other production factors also became more efficient in parallel with the energy intensity reductions. Compared to other countries, the somewhat higher share of energy expenditures in Japan in 1998 could thus be related to that the use of other production factors is more efficient, though quantification of this is beyond the scope of this study.

Decomposition of Changes in Energy Costs

Declines in energy costs have slowed with slowing energy intensity reductions

Figure 4-15

Decomposition of Energy Costs per Value-added for Primary Metals Production

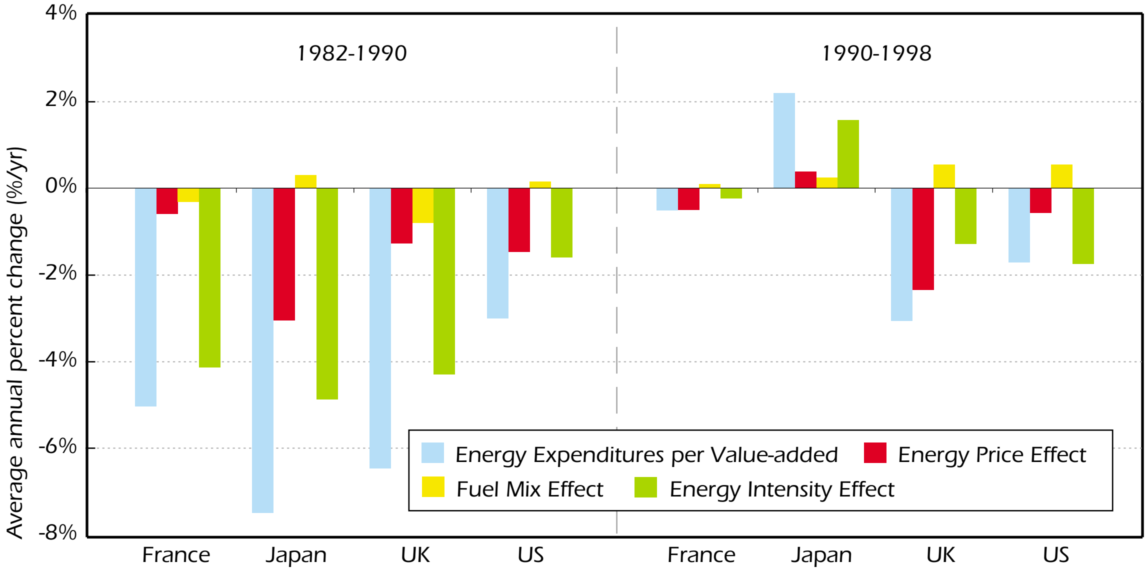


Figure 4-15 shows how energy expenditures relative to value-added changed as a function of changes in energy prices, fuel mix and energy intensities for the primary metals sector. Energy cost relative to value-added in this sector fell significantly before 1990 in all countries. The figure confirms that in Japan energy expenditures relative to value-added fell more than relative to intermediate product (see Figure 4-14). The decline in Japan was due to the combination of rapidly falling energy intensities and significant declines in fuel-weighted energy prices that led to energy costs falling by almost 8% per year on average relative to value-added between 1982 and 1990. These two factors also reduced energy costs per value-added in the United States, United Kingdom and France, but to a more modest degree. Examining data for other sub-sectors show to a large extent the same picture, expenditures fell as intensities and fuel prices declined.

The impact from changes in the fuel mix in primary metals production was modest. In other sub-sectors where more significant fuel switching took place, energy costs generally increased where electricity and gas took shares from coal, while costs fell where more expensive oil (per energy unit) was replaced by natural gas.

After 1990 energy costs relative to value-added in the primary metals sector only declined significantly in the United Kingdom, where energy expenditures fell as prices dropped. For all countries the lack of a considerable decline in energy intensities limited further reductions in energy costs. The same tendency can be observed in other manufacturing sub-sectors.

It is thus tempting to conclude that today the lower share of energy costs – which results from both successful energy efficiency improvements and lower energy prices – has made investments in energy efficiency less attractive than investing in ways to reduce other production costs compared to a couple of decades ago.

Chapter 5. HOUSEHOLDS

Highlights

- Households consume about 20% of total final energy in IEA countries. Natural gas and electricity are now the most important energy carriers in the residential fuel mix. Today about a third of the total end use of natural gas and electricity is in the household sector. Electricity and gas have driven the relatively modest growth in total household energy demand since the early 1970s. For a group of eleven IEA countries (IEA-11) (together accounting for more than 80% of IEA total residential energy use), energy consumption in households was up 17% between 1973 and 1998, with two-thirds of the growth coming after 1990. Over the 30-year period natural gas increased 40% and electricity doubled.
- Strong growth in the ownership and use of household appliances propelled the increase in electricity consumption. Traditional "big appliances" such as dishwashers and refrigerators dominated the growth up to the early 1980s. Since then their role in stimulating demand has been less important due to both saturation effects and improved appliance efficiencies. On the other hand, the use of "miscellaneous" appliances – from home electronics and office equipment to small kitchen gadgets – is growing strongly and is responsible for much of the recent increase in residential electricity demand.
- Despite the significant growth in electricity use for appliances, space heating remains the most important end use in almost all IEA countries. Naturally the demand for space heating varies with climate. Indeed, outdoor temperatures explain a good part of the large variation in per capita residential energy use in IEA countries.
- There are important differences among countries in how residential energy demand has developed since 1973. Most countries saw an increase in final energy use, and in some it was quite a significant increase, while in others it fell between 1973 and 1998.
- Most of the differences are related to how the demand for space heating evolved. In all countries, bigger homes and fewer people per house put an upward pressure on demand for space heating, although to varying degrees. On the other hand, helping to restrain demand growth, useful energy per area heated fell in most countries. The rates of decline vary dramatically. This reflects differences in energy efficiency improvements, and that some countries that had low heating levels in the early 1970s saw energy savings being eaten up as heating comfort increased to levels common in other IEA countries.
- Energy intensities for all household end uses fell steadily up to the early 1990s which led to energy savings in all countries. Since then, the decline in energy intensities has slowed markedly and even reversed in some countries. For IEA-11, energy use would have been 56% higher in 1998 if intensities had remained at 1973 levels.
- While electricity prices for IEA households have varied only moderately since 1973, the levels are significantly different between countries. Thus the economic incentives to stimulate improved energy efficiency of electricity-specific uses such as lighting and appliances vary. However, the fuel-weighted price paid for space heating varies much less. This indicates that non-price factors such as building codes, climate and cultural aspects are important to explain differences in the level of space heating intensities among countries.

- The shares of incomes that IEA households spent on energy grew with increasing fuel prices throughout the 1970s and early 1980s. With the general fall in prices since then, however, expenditures fell relative to income levels. By 1998 the share of household income for energy expanditures was comparable with the share paid in 1973 in most countries. The increased share of electricity in the fuel mix contributed to increased expenditures. On the other hand, lower growth in energy consumption relative to income helped reduce the importance of energy in household budgets. Clearly, without the energy savings achieved between 1973 and 1998, IEA households would have seen much more of their incomes being spent on energy.

Definitions, Methodology and Data Used in this Chapter

End Uses

Residential space heating, water heating, cooking, major appliances (refrigerators, freezers, clothes-washers, clothes-dryers and dishwashers), miscellaneous appliances and lighting.

Energy

Measured in most cases as final (delivered) energy. Data for the various end uses are from national sources, refer to chapter 2.

Useful Energy

As an approximation of the amount of useful heat that emanates from a space heater, boiler or furnace. Calculated as final energy for electricity and district heat, 66% of final energy for natural gas and oil, and 55% of final energy in coal, wood or other solids.

Climate-correction

To correct for year-to-year variations in climate, a country's space heating is adjusted using the ratio of the number of degree-days (DD) in a given year to the 30-year average degree-day number. The number of degree-days is calculated as the difference between average outdoor temperature and 18 degrees C and summed for all months excluding June, July and August, except for Australia where degree-days for the summer months (December, January and February) are negligible. When comparing absolute levels of residential energy demand, each country's space heating figure is adjusted taking the actual number of degree days in the year of comparison and dividing it by 2 700 degree-days, which is close to the average climate of the group of countries analysed here.

Activity

Population. Data are from OECD *National Accounts*.

Structure

Refers to per capita dwelling area for space heating and lighting; index of the square root of household occupancy for cooking and water heating; and per capita appliance ownership. Various national sources provide the data for dwelling area, number of dwellings and appliance ownership.

Intensity

Refers to useful energy and final energy use per square metre per degree-day for space heating; energy per capita for water heating and cooking; energy per appliance; and lighting energy per square metre of floor area.

Decomposition

The impacts of changes in activity, end-use energy intensity and the structure of energy demand on total residential energy use are measured using the decomposition method described in Chapter 2. An additional disaggregated decomposition is used to analyse space heating in more detail.

Price and Income Data

All energy price data are from IEA *Energy Prices and Taxes in OECD Countries*. Income data measured as Private Consumption Expenditure (PCE) are from OECD *National Accounts*. Prices and income levels are expressed in real terms (1995) and converted to US dollars using purchasing power parities (PPP), unless otherwise noted.

Country Coverage

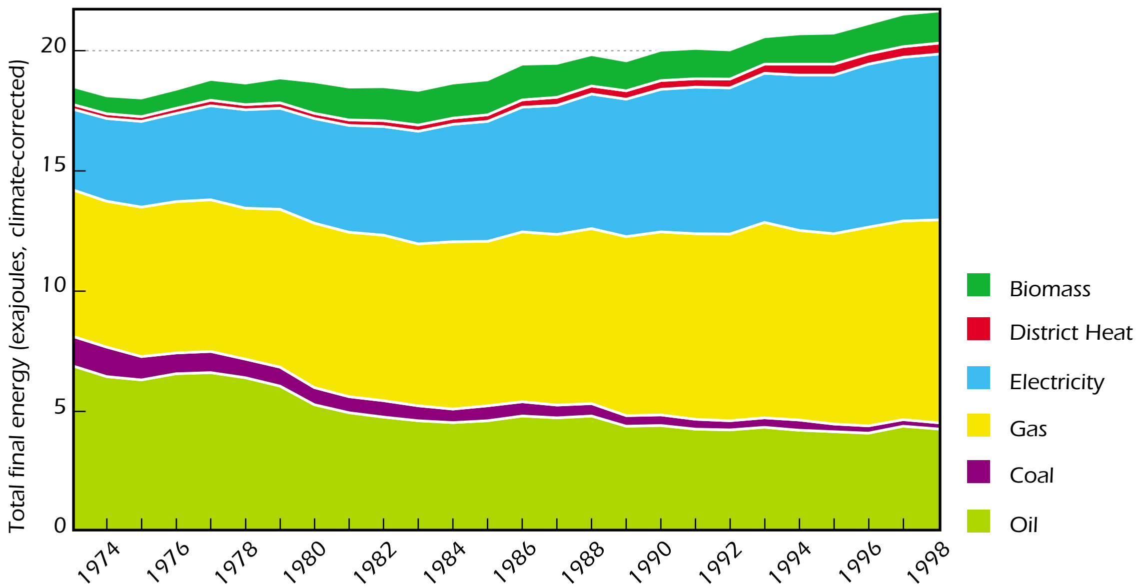
IEA has consistent time series with energy and structure data from 1973 or 1974 through 1998 and in some cases 1999 and 2000 for eleven IEA countries. This includes Australia, Denmark, Finland, France, Germany, Japan, Italy, Norway, Sweden, United Kingdom and United States. Aggregate results of this group are presented as the IEA-11. Together these countries accounted for more than 80% of total IEA residential energy use in 1998. A group of eight European countries within the IEA-11 is referred as EUR-8 in some instances. In addition, IEA has complete time series with residential data from 1979 for the Netherlands and 1981 for Canada.

Energy Use in Households by Fuel

Modest growth in energy use with electricity and natural gas in the driver's seat

Figure 5-1

Residential Energy Use by Fuel, IEA-11*



*Space heating corrected for yearly climate variations

Residential energy use in the IEA-11 countries grew by a modest 17% between 1973 and 1998. Energy use declined in the first couple of years after the oil price shock in 1973-74, then increased until 1979, before it again declined through 1983 when it reached the same level as in 1973. Since then, residential energy use has more or less grown steadily.

In 1973 oil was the dominant fuel accounting for 37% of energy consumption in households while electricity use only constituted 18%. Although oil consumption did grow during the 1990s in absolute terms, it continued to lose share and accounted for only 20% of residential demand in 1998. Electricity growth has been significant throughout the period and accounted for 32% in 1998. Natural gas use was already widespread in many IEA countries in 1973 when it accounted for a third of residential demand. Natural gas consumption has steadily increased since then and is now the dominant household fuel in IEA-11 countries with a 39% share in 1998. Coal use, once an important source of energy in households, was significantly reduced in most IEA countries before 1973 when its share was only 7%. Since then, coal has been even more marginalised and today it has almost disappeared from the IEA residential fuel mix. The share of all fossil fuels in households went down from 77% in 1973 to less than 60% in 1998.

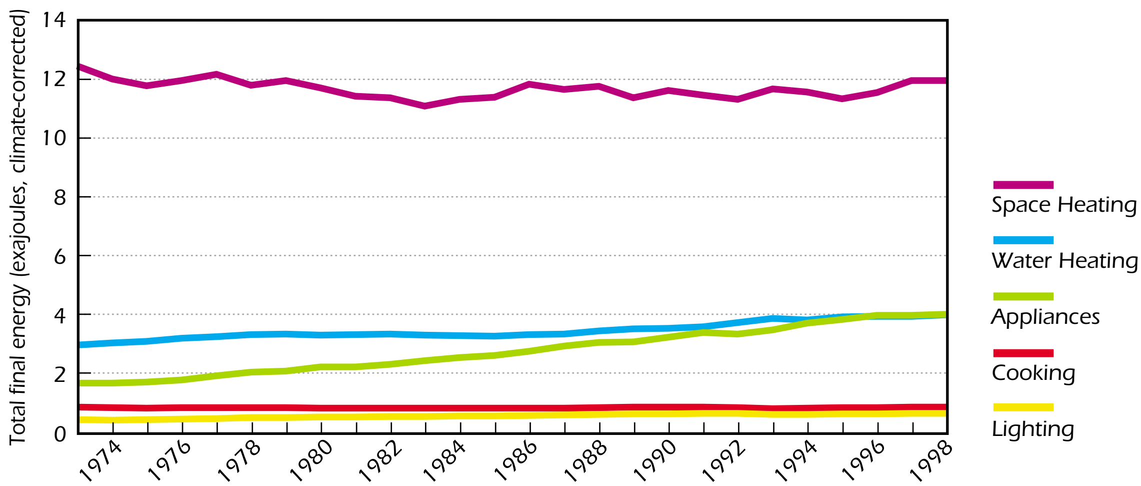
Changes in the fuel mix reflect both fuel substitutions within the same end use and structural shifts among residential energy uses, i.e., stronger growth in one end use compared to another. At least in part, the reduction in oil use is a result of fuel switching from oil to natural gas for space heating, or electric heating in some places, when oil prices rose. Increased use of electricity for space heating underlies some of the strong growth in electricity demand, but more important is the significant growth of electric appliances.

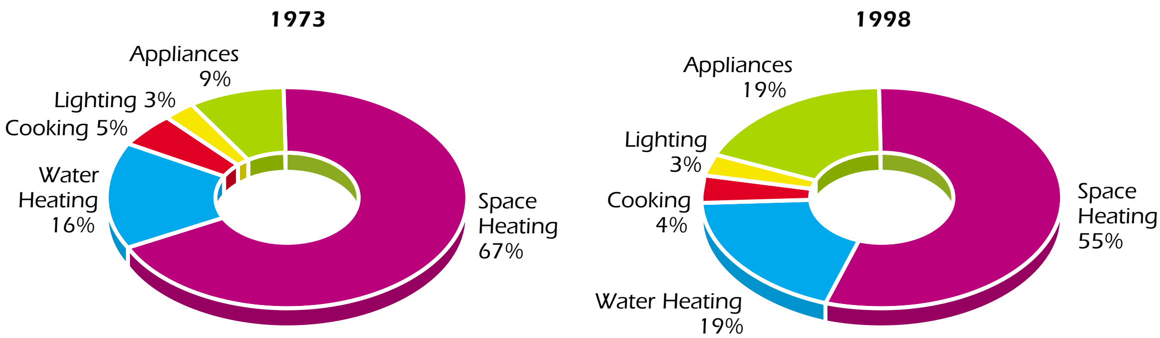
Residential End Use Shares

Space heating still dominates, but appliances are driving growth

Figure 5-2

Residential Energy Use by End Use, IEA-11*





*Space heating corrected for yearly climate variations

Over the period, the share of appliances in residential energy use has more than doubled within the IEA-11 group. While appliances accounted for less than 5% of residential energy use in many European countries in 1973, its share was already high in the United States (12%), Australia (17%) and Japan (21%). These variations are due to different appliance ownership levels and the relative importance of other end uses, notably space heating. By 1998 the share of appliances in residential energy use had increased to between 10 and 15% in most European countries, 24% in the United States, 26% in Australia and 29% in Japan.

Despite increasing shares of appliances, space heating is clearly the most important energy end use in households, accounting for more than half of total residential energy consumption in most of the IEA-11. Yet the share of space heating has declined in most of these countries. For example in the United States the share fell from 65% to 50%, in Denmark from 76% to 62% and in Italy from 76% to 52%. The average share for space heating in the IEA-11 declined from 67% to 55%.

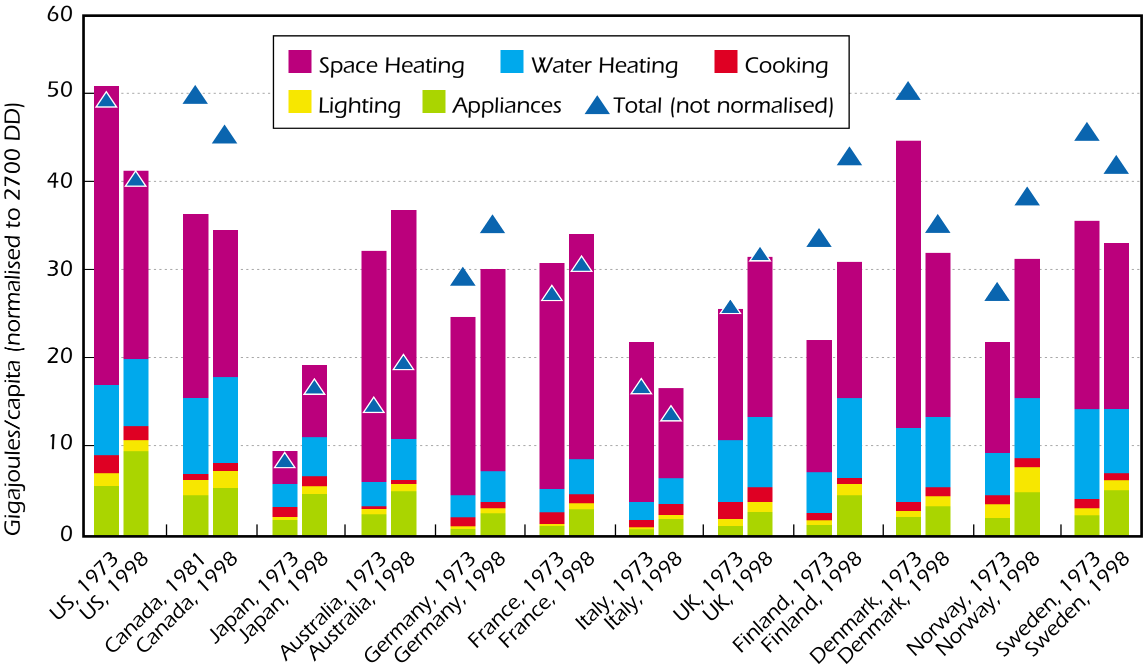
Energy demand for space heating naturally varies with winter temperatures and climate. In Australia with a relatively mild climate, space heating in 1998 only accounted for 40% of residential energy use while in much colder Finland the share was 64%.

Residential Energy Use Per Capita

Climate is important to explain differences in residential energy use

Figure 5-3

Energy Use per Capita by End Use, Actual versus Normalised to Common Climate[1]



The level of household energy use on a per capita basis varies significantly across IEA countries, as illustrated by the triangular markers in Figure 5-3. In 1973 Denmark had the highest consumption levels, closely followed by the United States and Sweden.[2] At the other end of the scale, an average Japanese household consumed only 18% of the energy an average American resident consumed in 1973. While Japanese consumption increased rapidly over the period, per capita consumption in the United States fell, so that in 1998 the consumption in Japan was 42% of that in the United States. Residential energy use in Finland and Sweden was marginally higher in 1998 than in the United States. The high consumption levels in Finland and Sweden are to a large extent due to their cold climates. This becomes clear when examining the bars in Figure 5-3 which show per capita energy use normalised to similar climate conditions. Since the United States has a milder climate than most of the other "high-consuming" countries, the US consumption levels stand out clearly as the highest in both 1973 and 1998 when corrected for climate differences.

1. For the comparison of the energy use levels in 1973, Figures 5-3 and 5-4 use data for 1972 and 1974 to represent 1973 for Denmark and Australia, respectively. This is due to a lack of good quality data for 1973 for these two countries. Data for Canada are not available before 1981, so this year is shown as the first bar in Figures 5-3 and 5-4.

2. Canada's per capita household energy use as shown for 1981 was slightly higher than the levels in the United States and Sweden in 1973.

In general the variances in per capita energy use are less on a climate-adjusted basis. Yet there are still significant differences. Although being considerably warmer than average, climate-adjusted household energy consumption in Japan remains lower than all countries in Figure 5-3, except Italy in 1998, despite Japan's growth of nearly 200% since 1973. Countries like Canada, Finland, Norway and Sweden move from being at the high end of the consumption scale in 1998 down to near average levels when their cold climate is taken into account. In warm Australia, however, energy use almost doubles with the degree-day correction, which puts it among the highest consuming countries.

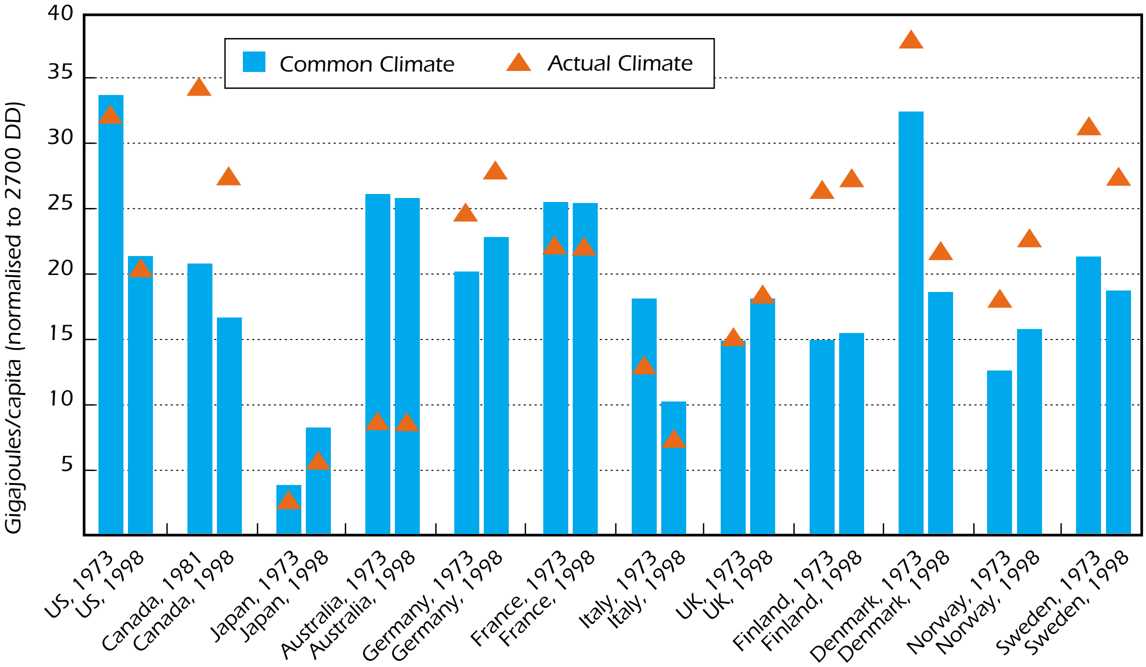
There are striking differences in trends over the period. Household energy consumption increased in most IEA-11 countries with quite significant escalations in Japan, Norway and Finland. But decreases in per capita consumption also occurred with the largest drop in Denmark, where energy use per capita fell more than 25% between 1973 and 1998. Interestingly, its neighbour, Norway increased per capita consumption such that even though climate-adjusted consumption in Denmark in 1973 was almost twice the level of Norway, both countries ended up at about the same level in 1998.

Space Heating Energy Use per Capita

Space heating trends vary significantly among the IEA countries

Figure 5-4

Space Heating Energy Use per Capita, Actual versus Normalised to Common Climate



The variations are even clearer in Figure 5-4 where space heating is shown on a per capita basis with and without climate adjustment. Looking back to 1973, Denmark had the highest space heating consumption before climate is taken into account, followed by the United States and Sweden (see footnote 1, Figure 5-3). Japan was at the low end of the scale, where an average person only used 10% of the energy a Dane used for space heating. When adjusting for climate, Japan's space heating consumption still was low and Denmark's high, although the US consumption in 1973 was higher than in Denmark.

By 1998 the Danish per capita space heating consumption had fallen by more than 40% to a level roughly at the average for IEA-11, while the United States remained relatively high despite a 27% drop since 1973. The countries in the figure fall into three groups according to their climate-corrected per capita space heating demand in 1998: Japan and Italy at the low end; Canada, the United Kingdom, Finland, Denmark, Norway and Sweden in the middle range; and France, Germany, Australia and the United States at the high end. Interestingly, countries with relatively cold climates fall into the medium group (Canada, Norway, Finland, Sweden), while the climate-correction moves relatively warm countries like Australia and France into the higher category. This may be because buildings in cold climates tend be better insulated and thus require less energy for space heating in an average climate than a home built in a warmer climate.

In addition to the different levels of space heating among countries, Figure 5-4 shows significant variations in the trends over time. Since 1973 per capita energy consumption for space heating declined strongly in the United States, Italy and Denmark and moderately in

Canada and Sweden. It changed little in Australia, France and Finland, while space heating demand increased in Japan, Germany, the United Kingdom and Norway.

To better understand these variations in space heating over time and why levels of final energy for space heating vary so much among countries it is useful to investigate the components that affect space heating demand (see box below).

Energy Use for Space Heating: A Decomposition Model

How much energy is needed for space heating depends on two factors in the aggregate: how much house area is to be heated; and how much energy is needed to heat each square metre of this area.[1] This can be expressed as:

Final energy for space heating per capita, $FE_h/\text{capita} = m^2/\text{capita} * FE_h/m^2$

The first component, which represents the aggregate driving force behind space heating demand, can be further split, or decomposed into:

$$m^2/\text{capita} = m^2/\text{dwelling} * \text{dwelling}/\text{capita},$$

to reflect that the space per person is increasing both if the homes are getting bigger (m^2/dwelling increase), and if the home is occupied by fewer people (dwelling/capita increase).

The final energy requirement for space heating per unit area heated, FE_h/m^2, is dependent on how efficient the heating equipment converts final energy into useful heat (FE_h/UE_h) and the demand for useful heat per unit of area, corrected for climate variations ($UE_{h,cc}/m^2$):

$$FE_{h,cc}/m^2 = FE_{h,cc}/UE_{h,cc} * UE_{h,cc}/m^2$$

The demand for useful energy per area in a given climate is dependent on behavioural factors such as average indoor temperature, building shell thermal efficiency and the penetration of central heating systems (which tend to increase the demand for useful heat due a more even distribution of the heat around the house).[2]

In summary, changes in per capita final energy for space heating can thus be expressed by:

$$FE_{h,cc}/\text{capita} = m^2/\text{dwelling} * \text{dwelling}/\text{capita} * FE_{h,cc}/UE_{h,cc} * UE_{h,cc}/m^2,$$

where the two first components reflect structural factors driving demand for space heating and the latter two are related to the energy efficiency of the heating equipment and building shell, respectively.[3]

1. Strictly speaking space heating depends on the building volume heated, not the area. However, since data on building volumes are seldom recorded, building area is used.

2. IEA corrects for penetration of central heating when analysing useful space heating intensities. Since information on indoor temperatures is rarely available, this factor is not taken into account in the analysis of how the intensity changes over time within one country, nor when analysing country differences.

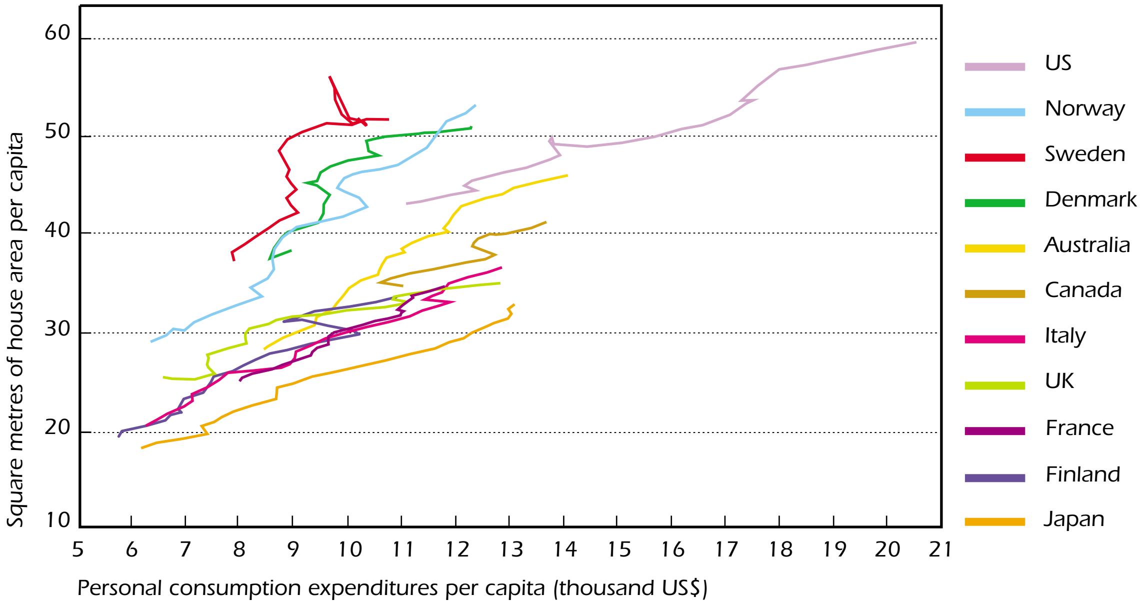
3. Data on heating equipment efficiency generally are not available. Therefore, the IEA calculates useful heat assuming 66% efficiency for natural gas and oil-based systems, 55% for all solid fuels and 100% for district heat and electricity heating. Calculated this way, changes in the FE_h/UE_h factor only reflect the impact of changes in the fuel mix used for space heating and not how the actual efficiency of the heating equipment evolves over time.

Floor Area and Income

Living space is getting bigger as we get richer

Figure 5-5

House Area per Capita and Personal Consumption Expenditures, 1970-1998[3]



Before investigating the development of dwelling size and household occupancy, it is useful to look at the causal relationship between per capita dwelling area and income. Figure 5-5 shows how dwelling area has varied with income in a number of countries. Note that each data point represents the combination of per capita income and house area for a given year, thus if income falls temporarily, the data points move to the left.

The continued growth in dwelling area as income grows is striking and has induced pressure on per capita space heating needs in all countries. In fact, looking closely at the results indicates that even during recessions, dwelling areas often continued to increase. Although the income elasticity differs (i.e., how much per capita dwelling area increases per unit of per capita income), all countries went through significant growth in per capita floor area between 1973 and 1998, often by more than 50%. Today the dwelling area per person varies by almost a factor 2, from just over 30 m^2 in Japan to almost 60 m^2 in the United States. Clearly, these variations offer an important explanation of differences in per capita space heating needs among countries.

Note also the significant dispersion in house area per capita at a given income level. Japan, for example, despite relatively high income levels has had the lowest dwelling area per capita throughout the period. On the other hand, when countries such as Denmark and Australia started catching up 15-20 years later with 1970s US income levels, their per capita house area roughly corresponded with the 1970s levels in the United States.

3. Floor area of vacation homes is not included in the data used for this study.

Dwelling Area and Household Occupancy

Bigger houses shared by smaller families

Table 5-1

Trends in Dwelling Area and Occupancy, 1973-1998

	House Area (m^2/dwelling)				Household Occupancy (persons/dwelling)			
	1973	1980	1990	1998	1973	1980	1990	1998
Australia	108	115	122	129	3.5	3.2	3.0	2.8
Canada	-	117	126	127	-	3.0	2.8	2.7
Denmark	102	106	107	108	2.7	2.4	2.2	2.1
Finland	65	69	74	76	3.1	2.8	2.5	2.3
France	78	81	86	88	3.1	2.9	2.7	2.6
Germany	-	-	82	84	-	-	2.3	2.2
W Germany	76	82	88	-	2.8	2.5	2.4	-
Italy	78	85	93	98	3.4	3.2	2.9	2.7
Japan	76	83	90	93	3.8	3.4	3.2	2.9
Norway	88	98	109	124	2.9	2.7	2.4	2.4
Sweden	96	102	111	114	2.4	2.3	2.1	2.2
UK	77	81	84	85	3.0	2.8	2.5	2.4
US	136	139	143	157	3.1	2.8	2.7	2.6
IEA-11	101	104	110	117	3.2	2.9	2.7	2.6

Changes in per capita dwelling area are related to changes in average house area and in the number of occupants (see box on space heating decomposition). The number of people per household has fallen in each country shown in Table 5-1. In 1973 the average IEA-11 dwelling housed 3.2 people, while in 1998 it was down to 2.6 inhabitants. This demographic trend has induced pressure on space heating energy demand. Lower household occupancy means that a larger number of dwellings are needed to house a given population while the heating needs of each of these dwellings are not necessarily lower just because fewer people live in them. Thus per capita space heating demand increases when average household occupancy decreases.

The declining trend in household occupancy implies that the area of each dwelling has increased less rapidly than area per capita as portrayed in Figure 5-5. In fact, in many countries the decrease in the number of occupants had a greater impact on area per capita than the growth in dwelling area. Note also that countries with lower than average per capita dwelling area tend to have higher occupancy so that the country variations in area per dwelling are slightly less than in area per capita.

The United States clearly has the largest homes, followed by Australia, Canada and Norway. Japanese homes were among the smallest in 1973 but became significantly larger over the period and now approach the average size of European homes. House area in Norway grew the fastest, increasing by more than 40% from 1973 levels, and now is nearly 10% larger than values in Sweden and approaching those in Canada and Australia.

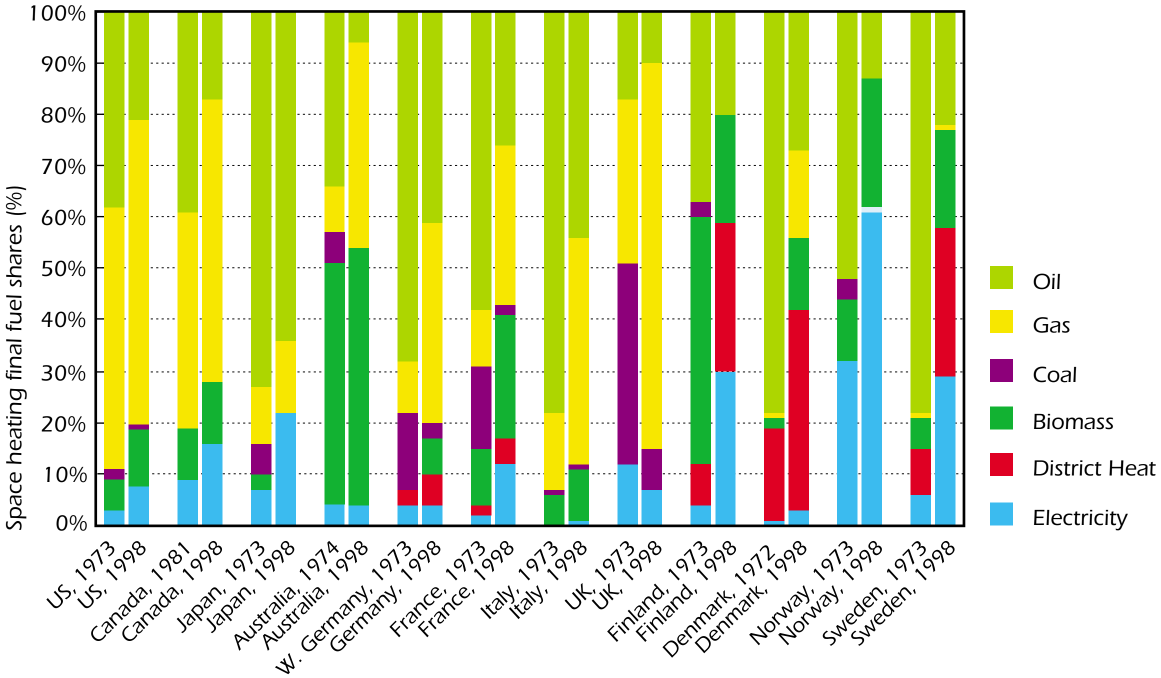
The variations in dwelling area are related to many factors other than income. The split between single family and multi-family housing is important and depends, among other things, on urbanisation, property prices and cultural factors. Also important is the mortgage tax policy. Many IEA countries have had (and some still have) generous tax deductions for interest paid on home loans. This policy has stimulated the building of larger dwellings than in countries where this indirect subsidy has not been provided, with important implications for the growth in energy demand.

Space Heating Fuel Mix

Space heating choices vary significantly

Figure 5-6

Share of Space Heating by Fuel



Space heating fuel shares vary significantly from country to country. Today natural gas is the most prominent fuel in the United States, Canada, France and the United Kingdom. Natural gas is also important in Germany and Italy where oil (including kerosene) is still the most widespread, and in Australia where biomass has the highest share of final energy demand for space heating. Oil is the most important space heating fuel in Japan. Oil is also significant in the space heating mix of the four Nordic countries, but generally in combination with wood, district heat and/or electricity.

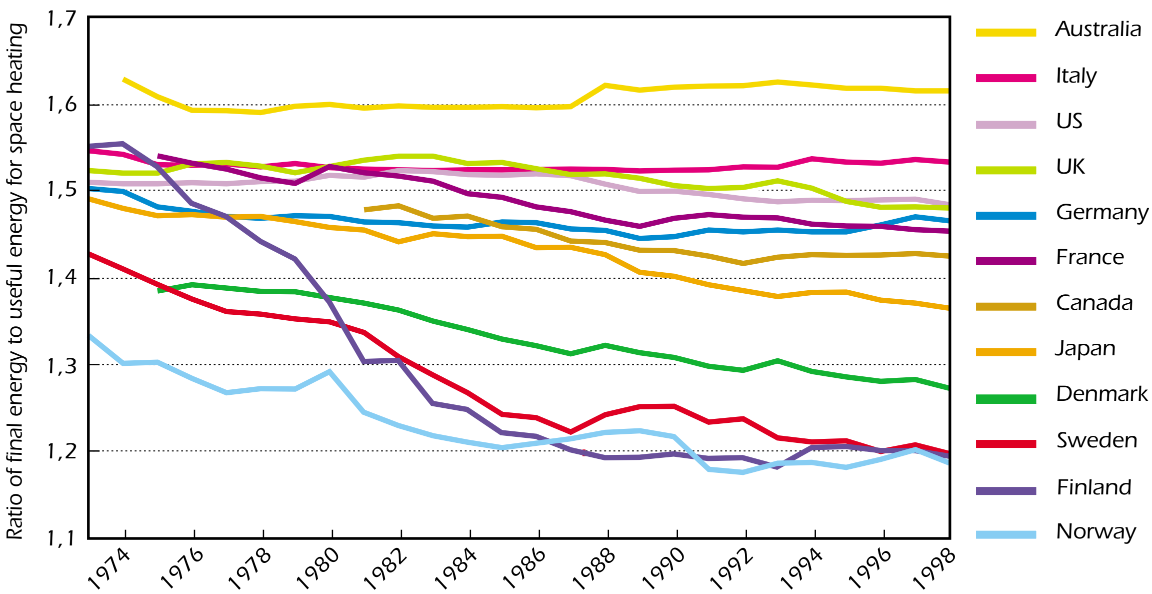
Oil had a relatively high share of the space heating market in 1973. As prices increased, oil was substituted to a large extent by natural gas in places where gas distribution was in place: by district heating in Denmark, Finland, and Sweden; and by electricity in Norway and to some extent Japan. In Norway the heavy reliance on electric heating (mostly resistance heaters) has been a result of access to inexpensive hydro-power. This resulted in less fuel flexibility than in its Nordic neighbours where centralised district heat production facilitates the use of various fuels, biomass, natural gas and oil, often in combination with combined heat and power generation. Although at a smaller scale than in Norway, electricity for space heating has increased in most of the countries shown in Figure 5-6. The low equipment cost and the convenience of modular units have made electric resistance heaters gain market shares even in countries where electricity prices are high.

Space Heating End Use Conversion Losses

Substituting electricity for fossil fuels reduces the need for final energy per unit of heat provided

Figure 5-7

Ratio of Final Energy to Useful Energy for Space Heating [4,5]



The choice of space heating fuel affects the consumption of final energy since converting oil, gas, coal and wood to useful heat implies losses at the end-use level, while the end-use efficiency of electricity and district heat is close to 100%. For example, assuming 66% efficiency for an oil-based heating system means that a household needs to buy 1.5 units of oil to produce one unit of useful heat compared to buying one unit of electricity or district heat to deliver the same amount of heat.[6]

Differences in space heating choices explain some of the variations in final energy for space heating. Figure 5-7 indicates that countries with primarily fossil fuel-based heating systems like Australia, Italy, the United Kingdom and United States have some 25% higher final energy consumption per unit of heat provided than in Finland, Norway and Sweden where electricity and district heat dominate. The downward trend in end-use losses indicated for the majority of countries in Figure 5-7, reflects the increased penetration of electric heating and/or district heat. In some cases, such as the four Nordic countries and Japan, this shift has had an important effect in restraining growth in final energy consumption for space heating.

4. Assumes 55% conversion efficiency for wood and coal, 66% for oil and gas, and district heat and electricity counted at 100%.

5. This means that the figure reflects only differences in the ratio of final to useful energy from changes in end-use fuel mix and not changes in the actual efficiency of the heating equipment in each country. The latter effect is not possible to capture since detailed data on heating equipment stock are not available.

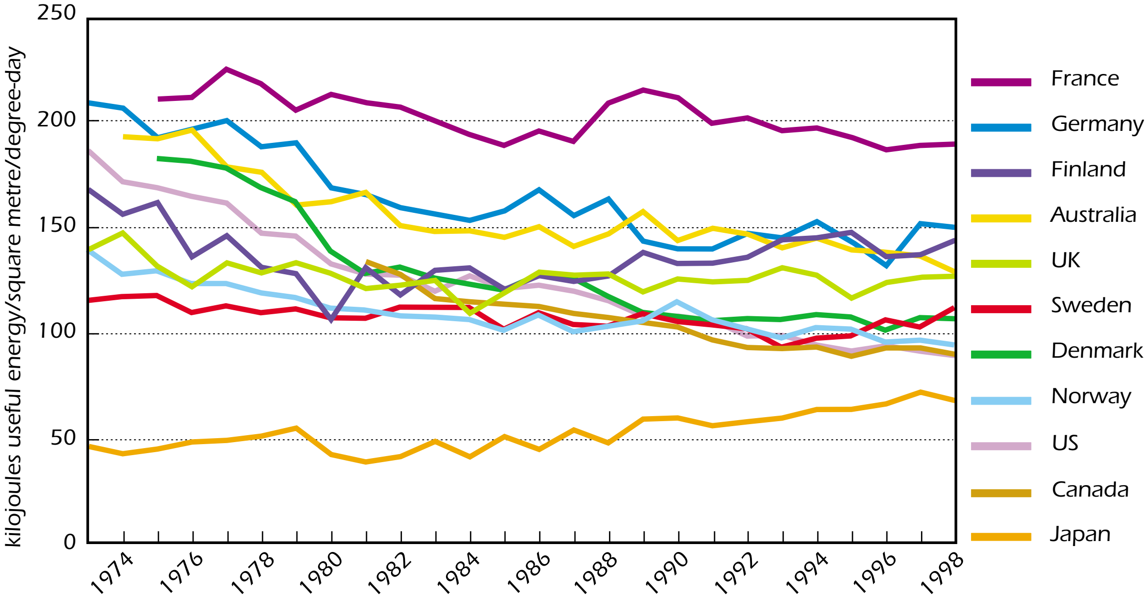
6. If the comparison of heating options is based on primary energy by including the losses of the power or heat plant, the picture would change depending on what fuel and plant type is used to produce the electricity or district heat.

Space Heating Energy Intensity

Space heating intensities have declined, but increased comfort levels offset the savings in some countries

Figure 5-8

Useful Space Heating Intensity



Since the choice of fuel affects the level of final energy for space heating it is more interesting to analyse useful energy intensities when assessing trends in space heating efficiency. To allow for comparisons across countries with different climates, the useful energy intensity shown in Figure 5-8 is divided by each country's yearly number of degree-days.

There was considerable divergence in intensities among countries in 1973 due to differences in heating practices and heat losses in buildings. Yet by 1998, intensities had converged markedly. It emerged as most countries with high intensities achieved significant reductions while countries with medium and low intensities in 1973 saw more moderate declines. Intensities fell over this period in all countries but Japan. This is not surprising considering the very low space heating intensity of Japanese homes in the early 1970s. The low intensity was due to relatively low indoor temperatures, shorter heating time and that only part of the living area was heated. Since 1973 intensity has increased as the average Japanese home upgraded indoor heating comfort to a greater degree than improved insulation of the dwellings reduced consumption. Today, nevertheless, Japan continues to have the lowest space heating intensity among IEA countries. A similar development also took place in Norway and the United Kingdom where income growth gave room for higher heating comfort levels, which ate up some of the savings from better insulation standards.

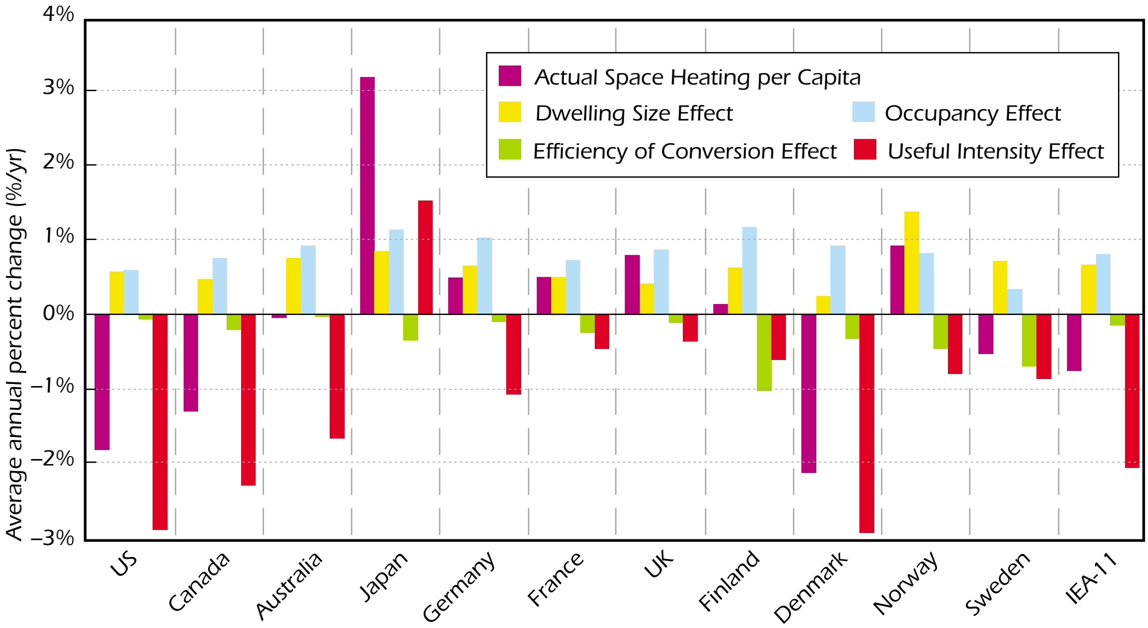
The countries with the strongest intensity declines between 1973 and 1998 had achieved the bulk of them by the mid-1980s. Since 1990 intensities have fallen in less than half of the countries. Norway is the only country where heating intensity fell more after 1990 than before as the negligible decline between 1973 and 1990 was followed by an average annual decline of 2.4% over the next eight years.

Space Heating Decomposition

Bigger houses and fewer occupants have been countered by changes in fuel mix and lower intensities, but to a varying degree

Figure 5-9

Decomposition of Changes in per Capita Space Heating, 1973-1998



The previous figures show that energy use for space heating is affected by a complex set of changing factors. Generally per capita space heating (Figure 5-4) converged among countries, although some factors pointed the other way. Figure 5-9 summarises how the components defined in the space heating decomposition box have impacted changes in per capita space heating (climate-corrected) in selected countries between 1973 and 1998. Per capita space heating fell in some countries and increased in others. However, larger dwelling area and fewer occupants per dwelling induced an upward pressure on demand. The effect of increasing dwelling area pushed up space heating needs by 0.3 - 0.8% per year on average in all countries except Norway, where the growth in per capita dwelling size averaged 1.4% per year. In most countries, the effect on per capita space heating needs from fewer occupants was stronger than the increase in dwelling size. Together these two factors would have raised per capita space heating energy use by between 1 and 2% in the countries shown in Figure 5-9.

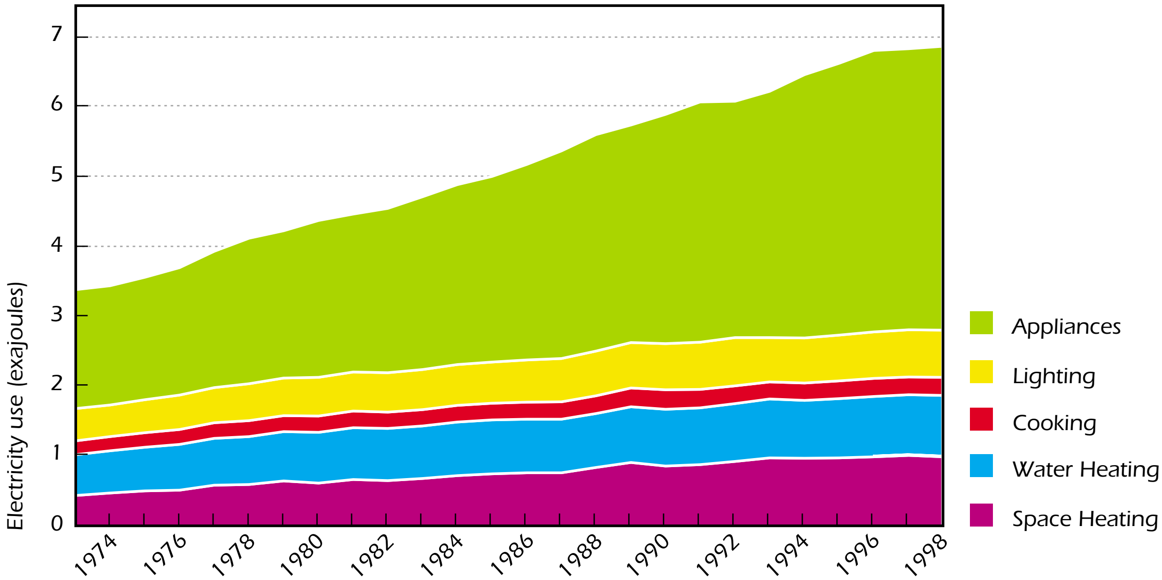
Countering the impact of these two driving factors have been lower end-use conversion losses, mostly due to the increased share of electricity in the space heating mix, and lower useful space heating intensity. Outside of Japan and Finland, the latter factor contributed the most to lowering energy use for space heating. Indeed, for the IEA-11 countries, the decline in space heating intensity averaged 2.1% per year, while the reduced final to useful energy ratio averaged a 0.2% decline annually since 1973. In total these two factors reduced IEA-11 space heating by more than changes in dwelling size and household occupancy drove heating needs up, so that per capita space heating energy use fell by 0.8% on average between 1973 and 1998.

Residential Electricity End Uses

Appliances are the main contributor to growth in electricity demand

Figure 5-10

Residential Electricity Demand by End Use, IEA-11[7]



Electricity use in IEA-11 households has more than doubled between 1973 and 1998. Today it accounts for almost one-third of total final residential energy consumption. This is up from 18% in 1973. Electricity use has increased in all residential end uses, most notably for space heating (doubling since 1973) and appliances (up 140%). This compares to a 50% increase for lighting and water heating, while electricity for cooking grew a modest 30%.

In 1973, appliances accounted for roughly half of the electricity use in IEA-11 households. By 1998, this share had increased to 58%. The share of electricity for space heating grew from 13% to 16%, while the shares for water heating fell from 17% to 12%, lighting from 14% to 10% and cooking from 6% to 4%.

The importance of appliances in total electricity consumption means that the strong growth in this end use has been the key factor in driving up residential electricity demand. Roughly two-thirds of the doubling of IEA-11 electricity demand between 1973 and 1998 came from appliances, while space heating accounted for 18%, water heating 8%, lighting 6% and cooking less than 2%.

7. The heating of hot water for wet appliances (dishwashers and laundry machines) is included with water heating and not with appliances in IEA's analysis. This is done to assure consistency among countries since wet appliances are fed with hot water in some places and with cold water in others.

Major Appliances

Ownership of major appliances is high
but reaching saturation…
and appliances have become more efficient

Table 5-2

Ownership and Unit Energy Consumption of Refrigerators and Refrigerator/freezers

	Refrigerator & Refrigerator/Freezer Ownership (units/dwelling)				Unit Energy Consumption (kWh/yr)			
	1973	1980	1990	1998	1973	1980	1990	1998
Australia	1.22	1.24	1.25	1.26	904	1050	873	773
Canada	-	0.99	1.18	1.22	-	1435	1225	816
Denmark	0.97	0.97	0.94	1.06	462	523	462	433
Finland	0.91	1.06	1.04	1.06	655	651	652	622
France	-	1.02	1.11	1.16	-	518	550	408
Germany	-	-	1.09	1.11	-	-	352	287
W Germany	0.99	1.12	1.31	-	343	345	312	-
Italy	1.00	1.09	1.13	1.14	240	290	360	361
Japan	1.04	1.15	1.19	1.21	439	680	666	616
Netherlands	0.88	1.04	1.05	1.16	360	350	376	342
Norway	0.89	1.05	1.30	1.43	516	538	551	538
Sweden	0.97	1.04	1.11	1.17	594	602	453	408
UK	0.73	0.91	1.02	1.05	425	465	509	492
US	1.00	1.14	1.14	1.15	1450	1396	1155	915

Ownership of major appliances such as refrigerators and dishwashers became widespread in the 1970s and early 1980s, which sparked demand for electricity.[8] Increased income levels and decreasing appliance prices fed the trend. But the growth rate of major appliances ownership began to slow significantly in most IEA countries through the 1980s. This saturation effect is illustrated with the example of refrigerators and refrigerators-freezer ownership in Table 6-2.

Yet as the ownership of major appliances increased, they became steadily more energy efficient: the estimated Unit Energy Consumption (UEC) per appliance and per year dropped for most appliances in most countries. This effect is illustrated for refrigerators and refrigerators/freezers in Table 5-2. However, the UEC measure depends not only on technical efficiency but also on size and other characteristics, e.g., how often clothes and dishes are washed. Indeed, the increase in UEC for refrigerators and refrigerators/freezers seen for some countries in Table 5-2, e.g., Japan and Italy, is not due to lower efficiency, but rather that that the units became larger and included larger freezing compartments.

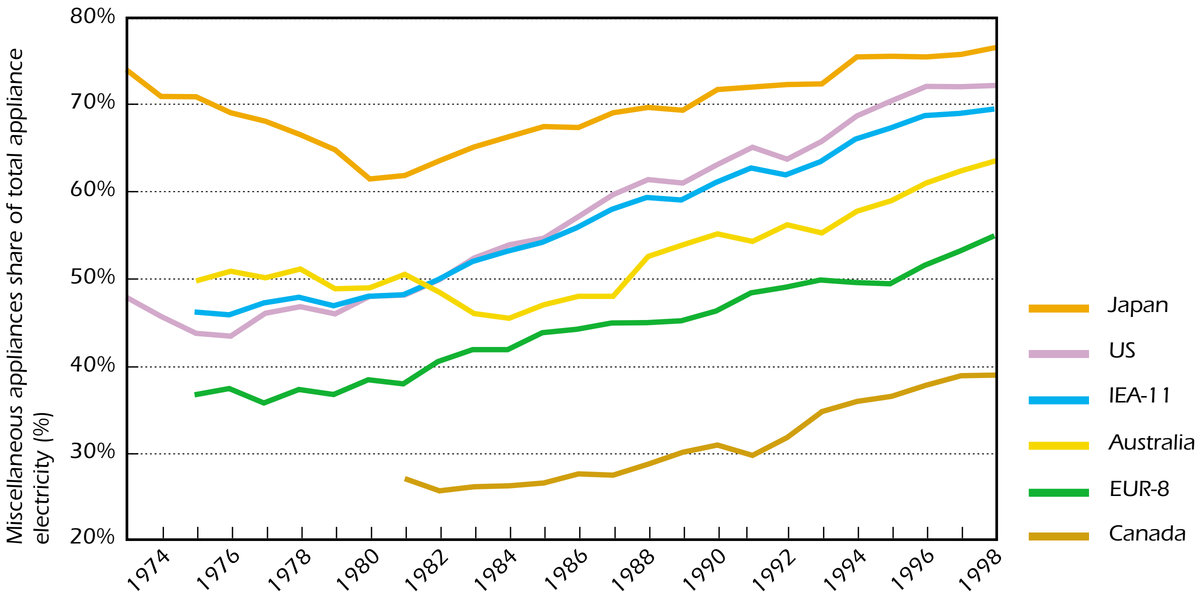
8. Major appliances are defined here as refrigerators, freezers, combination refrigerator-freezers, clothes-washers, clothes-dryers and dishwashers.

Miscellaneous Appliances

Increased ownership of "miscellaneous appliances" now drives growth in electricity demand for appliances

Figure 5-11

Share of Total Electricity Use for Miscellaneous Appliances



While ownership of major appliances may be stabilising, the ownership of "miscellaneous" appliances is now growing strongly and is responsible for much of the recent growth in appliance electricity demand. Miscellaneous appliances range from home electronics and office equipment to small kitchen appliances. The enormous diversity of technologies and their uses within the miscellaneous category makes precise measurement of ownership in the aggregate difficult. The best available proxy to evaluate aggregate ownership is the share of appliance electricity use for miscellaneous appliances.

Figure 5-11 shows that miscellaneous appliances now account for roughly 70% of appliance electricity use within IEA-11, up from 45% in 1975. Note the trend in Japan where the share of miscellaneous appliances fell through the 1970s as the ownership and use of major appliances increased. Similar trends can be observed for the United States (before 1976) and for Australia (before 1984). However, since the mid-1980s the share of miscellaneous appliances has grown in all countries displayed in the figure.

Since there is little indication that ownership of miscellaneous appliances is saturating, this group of appliances is likely to continue being an important stimulant for electricity demand growth in IEA countries. There are, however, ways to reduce this growth through improved energy efficiency.[9]

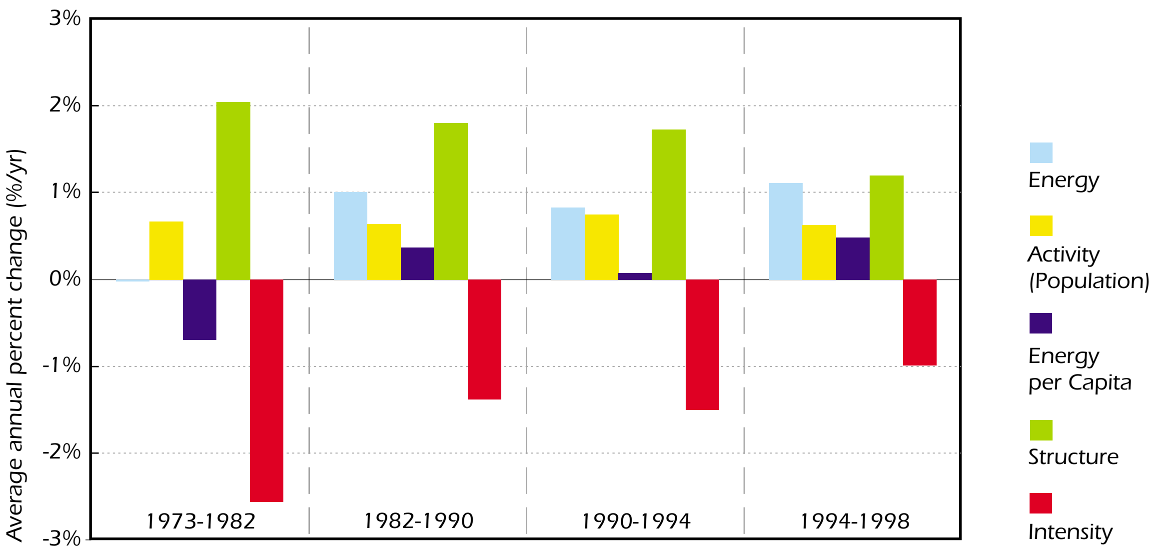
9. Cool Appliances; Policy Strategies for Energy-Efficient Homes, *published by the IEA in 2003 shows how stronger policy measures could save significant amounts of electricity related to the use of appliances. A large potential for savings is standby consumption. The IEA's 2001 publication* Things That Go Blip in the Night; Standby Power and How to Limit It *provides guidance on relevant policy strategies.*

Decomposition of Household Energy Demand

Intensity declines have slowed in recent years

Figure 5-12

Decomposition of Changes in Total Residential Energy Use, IEA-11*



*Climate-corrected

Figure 5-12 summarises the impact that changes in activity, structure and end-use intensities have had on total residential energy use in IEA-11 countries, using the decomposition approach described in Chapter 2. Recall that while the activity component for the overall residential decomposition is simply population growth, structural changes include: home area per capita (for space heating and lighting); appliance ownership per capita; and household occupancy (for water heating and cooking). The intensity effect includes the impact of changes in all residential end-use intensities.

Population has grown relatively steadily at around 0.7% per year between 1973 and 1998 in the IEA-11, but growth in residential energy use has fluctuated. Zero change in energy use between 1973 and 1982 led to a decline in per capita energy consumption. Between 1982 and 1994, energy use increased at a slightly higher rate than population. After 1994 residential energy use grew at a higher rate than in any period before, even though the upward effect on energy use from the structural component was less than in the previous periods. In fact, while the structure effect, driven by increases in house area and appliance ownership and decreases in household occupancy, pushed up energy use at an annual rate of between 1.8 and 2.1% until 1994, the structure induced growth was down to 1.2% after 1994, reflecting a slower growth in house area and some saturation in appliance ownership.

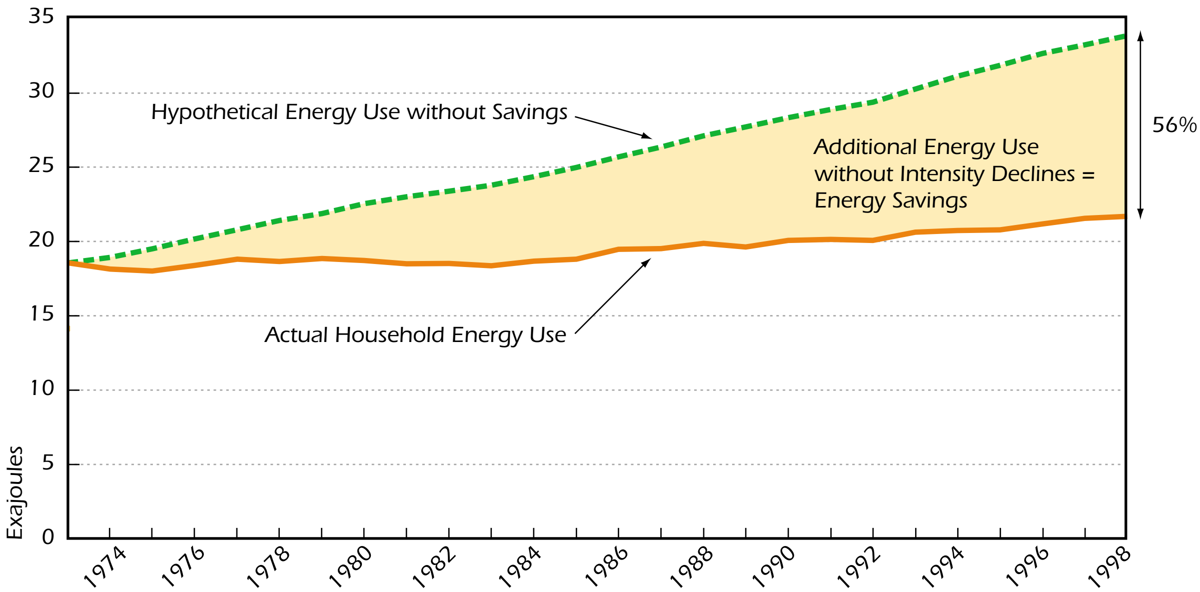
Declines in energy intensities have largely offset the increases driven by the structural components between 1973 and 1998, i.e., residential energy use grew at about the same average rate as population. However, since 1994 the decline in intensity has been slower than in the periods before, primarily caused by slowing declines in space heating intensities outside of the United States (see Figure 5-8).

Energy Savings in Households

Significant savings of residential demand, but saving rates have slowed

Figure 5-13

Actual Climate-corrected Energy Use and Hypothetical Energy Use without Intensity Reductions, IEA-11



How much did declining energy intensities reduce residential energy use in IEA-11 between 1973 and 1998? The lower line in Figure 5-13 shows actual climate-corrected IEA-11 energy use, including the effect of changes in energy intensities. The upper line represents the hypothetical energy use that would have occurred if no changes in energy intensities had taken place since 1973. Energy savings due to declining energy intensities are then defined as the differences between the two curves (see equation 5 in Chapter 2 and Chapter 3, Figure 3-16).

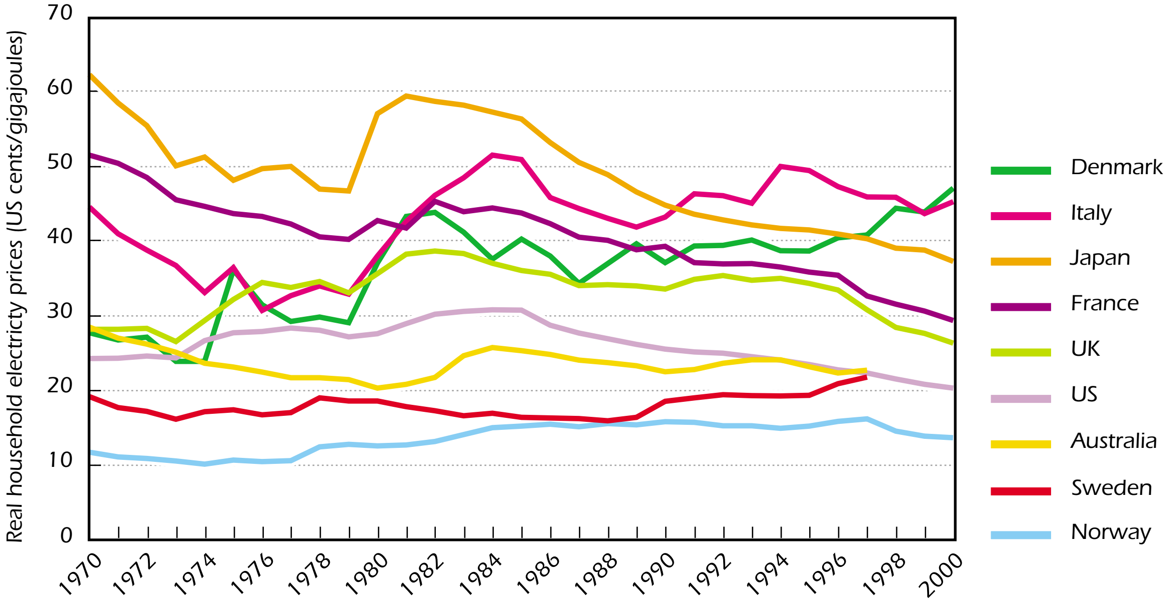
The figure clearly indicates how declining energy intensities have led to savings of residential energy use. By 1998 the savings amounted to 12.2 EJ, which correspond to 56% of the actual 1998 residential energy use level. In other words, energy use in 1998 would have been 56% higher in 1998 if intensities of the various residential end uses had remained at 1973 levels.

Residential Electricity Prices

Only moderate changes in real electricity prices since 1973, but significant differences among countries

Figure 5-14

Residential Electricity Prices in Real Terms, Including Taxes



In the majority of IEA countries residential electricity prices in real terms have undergone less dramatic changes than oil prices, and to some extent less than coal and gas prices. Fossil fuel prices increased significantly in the aftermath of the oil price shocks in 1973-1974 and 1979, and fell again with the crash in crude oil prices in 1986 (see Figure 3-4). For the countries shown in Figure 5-14, electricity prices between 1973 and 1986 increased moderately in most and declined in a few. After 1986 electricity prices fluctuated somewhat, but with a general downward trend, especially over the last few years. In fact, only in Denmark where electricity taxes increased during this period, were real prices in 2000 higher than in 1986.

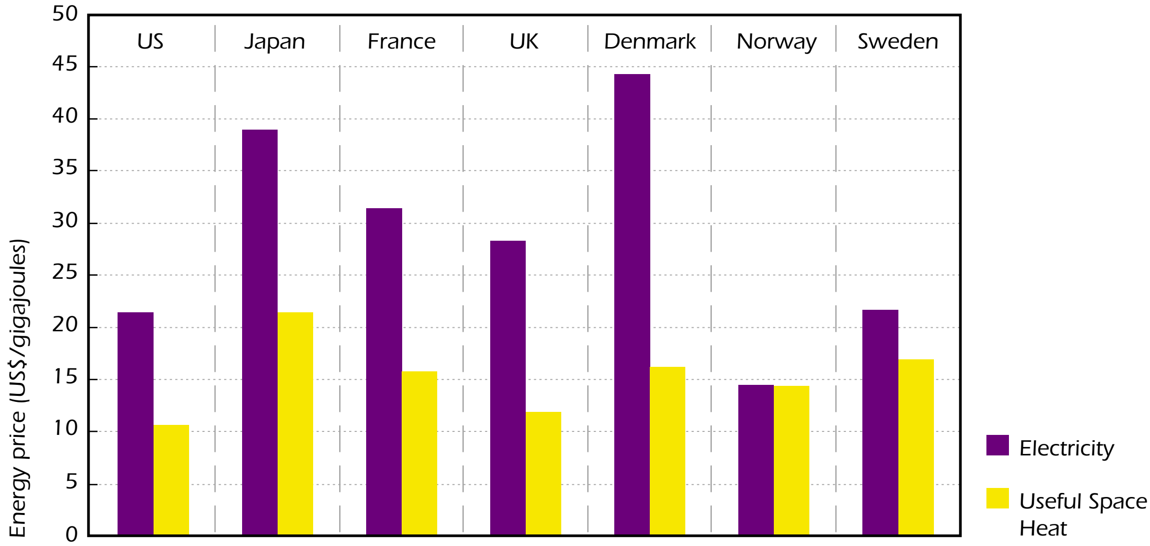
There is a striking variation in residential electricity price levels among countries. In 2000, there was a 3.5 factor difference between Denmark with the highest price in this group and Norway with the lowest price. Since both these countries belong to the common Nordic electricity market, the price differential is mostly due to differences in taxation. This divergence in policy between the two neighbouring countries reflects very different resource endowments; Norwegian consumers' access to inexpensive hydropower has been considered a public good, while in energy import-dependent Denmark, reducing fuel inputs for power generation through taxation of electricity has been more generally practiced.

Electricity and Useful Heat Prices

The price paid for useful space heating varies much less than electricity prices

Figure 5-15

Electricity Prices and Fuel-weighted Price per Unit of Useful Space Heat, 1998



In countries such as Norway, where the share of electricity in space heating is high, the price of electricity is a good indicator of what consumers pay to heat their homes. Most countries, however, rely primarily on other energy carriers for heating. To compare what households actually pay for space heating it is thus more revealing to investigate fuel-consumption-weighted prices. In Figure 5-15 this weighted price, calculated by multiplying the consumption of each heating fuel by its price and dividing by total useful space heating, is compared against electricity prices in 1998.[10]

As the figure indicates the difference between the electricity price and the useful space-heating price is smallest in Norway followed by Sweden, the two countries that use the most electricity for space heating. For the other countries, the useful space-heating price is 50% or less of the electricity price. In Denmark, for example, consumers pay about three times more for electricity than they pay per unit of useful heat provided to their homes. The differences would have been even larger if electricity prices were compared against fuel-weighted price per final energy for space heating instead of per unit of useful energy.

Consequently, the variations among countries in space heating prices are much less than for electricity prices. This indicates that non-price factors such as building codes, climate (homes in cold climates tend to be better insulated) and cultural aspects (e.g., preference for indoor temperature) are important to explain differences in the level of space heating intensities (Figure 5-8). However, the strong variations in electricity prices indicate differences in the economic incentives to undertake energy efficiency improvements of electricity-specific uses such as lighting and appliances.

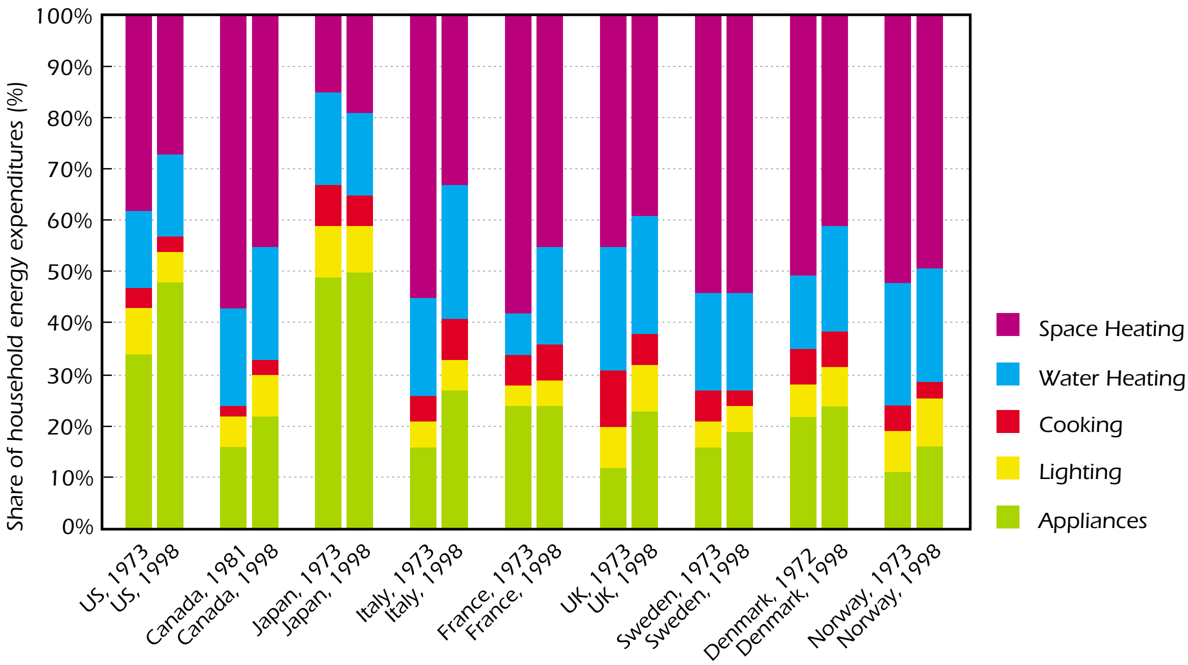
10. The IEA does not report prices for wood and district heat, so consumption-weighted price excludes these two heating sources. The only exception is for Sweden and Denmark where prices from national data were used to calculate the price including district heat.

Energy Expenditures by End Use

Appliances are taking over from space heating as the most expensive residential end use in countries with warm to moderate climates

Figure 5-16

Shares of Residential Energy Expenditures by End Use



With space heating being the most significant residential energy use in most countries, it is not surprising that it constitutes the largest share of household energy expenditures. As seen in Figure 5-15, however, prices for space heating are normally much lower than for electricity. This means that the expenditure share for space heating is generally lower, and the expenditure share for electricity-specific applications is generally higher, than their shares of residential energy consumption would imply.

The low variation in space heating prices from country to country indicates that variations in consumption levels are important to explain differences in expenditures for space heating. While for electricity dominated end uses, differences in expenditures are clearly a result of both of price and consumption level divergences.

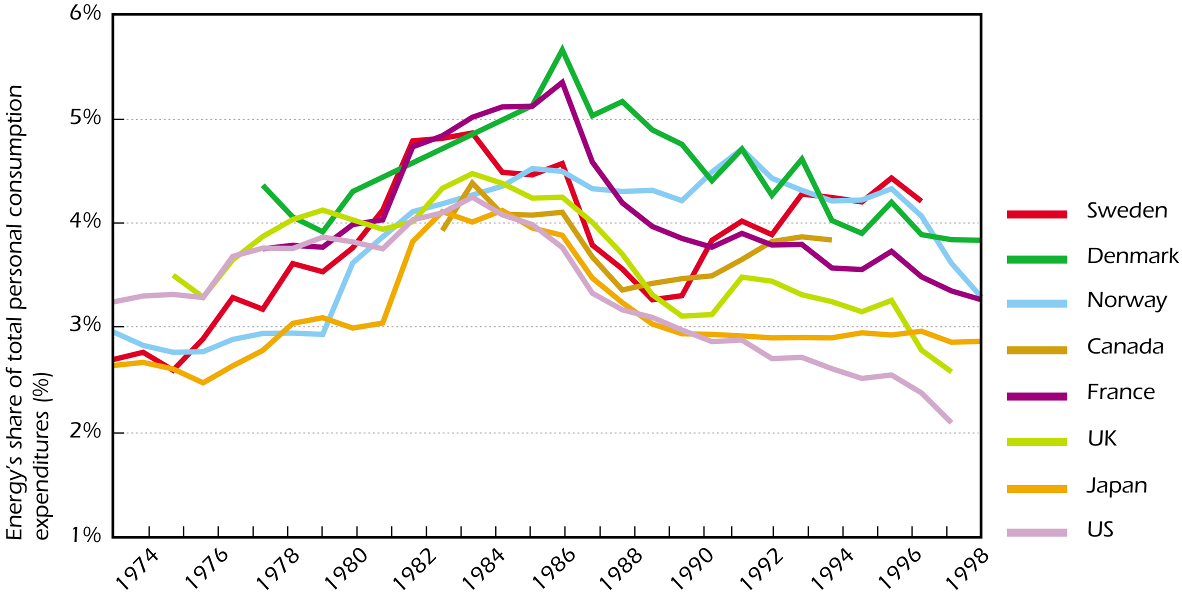
Besides Japan, all countries in Figure 5-16 have seen a reduction in the expenditure share for space heating between 1973 and 1998, driven mostly by reduced intensities. In 1998 only consumers in Sweden and Norway spent 50% or more of their energy budgets to heat their homes. On the other hand, only in Japan did electric appliances account for more than half of energy expenditures, although the share of this end use has increased in all countries since 1973.

Energy Expenditures as a Share of Personal Income

IEA households today spend roughly the same share of their incomes on energy as in 1973

Figure 5-17

Share of Residential Energy Expenditures in Total Personal Consumption Expenditures



The share of disposable incomes that IEA households pay for energy has varied significantly over the last three decades. In the mid 1970s it was between 2.5 and 4% in the group of countries shown in Figure 5-17. The share increased to between 4 and 5.5% by the mid-1980s and then started to decline in most countries. By 1998, the shares were roughly back into the same band as in the mid 1970s.

What percentage of total income is spent on household energy depends on the price of purchased fuel, the mix of fuels used and the level of residential energy demand per unit of income. To better understand the development of the shares shown in Figure 5-17 it is interesting to look at how each of these components have evolved.

This can be done by decomposing changes in the expenditure share into changes in residential energy demand per unit of income, real fuel prices and fuel mix through holding all but one factor constant at the 1990-level. In this manner, the impact from changes in prices can be calculated as the change in real prices for oil, natural gas, coal and electricity, weighted at the 1990 fuel mix and consumption levels. Conversely, the change in expenditure share resulting from changes in the fuel mix is calculated holding relative fuel prices and energy demand per unit of income constant at the 1990-level. Then the impact from changes in energy demand per unit of income is calculated with prices and fuel mix at 1990-levels.

Factors Affecting the Development of Energy Expenditures

Strong growth in energy expenditures due to higher prices reversed after 1982

Figure 5-18

Decomposition of Changes in Residential Energy Expenditures per Unit of Income

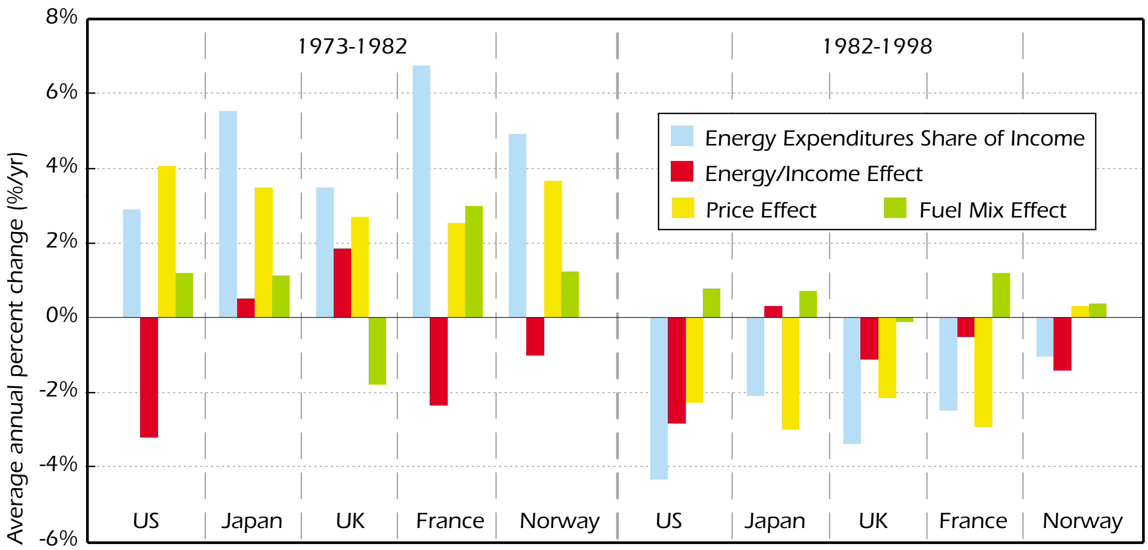


Figure 5-18 shows changes in the energy expenditure share decomposed as described on the previous page. The share of energy expenditures in disposable income increased rapidly between 1973 and 1982 in all the countries shown, indicating that energy was a much bigger burden on household budgets. The average annual growth ranged from 2.9% in the United States to 6.8% in France. In the United States, the expenditure share grew even though energy demand per unit of income fell by more than 3% per year on average. This growth was primarily driven by increased real prices for fuels and electricity, although an increased share of electricity in the fuel mix also contributed (electricity is generally more expensive than other energy carriers). Increased prices also drove up expenditures in the other countries, as did the higher share of electricity, except in the United Kingdom, where the electricity share actually fell between 1973 and 1982.

After 1982 the picture changed: the share of energy expenditures fell in all countries, as also shown in Figure 5-17. The main reason for this turn-around was a strong decline in energy prices in all countries except Norway. On the other hand, increased shares of electricity in the fuel mix driven by more appliances continued to induce a moderate upward pressure on energy expenditures in most countries. The fall in prices was augmented by a decline in energy demand per unit of income in all countries except Japan, where residential energy demand grew slightly faster than income. Taken over the whole period, lower growth in energy consumption relative to income helped reduce the importance of energy in the household budgets in all IEA-11 countries, except Japan. Clearly, without the energy savings achieved between 1973 and 1998, IEA households would have seen much more of their incomes being spent on energy.

Chapter 6. SERVICE

Highlights

- The service sector consumes 13% of total final energy use in IEA countries. In a group of eleven IEA countries (IEA-11) (together accounting for 86% of total service sector energy use in IEA countries in 2000), energy consumption increased 35% from 1973 to 2000. Electricity now dominates the service sector fuel mix, accounting for nearly 50% of total consumption, which corresponds to 31% of total electricity demand in the IEA-11.
- Strong growth in service sector output, measured as value-added, and the accompanying growth in floor area for service buildings are the main drivers behind the growth in energy demand in the service sector.
- Although a small part of the growth in electricity use in the sector resulted from fuel switching away from fossil fuels, much of the growth can be attributed to the proliferation of electricity-based end uses such as cooling, ventilation, lighting, and an increasingly diverse array of office and network equipment.
- Fuel use (excluding electricity) per square metre of building area fell significantly in all of the IEA-11 countries between 1973 and 1990. Except for countries where electricity became an important space heating choice, these trends indicate improved heating practices. Declines in fuel use per square metre ranged from 5.2% per year in Denmark to 2.9% per year in the United States. Since 1990, however, fuel intensity declines have slowed significantly in all IEA-11 countries with the exception of Finland and France, indicating lower rates of space heating energy savings.
- Total energy use (fuels and electricity) per building area also fell in nearly all of the IEA-11 countries through 1990. However, after 1990 the decline in energy use per area slowed in most counties. As electricity use per area continued to increase, the slowing decline in fuel intensity has led to very little or no reduction in total energy use per square metre since 1990.
- Energy use relative to value-added declined more than it did relative to building area in most of the IEA-11 countries both before and after 1990. From 1973 to 1982, the decline in energy per value-added largely offset the growth in service value-added. After 1982, intensity declines slowed in many countries while service output continued to increase strongly. As a result, service sector energy use grew steadily at roughly 2% per year from 1982 to 1998.
- Energy expenditures, relative to value-added, increased significantly in the years following the oil price shocks. During the period of declining oil prices in the mid to late 1980s, energy expenditures fell in most countries. Since then, relatively stable prices combined with a steady increase in the share of electricity and a slower decline in energy intensities accelerated the growth in energy expanditures. By 1998, energy expenditures, relative to service sector value-added, had increased significantly from 1973 levels in a majority of the countries despite the declines in energy intensities that occured during the period.

Definitions and Data Used in this Chapter

Sectors

The service sector, also known as the commercial and public sector or tertiary sector, comprises activities that take place in non-residential, non-industrial, non-agricultural buildings such as offices, hospitals, schools, shops, warehouses, etc. Since service buildings house different kinds of enterprises, it is difficult to further disaggregate the service sector into sub-sectors or building categories that are meaningful for energy use analysis. In addition, energy data by either sub-sectors or building category are generally not available on a consistent basis for IEA countries. Consequently, this study only analyses energy use at the aggregate sector level.

Energy

Measured as final energy. Data are generally from IEA *Energy Balances of OECD Countries* supplemented with data from national sources (See Chapter 2).

Activity

Contribution to GDP from the service sector, here termed value-added, measured in real terms (1995) and converted to US dollars using purchasing power parities. Value-added data are taken from the OECD *National Accounts*. Floor area data are also used where available from national sources, although some countries lack complete time series or do not have estimates available.

Structure

Analysis of structural change is not included since the sector is not disaggregated into sub-categories (see above).

Intensity

Final energy use per activity. Energy intensity is primarily measured in terms of economic output, but energy use per floor area is also presented as an alternate measure of energy intensity where data are available.

Energy Prices

Energy price data are from IEA *Energy Prices and Taxes*.

Decomposition

Changes in service sector energy use are decomposed into changes in output (value- added) and energy intensity using the decomposition method described in Chapter 2.

Country Coverage

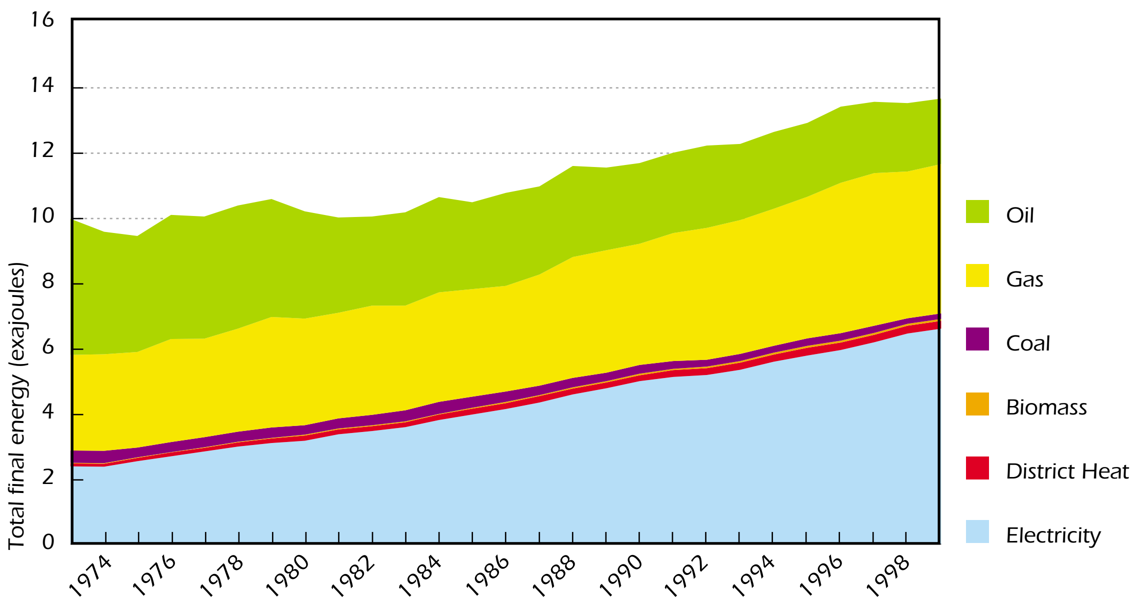
IEA has consistent time series with energy and value-added data from 1973 or 1974 through 1998 and in some cases 1999 and 2000 for eleven IEA countries. This includes Australia, Denmark, Finland, France, Germany, Japan, Italy, Norway, Sweden, the United Kingdom and the United States. When the aggregate results of this group are presented the group is referred to as IEA-11. Together these countries accounted for 86% of total IEA service sector energy use in 1998. In addition, IEA has complete time series with service sector data but for shorter periods for the Netherlands and Canada.

Energy Use in Service Sector by Fuel

Electricity drives the growth of energy use

Figure 6-1

Energy Use in Service Sector by Fuel, IEA-11



Energy use in the service sector has grown strongly since 1973, increasing more than 35% in the IEA-11. Following short-term declines in energy consumption after the oil price shocks in 1973-74 and 1979, service sector energy use grew steadily, averaging nearly 2% per year since 1982.

The service sector accounted for 13% of total final energy use in the IEA-11 countries in 1998, and a third of IEA-11 electricity demand.

There has been a consistent trend toward less oil and more electricity and natural gas in the sector's fuel mix throughout the last three decades. In 1973, oil was the dominant fuel at 42% of total energy use with natural gas and electricity accounting for 29% and 24%, respectively. In the wake of the oil price shocks of the 1970s, oil consumption declined in both absolute and relative terms, while gas and electricity steadily increased their share. Natural gas now accounts for a third and electricity for nearly half of energy consumption in the service sector.

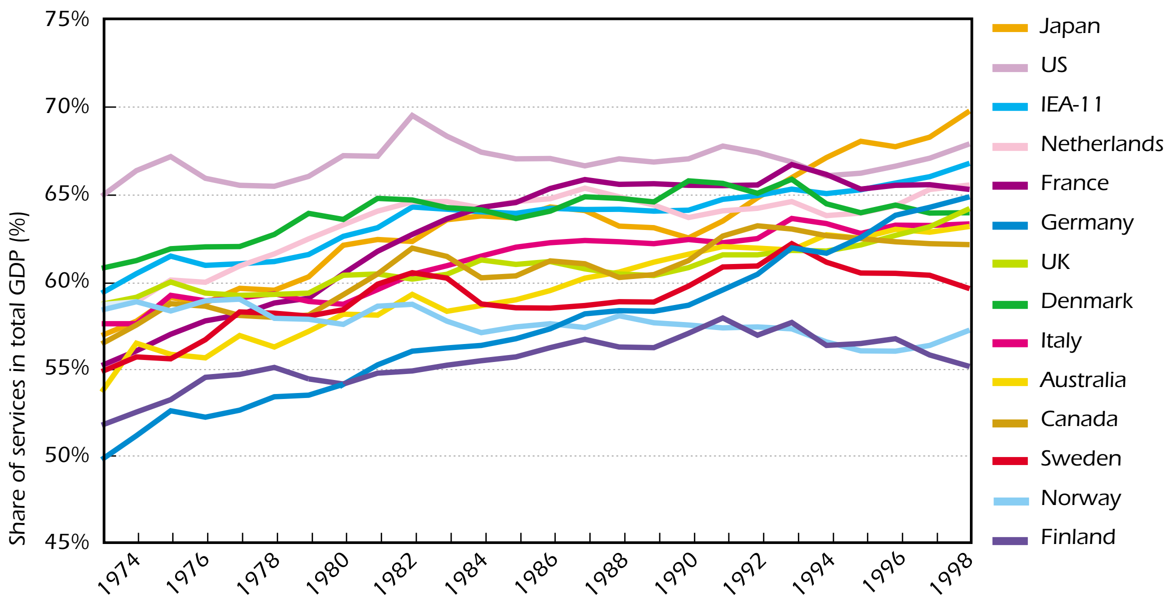
The changes in the fuel mix partially reflect price-induced fuel substitution away from oil during the high-price periods. Except for a few countries where inexpensive electricity was available as an option for space heating, the increase in electricity share to a large extent reflects shifts toward more electricity-intensive end uses such as air-conditioning and information technology equipment.

Service Sector Output

Service sector has increased its dominance in total GDP

Figure 6-2

Share of Service Sector in Total GDP



A strong increase in service sector value-added has been the main driver behind growth in energy use. In fact, growth in service sector output contributed to the bulk of the growth in total GDP in most IEA countries. Economic output from the service sector in 1973 accounted for 50% or more of total GDP for the countries included in Figure 6-2. By 1998, the service sector had boosted its dominance in total GDP with a 67% average share for the IEA-11, up from the average 59% in 1973.

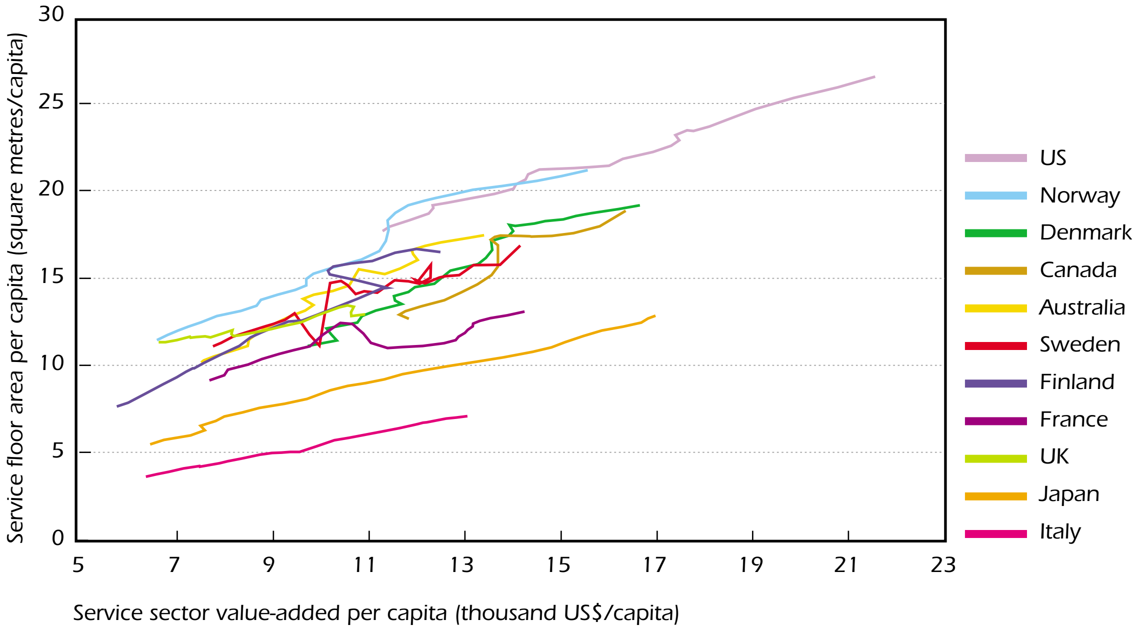
General trends were similar across IEA countries, yet data for individual countries show some interesting differences. The strongest growth in service sector output relative to total GDP occurred in Germany, with a 15 percentage-points increase in the GDP share in the 1973 to 1998 period, and in Japan where the GDP share increased 13 percentage-points. This represents average service sector value-added growth rates of 3.2% and 3.9% per year, respectively. In contrast, the United States service sector which was 65% of GDP in 1973, remained at nearly that level until the mid-1990s, when the share started to increase. The service sectors in Finland and Sweden actually experienced declines in their GDP shares during the 1990s as large increases in manufacturing output related to the cellular phone industry displaced the service sector in their respective GDP structures. The expansion of the petroleum sector has caused a similar effect in Norway since the late 1970s.

Service Sector Output and Floor Area

Built area for service sector is growing with economic output

Figure 6-3

Service Sector Floor Area per Capita and Value-added per Capita, 1970-1999



As the service sector has expanded, the stock of public and commercial buildings similarly has increased. The link between increases in service output and the total built area of the sector is important since energy consumption for several key end-uses in buildings is driven mainly by growth in floor area. These end uses include space heating, space cooling, ventilation and lighting.

Figure 6-3 shows how service sector floor area per capita has evolved with respect to the growth in services value-added per capita across IEA countries. Note that each data point represents the combination of per capita service sector value-added and floor area for a given year. Thus, if services value-added falls temporarily, the data points move to the left.

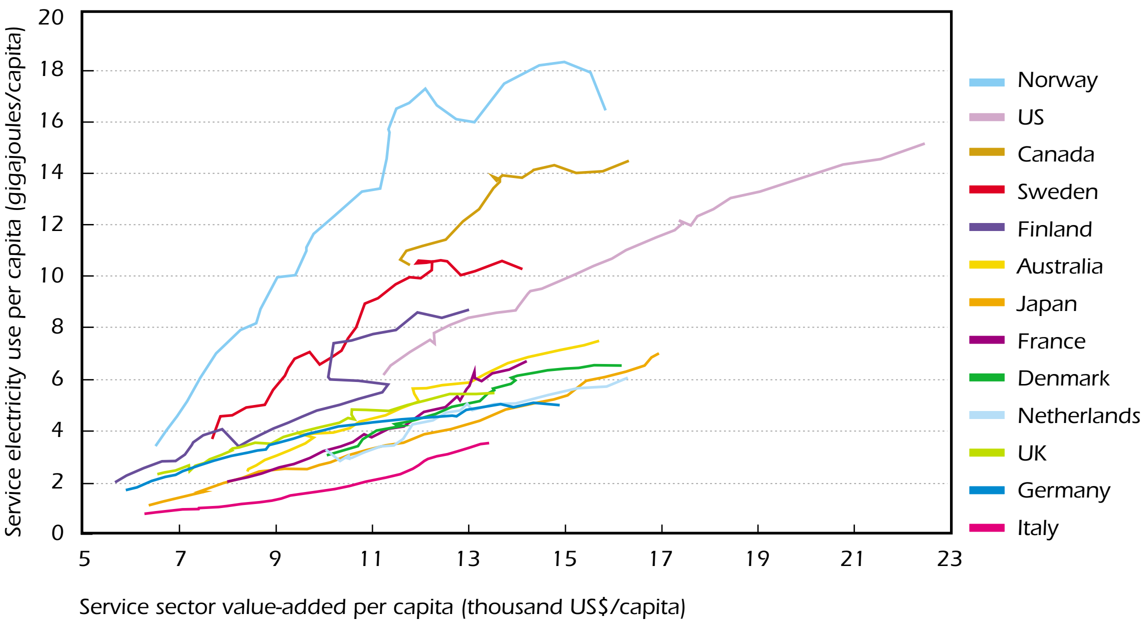
Most of the countries included in Figure 6-3 have similar relationships between growth in service floor area and sector value-added after normalising for differences in population. Italy and Japan clearly require less floor space per unit of service sector value-added generated, yet both countries display growth rates in this factor that are similar to countries where floor area per value-added is much higher.

Service Sector Output and Electricity Use

Electricity consumption is also rising as the service sector expands

Figure 6-4

Service Sector Electricity Use per Capita and Value-added per Capita, 1970-1999



The growth in service sector value-added and floor area have driven substantial increases in energy use, particularly in demand for electricity as shown in Figure 6-4. Indeed, the growth in electricity between 1970 and 1999 outpaced the growth of service sector output in most of the countries included in the figure.

In some countries a part of the growth in electricity use was a result of fuel switching away from fossil fuels, but much of the growth since 1973 was due to the proliferation of a wide array of electric end-uses. As the service sector expanded, the use of central heating, ventilation, and cooling (HVAC) systems expanded steadily, as did lighting levels and total lit area. The use of office and network equipment grew even faster as computers, photocopiers, and printers became ubiquitous features in nearly all parts of the service economy.

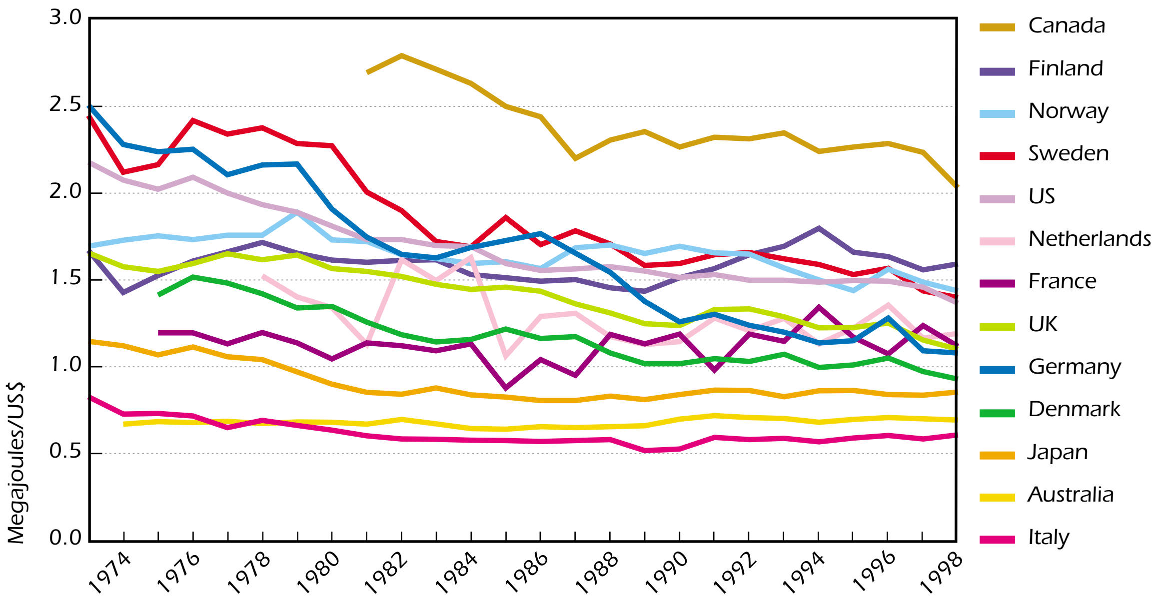
Most of the countries depicted in Figure 6-4 show strikingly similar relationships between electricity use and service value-added with the notable exceptions of Norway, Canada, Sweden and Finland. The high levels of per capita electricity consumption in these countries reflect their significant use of electric space heating augmented by the impact of cold climates. In Norway, for example, electricity accounts for approximately 80% of the space heating demand in commercial buildings, which helps to explain its extraordinary growth in electricity use.

Service Sector Energy Intensity

Energy use relative to value-added declined strongly in many countries, but changed little in others

Figure 6-5

Energy Use per Service Sector Value-added



Total energy use in the service sector grew less rapidly than value-added in most of the countries. As Figure 6-5 shows, the declines in total energy use per unit of service sector value-added were significant in several countries: they were particularly strong in the United States, Canada, Germany, Sweden and Denmark. On the other hand, energy use per value-added declined very little or not at all in Italy, Australia, Finland and France.

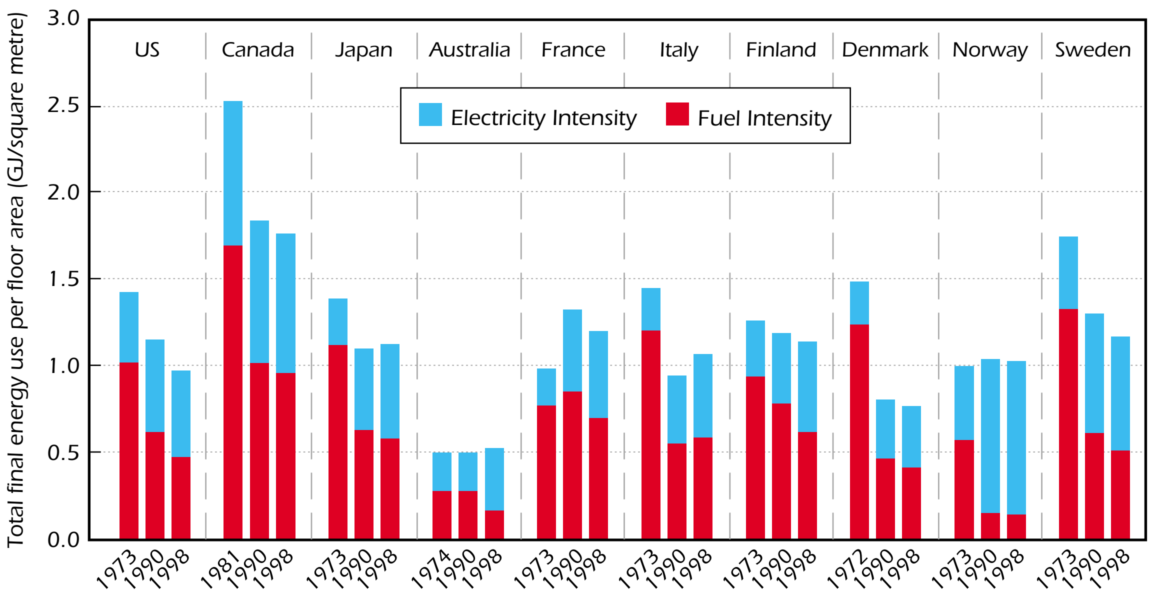
Interpreting these trends with respect to changes in energy efficiency is difficult. Different service sector activities can produce very different levels of economic output while consuming nearly the same amount of energy. For example, buildings in the finance sector can have the same final energy demand profile as buildings in the retail sector, yet generate significantly different levels of economic output.

Energy Use and Floor Area

Reductions in fuel use per area have slowed since 1990

Figure 6-6

Electricity and Fuel Use per Unit of Floor Area



The intensity of energy use per unit of floor area generally fell less than energy per value-added. This is because the value generated per area in the service sector increased in most countries. In fact, in Australia, France and Norway total energy use per unit of floor area was even higher in 1998 than in 1973. In all other countries this intensity fell between 1973 and 1990, but after 1990 most countries either experienced a significant slowing of the decline in the intensity, or an increase.

Separating the electricity and fuel components of the energy per floor area ratio gives additional insights. Changes in fuel use per square metre provide a proxy for space heating intensity trends in countries where electric space heating is not significant, which is most countries other than Norway, Canada, Finland and Sweden. In the other countries this intensity fell considerably between 1973 and 1990. This indicates significant savings of space heating energy, but after 1990 the rates of these savings generally slowed.

Contrary to fuel use, electricity use per unit of floor area increased throughout the entire period in all of the countries shown in Figure 6-6. This reflects the growth of electricity end-uses such as space cooling, ventilation, lighting and office equipment. Since 1990, continued growth in electricity use has led to increases in total energy use relative to floor area in Japan, Italy and Australia.

Impact of Changes in Output and Intensity on Energy Demand

Rates of decline in intensity slowed, then rebounded after 1994

Figure 6-7

Decomposition of Changes in Service Sector Energy Use, IEA-11[1]

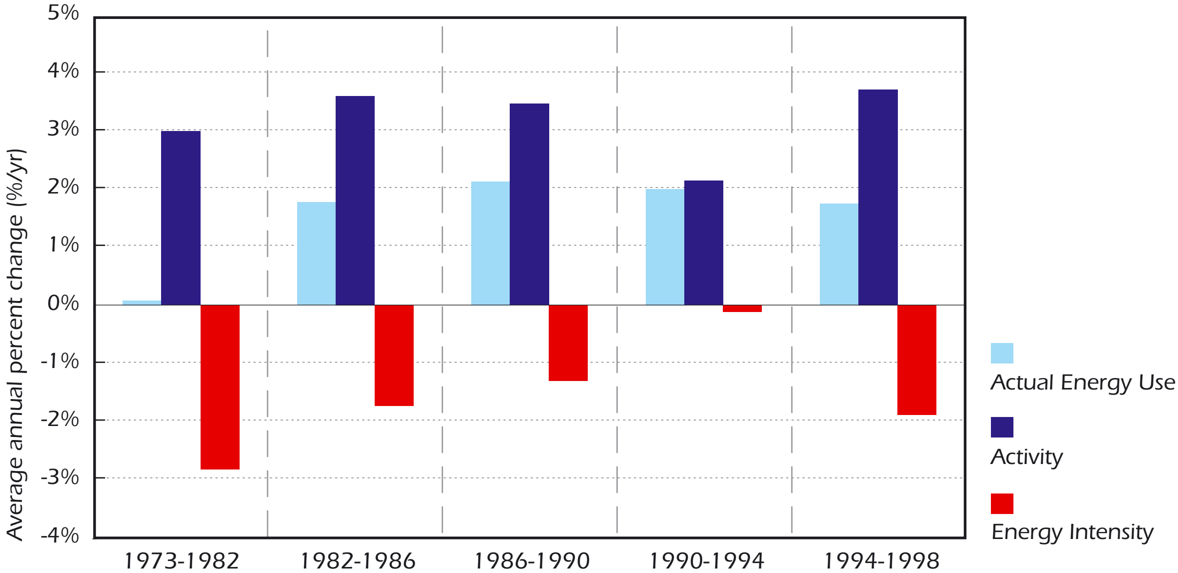


Figure 6-7 summarises the impact changes in activity (value-added) and energy intensity (energy per value-added) have had on total service sector energy use in the IEA-11, using the decomposition approach described in Chapter 2. Strong, sustained growth in service output has driven growth in service sector energy use. Service value-added grew by an average of 3.1% per year between 1973 and 1998 in the IEA-11. After slowing somewhat in the early 1990s due to recession in many IEA economies, growth in output rebounded and grew at 3.7% per year after 1994. Between 1973 and 1982 the strong decline in energy intensity was enough to offset all the growth in output, with no net change in energy use as a result. Since then, energy use has grown steadily at a little under 2% per year as decline rates in energy intensity gradually slowed. While the fall in intensity came to a halt between 1990 and 1994, the most recent trends show that energy intensities are once again falling significantly.

1. Note that the service sector is not further disaggregated into end uses or sub-sectors and thus the aggregate energy per value-added ratio represents the energy intensity effect. For the same reason, structural changes are not defined for the decomposition analysis of this sector.

Energy Savings

Significant energy savings in the service sector

Figure 6-8

Actual Energy Use and Hypothetical Energy Use without Intensity Reductions, IEA-11

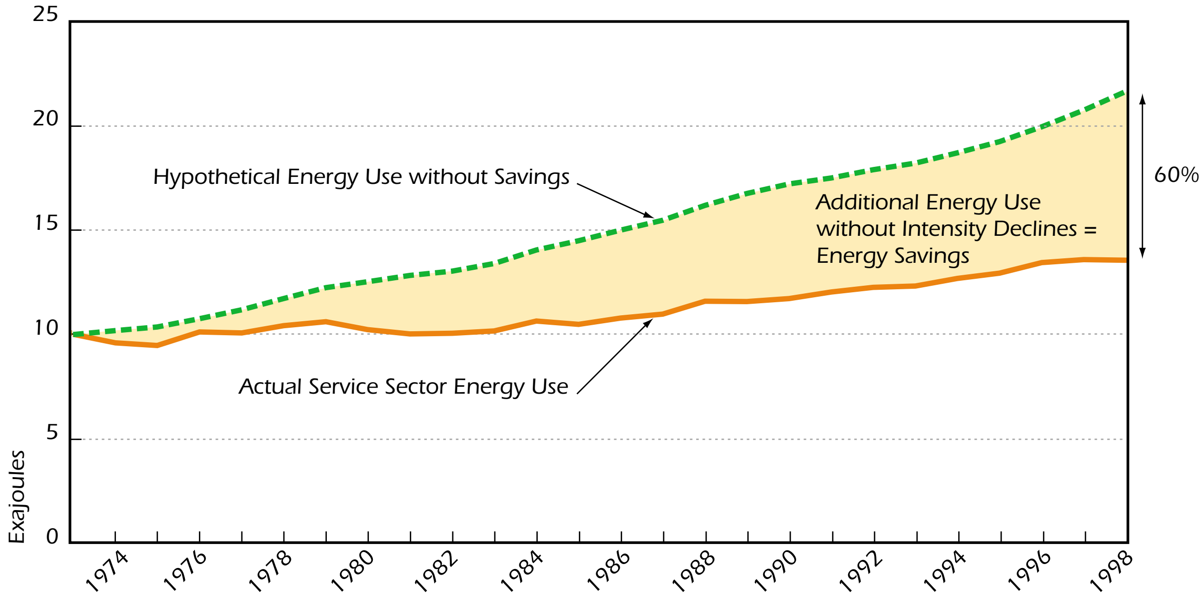


Figure 6-8 illustrates the energy savings in the IEA-11 countries between 1973 and 1998 resulting from the decline in energy intensity (energy per value-added). The upper line represents the hypothetical energy use that would have occurred if no changes in energy intensity had taken place. Energy savings are defined as the difference between the two curves. Note that energy intensity is measured as energy use per value-added in this calculation (See equation 5 in Chapter 2 and in Chapter 3, Figure 3-16).

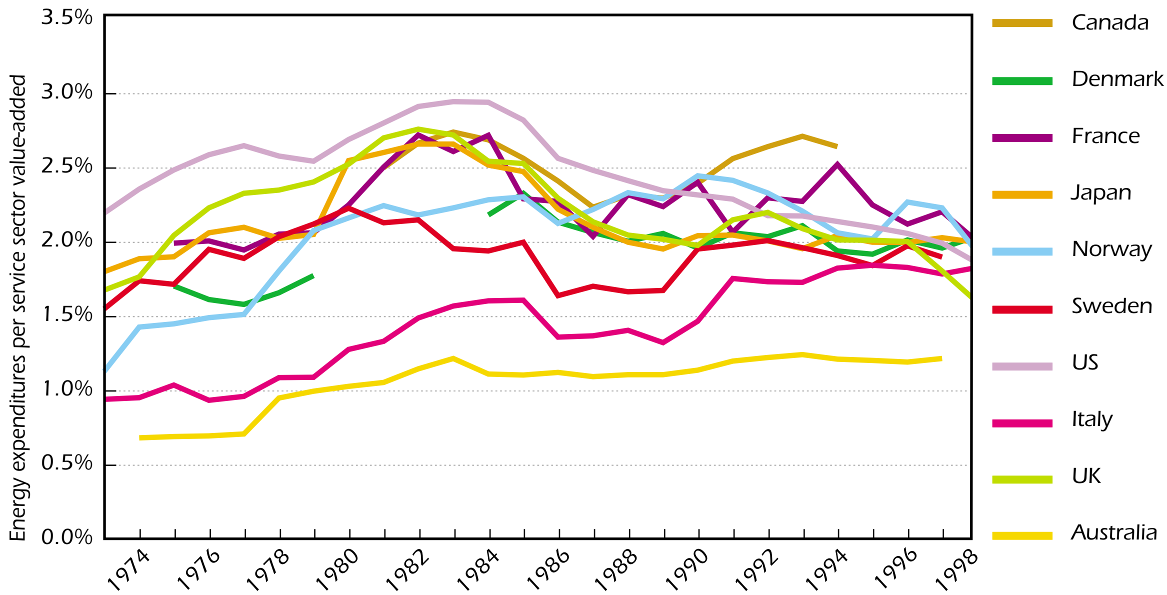
On-going reductions in energy intensity contributed to significant energy savings in the service sector, although after 1990, the rate of energy savings came to a halt, but only until 1994 when energy intensity again began to decline rapidly. By 1998, total savings amounted to 8.1 EJ, which corresponds to 60% of 1998 energy use. In other words, without the decline in energy intensity that took place in the 1973-1998 period, service sector energy use in 1998 would have been 60% higher.

Energy Expenditures Relative to Output

Energy expenditures relative to output grew as electricity gained share in the fuel mix

Figure 6-9

Service Sector Energy Expenditures Relative to Value-added



Service sector energy expenditures relative to value-added in selected IEA countries are depicted in Figure 6-9. Energy expenditures per value-added are a function of energy intensity (measured as energy use per value-added), the mix of fuels used, and the price of each fuel. Changes in these three factors over time led to the changes shown in the figure.

During the 1970s, when oil was still an important fuel in the service sector, energy expenditures increased relative to value-added as oil prices rose. This happened despite that energy intensities fell significantly in most countries. The decline in oil prices in the mid- to late 1980s was augmented by continued reductions in energy intensities so that energy expenditures fell in all countries but Norway, where hydro-electricity was dominant in the fuel mix. As electricity became the most important energy carrier in other countries, energy expenditures began to rise due to the generally higher cost of electricity relative to fossil fuels. By 1998, energy expenditures per value-added had increased from1973 levels in most countries. The largest increases occurred in Australia, Italy and Norway, where modest declines in energy intensity combined with higher shares of electricity, led to a more than doubling of energy expenditures relative to value-added.

Exceptions to the general trend of higher expenditures per value-added in 1998 than in 1973 were the United States, the United Kingdom and Japan. In these countries electricity prices in real terms peaked in 1982 and then declined steadily through 1998. Whereas in the other countries shown, electricity prices either increased steadily throughout the 1973-1998 period or fell temporarily before increasing again in the 1990s. The falling electricity prices since

1982 coupled with significant declines in energy intensity in the United States and the United Kingdom resulted in energy expenditures relative to value-added that were lower in 1998 than in 1973. In Japan, the decline in electricity prices was offset by the combined impact of strong growth in electricity use relative to fuel use and little to no change in energy intensity after the mid 1980s. As a result, energy expenditures relative to value-added increased slightly in Japan from 1973 to 1998, although they have remained essentially unchanged since 1988.

Chapter 7. PASSENGER TRANSPORT

Highlights

- Passenger travel today constitutes about a quarter of final energy demand calculated for a group of eleven IEA countries (IEA-11), which is up from 20% in 1973. Passenger transport is almost exclusively based on petroleum products. Growth in passenger travel has been the biggest contributor to increased oil demand. By 1998, it accounted for 53% of total final oil demand in IEA-11, while in 1973 the share was 38%.

- Cars and airplanes account, by far, for most of the increase in passenger transport energy use. Air travel has increased at the fastest rate of any mode: it nearly tripled its share of total travel activity from 1973 to 1998. Car ownership levels have risen by 100% or more in many countries, though travel per vehicle has remained fairly stable. Travel growth rates were higher in the late 1990s than the early 1990s, though some slowing has occurred between 1998 and 2000.

- Changes in passenger transport energy use, as well as its components (travel activity and energy intensity), are related to income growth and changes in fuel prices, among other factors. Countries with relatively high fuel prices tend to have lower average vehicle energy intensities and fuel use than countries where fuel prices are low. Increases in car ownership and travel levels are closely related to income growth. Together, these relationships help account for large differences in transport energy use per capita among countries.

- After-tax fuel prices vary by a factor of nearly five across IEA countries. The highest fuel prices are found in European countries, while the United States has the lowest prices. Real gasoline prices peaked in the early 1980s and have generally fallen since then. In most European countries much of this decline was offset by increasing fuel taxes. Still real prices, including taxes, were lower in the late 1990s than in the early 1980s in almost all IEA countries. Since average car fuel intensity has declined, albeit moderately, in most countries, the real cost per kilometre of driving has also generally fallen since 1973 and particularly since the early 1980s.

- Energy intensities for all passenger transport modes have declined, but not nearly enough to offset the growth in travel activity and the shift to more energy-intensive modes (i.e., away from buses and trains to cars and planes). The rate of decline in average energy intensity for all travel modes slowed in the 1990s compared with the 1970s and 1980s. Air travel intensity declined the fastest, but not fast enough to offset the growth in air travel activity, with significant increases in air travel energy use as a result.

- Though air travel has experienced the highest growth rates, cars continue to use the biggest share of energy in passenger travel, as well as accounting for most of the increase in energy use since 1973. While the declines in stock-average fuel intensities for cars generally have slowed in recent years, improvements in *new* car fuel intensity are evident since the mid-1990s in some countries, particularly in Europe and Japan. This recent decline in new vehicle intensity has begun to dampen the rate of increase in car fuel consumption in these countries.

Definitions and Data Used in this Chapter

Sub-sectors

This chapter looks at personal transportation in light-duty vehicles (LDVs) (defined as cars, minivans, sport-utility vehicles and personal-use pickup trucks), buses, trains and domestic air travel. Surface travel is defined as total travel less air travel. *"Cars" are used in this book to denote light-duty vehicles unless specific reference is made to cars versus trucks and vans used for personal travel.*

Mode

Method of travel, e.g., cars, buses, rail, water, air.

Activity

The main activity indicator is travel measured in passenger-kilometres for each mode, the measure of how far people move.

Structure

The modal mix, described by the share of total travel by each mode.

Intensity

Vehicle energy intensity is energy use per vehicle-kilometre (vkm) for cars. Modal intensity is energy use per passenger-kilometre (pkm) for each travel mode.

Decomposition

The impacts of changes in activity, structure and intensity on total travel energy use are calculated using the decomposition method described in Chapter 2.

Data

Data for fuel use and transport activity are from national sources. (See Chapter 2).
Energy price data are from IEA *Energy Prices and Taxes in OECD Countries*.

Country Coverage

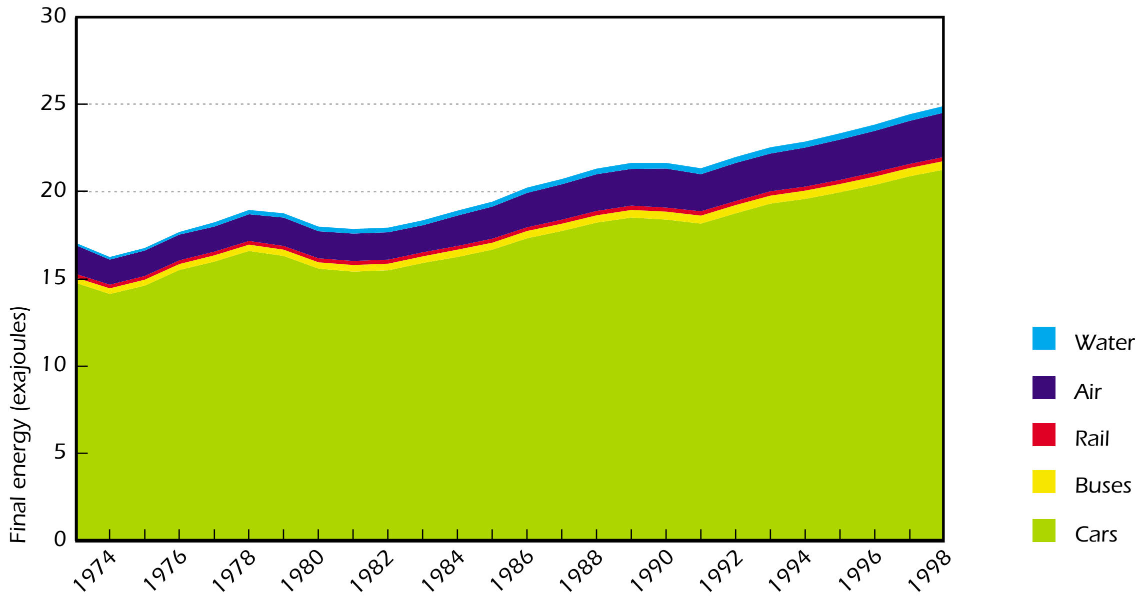
IEA has consistent time series with energy and activity data from 1973 through 1998 and in some cases 1999 and 2000 for eleven IEA countries. This includes Australia, Denmark, Finland, France, Germany, Japan, Italy, Norway, Sweden, the United Kingdom and the United States. When the aggregate results of this group are presented the group is referred to as IEA-11. The group of eight European countries within the IEA-11 is sometimes referred to as *EUR*-8 and includes Denmark, Finland, France, Germany, Italy, Norway, Sweden and the United Kingdom. In addition, IEA has complete time series with passenger travel data but for shorter periods for the Netherlands and Canada.

Energy Use in Passenger Transport by Mode

Energy used to move people was 45% higher in 1998 than in 1973

Figure 7-1

Energy Use in Passenger Transport by Mode, IEA-11



Energy use for passenger travel in a group of eleven IEA countries (IEA-11) has increased by 45% since 1973. However, the growth has been uneven. Energy use dipped after the two oil price shocks in the 1970s, and during the two recessions in the early 1980s and 1990s. Yet the overall direction has been substantially up. The vast majority of the overall increase in energy use, about 80%, is from light-duty vehicles (LDVs), which include cars, minivans, sport-utility vehicles and personal-use pickup trucks (referred to collectively as "cars" in this publication). Rising air travel accounts for most of the rest of the increase. While energy use for buses, passenger rail and ships also increased, by 1998 these modes represented only 4% of passenger transport energy use. Cars accounted for 84%, a share only slightly lower than in 1973. Overall, the modal mix of energy use has changed little since 1973.

Passenger transport remains almost exclusively dependent on oil products. Gasoline, diesel and jet fuels account for more than 98% of energy use for travel. In a few countries, e.g., Japan, Australia and Italy, some LPG is used for road transport, much of which is derived from natural gas. Electricity for passenger rail travel accounts for less than 1% of total passenger travel energy use, while alternative fuels, such as CNG and biofuels, have not yet made significant in-roads in IEA countries.

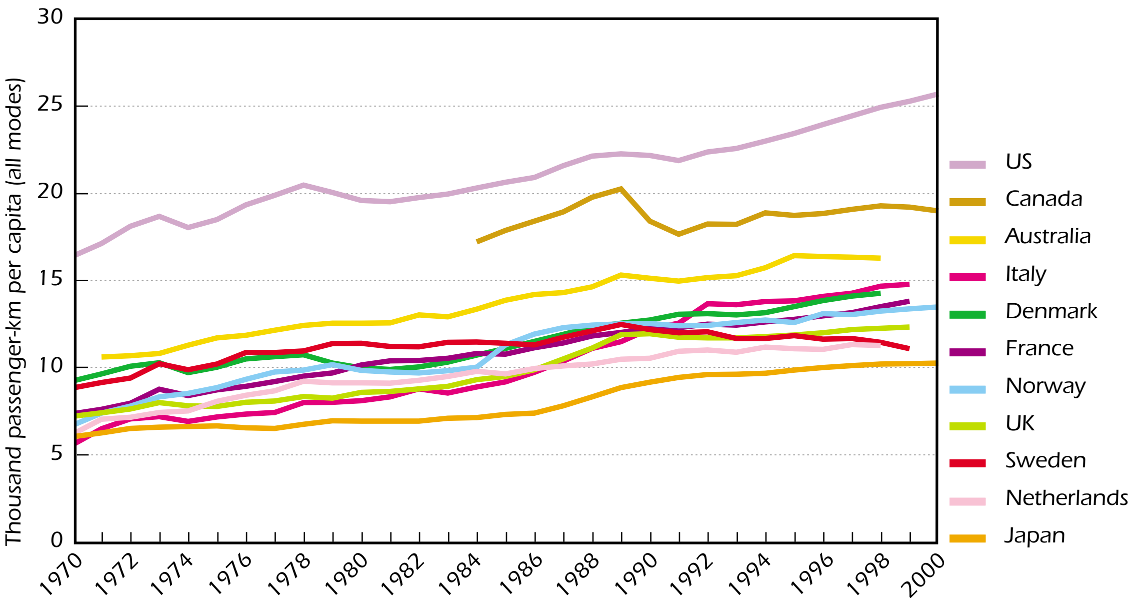
While there has been little fuel switching for cars, there are a few trends worth noting. The most important has been the "dieselisation" of cars in IEA-Europe, where the diesel share of fuel use has increased from less than 3% in 1973 to more than 20% in 1998 and is still rising rapidly. For example, in France, the share of diesel is approaching 50%. The increasing popularity of diesel vehicles in Europe is related both to their much-improved quality and to policies promoting diesel, primarily through reduced fuel taxes.

Passenger Travel Activity

Passenger travel has increased steadily in all countries

Figure 7-2

Passenger Travel per Capita, all Modes



IEA countries have experienced sustained increases in passenger travel activity since 1973. Yet, the picture varies widely from country to country: passenger-kilometre (passenger-km) travel per capita increased from 35% in Sweden at the lower end to more than 150% in Italy. Italy and other countries with relatively low levels of travel in 1970 have played "catch-up" to those with higher levels. Yet in 2000, there was still a wide spread in average travel per capita. The United States, Canada and Australia are well above the European countries, and even significantly separated from each other. The United States has the highest levels of travel per capita in the world, more than 25 000 kilometres per person per year. This reflects high US car ownership and utilisation rates, as shown in Figures 7-6 and 7-8.

Travel speed is an important factor in how much and how far people choose to travel. The relationship between time spent travelling, travel speed and overall travel is discussed in the following box.

Going Faster, Going Farther

That humans around the world spend similar amounts of time and money (as a percentage of their overall budgets) on travel is increasingly recognised by research on passenger travel. Studies by Tanner (1961) and Zahavi (1981) first recognised similarities in "*travel time budgets*" and cost budgets in certain countries and regions. More recently Schafer (2000) conducted a review of patterns across a wide array of countries, with quite varying incomes, and including both motorized and non-motorized modes of travel. The results suggest that as people gain access to faster modes of travel, they do not cut down on the amount of time they spend travelling – instead they travel farther. Increased mobility appears to trigger changes in lifestyles such as living farther from work, and more and longer trips away from home. Schafer found that in places as different as Ghana from New York, studies estimate average time spent travelling per person to be about one hour per day (with a standard deviation (SD) of about 15 minutes) and average expenditure of about 10% of income (SD of 3 %).

One implication is that travel per capita will likely continue to increase as long as people gain access to faster and more flexible modes, e.g., going from walking, to biking, to buses, to cars, to airplanes. On the other hand, there may be limits to how much people are willing to travel, if it means increasing travel times much beyond an hour per day, on average. Once most people have access to a car, the aggregate rate of increase in car travel may moderate considerably, as the only way for further increases to occur is by increasing the amount of time each person spends travelling by car (unless car speeds increase). Several analysts have predicted that car travel growth in the United States will slow as vehicle ownership saturation occurs, in part for this reason (e.g., Lave, 1991).

A second implication is that people will unlikely pay more than a certain percentage of their income on travelling. So in order to move to faster modes, they need higher incomes. Conversely, as incomes increase, people are likely to switch to faster modes. Does this make it inevitable that the entire world will own cars as they can afford them? Not necessarily, as long as other modes can provide similar speed and travel time. European and Japanese cities have often succeeded in creating transit and intercity rail systems that allow people to get where they want to go as fast, or faster, as by car, which may help explain the lower car ownership rates in these regions compared to North America.

Sources: Tanner, J.C., Factors Affecting the Amount of Travel. Road Research Technical Paper No. 51, London: HMSO, 1961.

Zahavi, Y., The UMOT-Urban Interactions, DOT-RSPA-DPB 10/7, US Dept. of Transportation, Washington DC. , 1981.

Schafer, A., Regularities in Travel Demand: An International Perspective, Journal of Transportation and Statistics, 3:3, 2000.

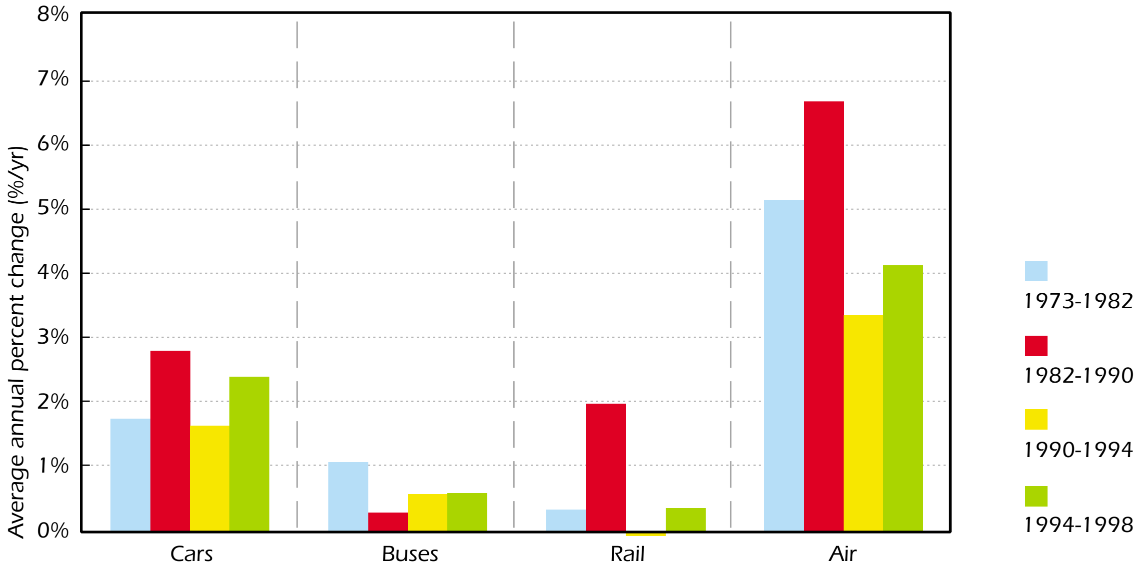
Lave, C., Future Growth of Auto Travel in the U.S.: A Non-Problem, in Energy and Environment in the 21st Century, *edited by J.W. Tester and D.O. Wood, pp. 227-229, MIT Press, Cambridge, 1991.*

Growth in Passenger Travel by Mode

Growth rates are highest for air travel although rates have slowed since 1990

Figure 7-3

Passenger Travel by Mode (Passenger-km/Capita)



Across the IEA-11, air travel has had the highest growth rates in passenger-km since 1973, reaching 6.7% average annual increase from 1982 to 1990. However, air travel growth rates fell to the 3 - 4% range during the 1990s, a sign of the "maturing" of air travel, and perhaps also a sign of some emerging constraints to growth such as available airport capacity. Car travel maintained historical growth rates of 1.5% - 3% per year throughout the period, with a slight decline during the 1990s. Bus and rail have been the slowest growing passenger modes at below 1% per year since 1990.

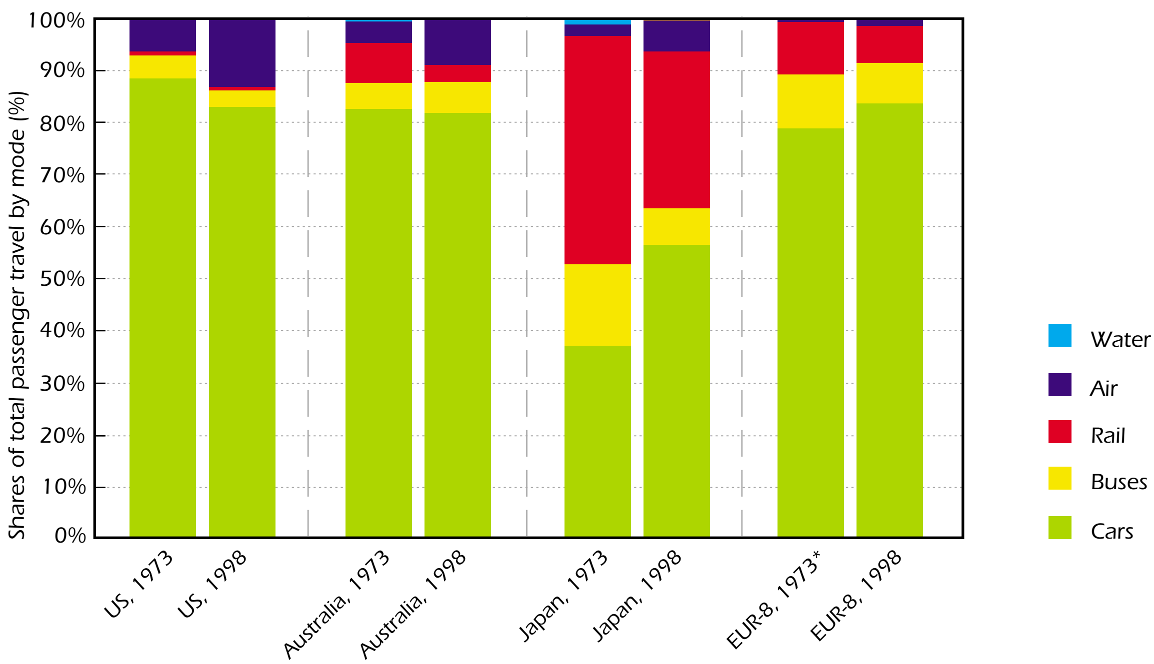
With air travel still showing twice the growth rate of car travel, it can be expected to be the fastest growing mode for some time. Car travel growth itself could begin to moderate, as rates of car ownership growth begin to slow in IEA countries. (For countries with data available through 2000, car travel growth appears to have slowed somewhat in the 1998-2000 period.) With the very slow travel growth rates for bus and rail, these will likely continue to lose market shares to car travel and air travel.

Passenger Travel by Mode

Cars dominate in all countries

Figure 7-4

Modal Share of Passenger Travel (Passenger-km)



* EUR-8 includes: Denmark, Finland, France, Germany, Italy, Norway, Sweden, United Kingdom.

Despite the higher growth rates in air travel, cars clearly dominate the overall modal split in passenger transport and account for an average of about 80% of passenger-kilometres travelled across the IEA and a much higher share of surface travel (i.e., excluding air). On average across IEA-11 countries, as a share of surface passenger transport, car travel has increased from about 83% to nearly 90% between 1973 and 1998. Yet the share of car travel has declined in some countries (mainly the United States), while it has increased markedly in others (Japan). Car travel share has declined where there have been strong increases in domestic air travel, but has increased relative to rail and bus in all regions. As would be expected from the low growth rates seen in Figure 7-3, in nearly all countries the share of rail and bus travel has declined significantly.

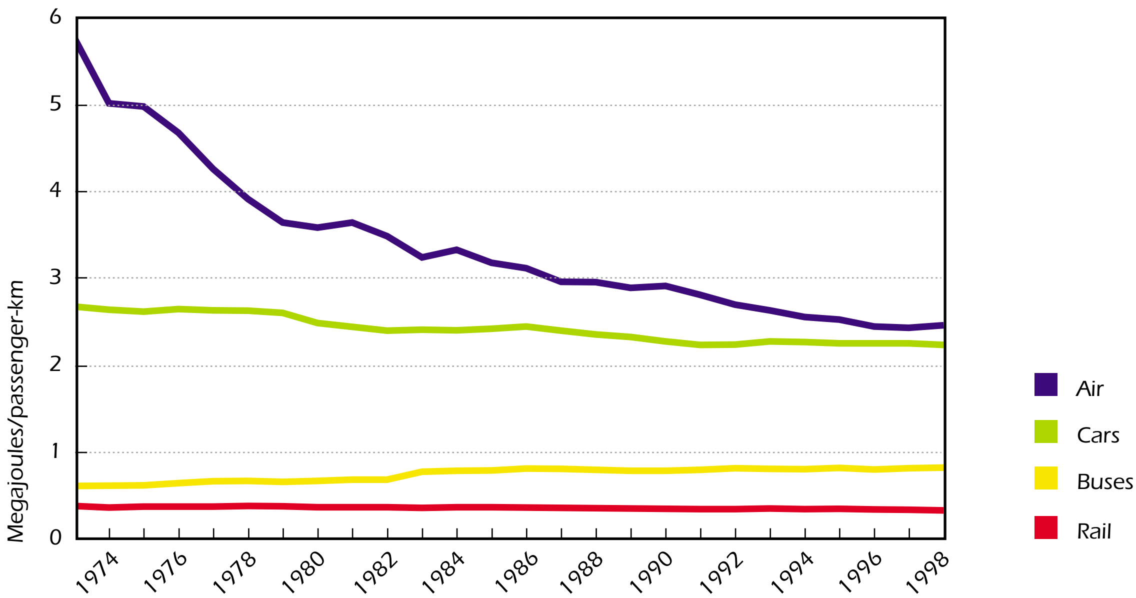
Japan is an unusual case, with its very high share of rail. By 1973, Japan had developed a strong urban and regional rail system that provided nearly half of all passenger-kilometres of travel. Since that system was already fairly mature in 1973, it has not grown substantially since then, and as a result has lost considerable market share to cars, with car ownership and travel growing dramatically between 1973 and 1998. But rail still accounts for nearly one-third of passenger travel in Japan, much more than in any other IEA country.

Modal Energy Intensities

Energy intensity of air travel has declined the most, but remains the most energy intensive mode

Figure 7-5

Energy per Passenger-kilometre by Mode, IEA-11



Since the 1970s, the energy intensity of most passenger transport modes has declined, but none nearly so much as air travel. Air travel intensity in the IEA-11 has dropped by more than 50%.[1] It now takes less than half the energy to move a passenger one kilometre through the air as it did in 1973. This revolution in air travel energy intensity results from a number of factors. Most important have been the advances in aircraft technical efficiency, with steady improvements in plane and especially engine design. However, trends toward larger and fuller airplanes have also contributed. At the margin, filling an empty seat moves one more passenger a long distance, with almost no change in energy use.

Energy intensities of other modes have not declined as much. Car energy intensity declined by a little more than 10% across the IEA-11, with much bigger reductions in those countries that started with relatively high energy intensity levels, such as the United States and Canada. The modest declines in car energy intensity in most countries do not mean that cars have not become much more efficient. On the contrary, important technical improvements have been made to engine and other vehicle components, but these have been largely offset by heavier, larger and more powerful cars. In addition, since this intensity is measured on a per passenger-kilometre basis, reductions in load factors (average number of passengers per vehicle) have also contributed to offsetting technical vehicle improvements.

1. Data separating domestic and international air travel are not readily available in many countries. The air travel energy intensity shown in the figure is affected by the assumptions made to separate these data.

While rail travel is the least energy-intensive mode, intensity has not declined much in recent years.

Bus travel has seen an actual increase in energy use per passenger-kilometre, mainly due to fewer people on each bus. In a few countries, such as the United States, this effect has been significant and means that the reductions in energy use from shifting passenger travel from cars to buses will be small, unless load factors increase. On the other hand, most European countries maintain relatively high ridership levels for transit and other types of buses. Thus, overall for the IEA-11, buses still use only about one-third as much energy per passenger-kilometre as cars.

Energy Use by Cars: A Decomposition Model

To better understand why energy use by cars is changing over time and how it varies among countries, it is useful to look at the different components that affect it.

How much energy cars (light-duty vehicles) use per capita depends on three factors: how many people have cars; how far each car is driven every year; and how much energy is used per kilometre driven. This can be expressed as:

Final energy per capita for cars: FE_c / capita = Cars / capita * km / Car * FEc / km

The demand for energy is thus dependent on behavioural factors such as how many cars families own, and how much they drive them each year (which in turn is a function of where they choose to live and work and the types of trips they take). It is also dependent on technical factors such as the efficiency of the vehicles used. Of course, technical efficiency is also subject to behavioural influence: people may choose to buy more or less efficient cars depending on their income, fuel price, and other factors.

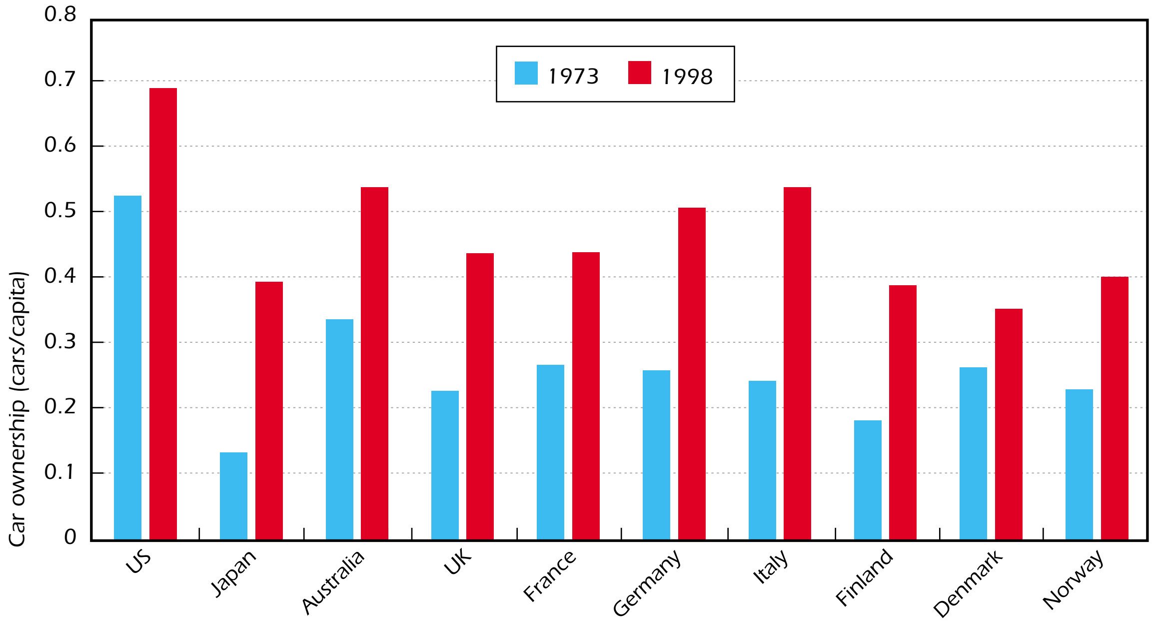
Starting with car ownership, the following pages illustrate the development of each of these factors for selected IEA countries. Figure 7-16 summarises how each factor has affected energy use for cars using this decomposition approach.

Car Ownership

Car ownership levels have risen dramatically in all IEA countries

Figure 7-6

Car Ownership (Cars per Capita)



The principal driver behind increased passenger travel is car ownership. Once individuals and families own a car, their travel by car, and their total passenger-kilometres of travel rise dramatically. In 1973, ownership rates were still modest: from as low as one car per nine people in Japan to about one car for every other person in the United States. By 1998, no IEA country had a rate below 0.35 cars per capita, and the rate in the United States had risen to 0.7. Japan had the fastest growth in ownership with a three-fold increase from its relatively small base.

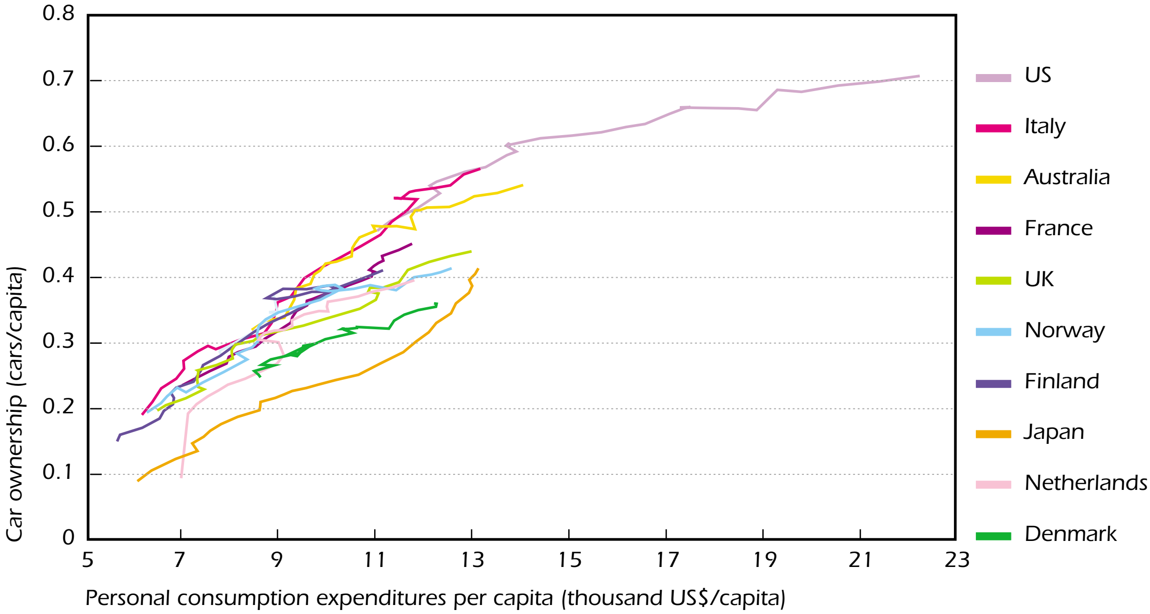
Car ownership levels for European countries are now generally in the range of 0.35 to 0.5 cars per capita, though Italy is well above 0.5. It is unclear why Italy has such a high car ownership level compared to other western European countries, but it becomes clear why the United States has an even higher ownership level in observing the following figure.

Car Ownership and Income

The United States leads the way in both car ownership and income

Figure 7-7

Car Ownership per Capita and Personal Consumption Expenditures, 1970 - 2000



When car ownership trends are plotted against income, or in this case the even more revealing indicator, personal expenditures, a fairly tight relationship emerges. IEA countries have shown a steady increase in both factors, thus the time trend is upward and toward the right. It is likely that other IEA countries may take many more years to reach the high ownership levels of the United States, as its position on the chart 30 years ago was about where many are today. It is clear though that the rate of growth in car ownership in the United States has slowed as the average expenditure increased above about $13 000 per person per year. Might the United States be reaching a saturation point somewhere around 0.7 cars per capita? It is possible, though many families in the United States now have more cars than people, suggesting that there may be no inherent upper limit.

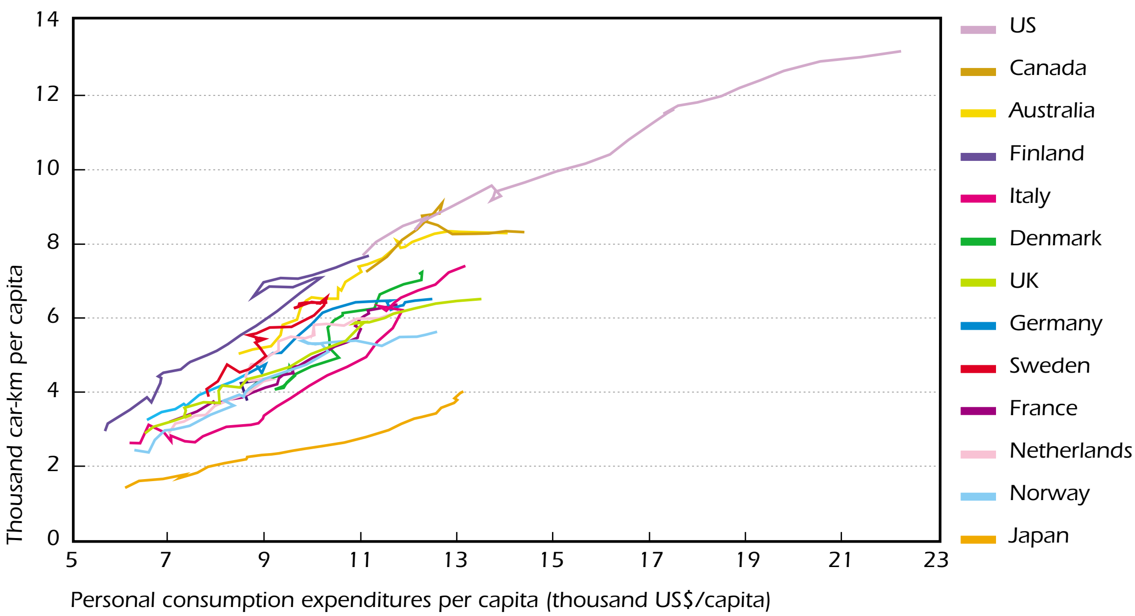
Among European IEA countries, Japan and Australia, there is significant variation in the relationship between car ownership and personal expenditures. Though the rate of change is similar, some have much higher car ownership levels relative to expenditure. Japan has historically had the lowest ratio (reflecting its high urbanisation and strong mass transit systems), but ownership growth is strong there and it is rapidly approaching the levels of many European countries. Denmark and Norway's relatively low ownership level reflects high vehicle taxes. The United Kingdom's relatively slow growth rate in recent years may be related to high fuel tax increases and other policy initiatives to control the growth of car travel. Italy's position may simply reflect a propensity towards relatively high car ownership at given income levels; although this is offset by a relatively low level of driving per vehicle, as shown in the next figure.

Car Travel and Income

The trend for car travel is quite similar to car ownership

Figure 7-8

Car-kilometres per Capita and Personal Consumption Expenditures, 1970-2000



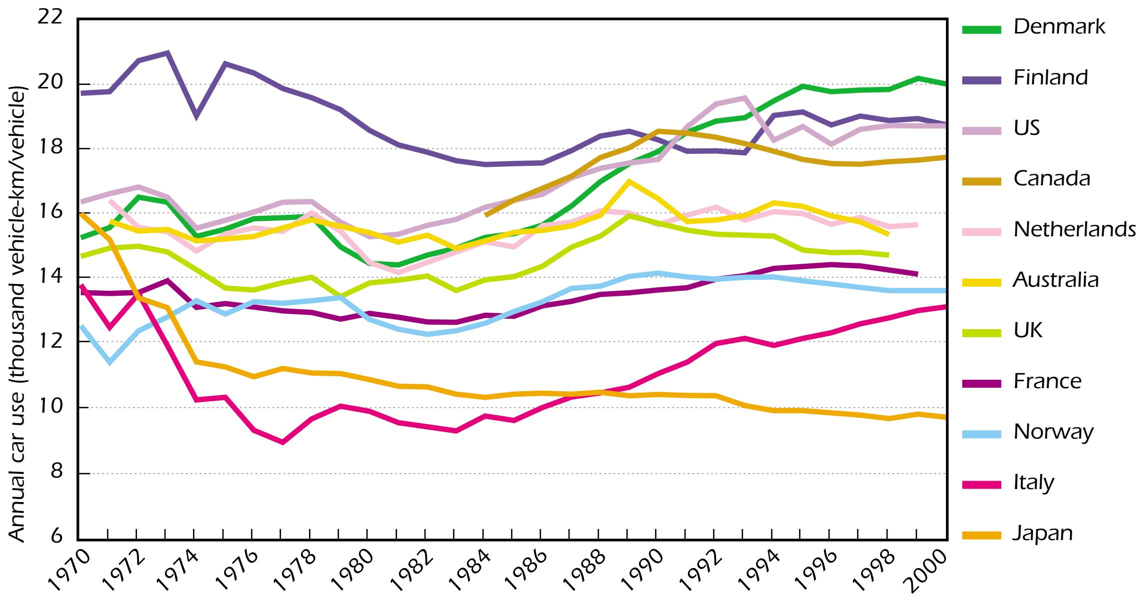
The picture for car travel per capita versus income looks strikingly similar to car ownership versus income. It is not obvious that this would be the case, since travel levels per vehicle vary in different countries (see next figure). These differences spread out some of the countries. For example, Japan is further apart from other countries for travel than it is for ownership, due to its low average travel per vehicle. But the trends and approximate growth patterns are similar, with the United States far beyond the travel levels (and expenditures) of other countries. This suggests that as other countries reach similar income and car ownership levels to the United States, they may also see travel levels per capita rise to something approaching current US levels. This is not the whole story, since the United States also has very high levels of travel per vehicle, as the next figure shows.

Annual Car Use

Travel per vehicle is fairly stable over time

Figure 7-9

Annual kilometres per Vehicle



While passenger travel and car ownership levels have risen steadily since 1973, the average use of each vehicle has not. On average, vehicles are driven between 10 000 and 20 000 kilometres per year, depending on the country. In Finland and Japan there has been a noticeable decline in utilisation levels over time, while in Denmark and the United States, rates have increased. France and Australia have had the most stable levels of travel per vehicle, fluctuating by no more than 2 000 km/vehicle per year since 1973.

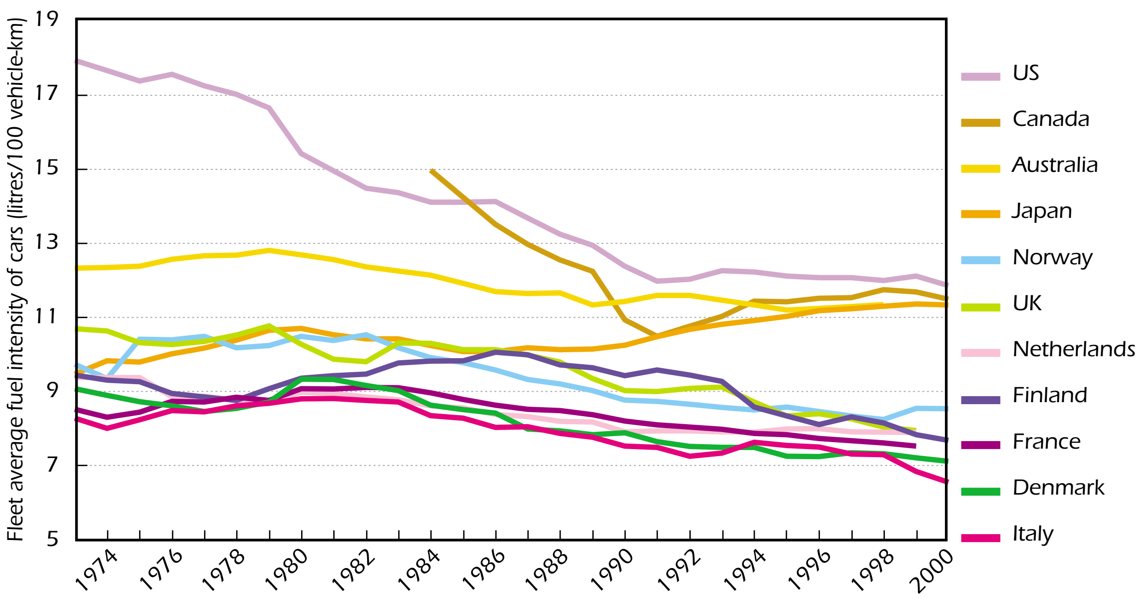
Steady utilisation levels appear to reflect that, in most countries, levels of car travel (car-km) have grown at about the same rate as car ownership. But it also reflects that if one person is driving the car, another can't be. For travel-per-vehicle to increase substantially, the vehicle would need to be driven more hours per day (or at higher speeds). Most vehicles in IEA countries are not shared much over the course of a typical day, so most are operated only for the one-to-two hours per day, on average, that their driver needs them. This results in a fairly constant utilisation rate. In some countries where car ownership levels are held down through policy measures, such as the high taxes on new cars in Denmark, the travel per vehicle is higher than average. In these countries there may be more people willing to share cars in order to increase their mobility, and cars then get used more over the course of the day.

Car Fuel Intensity

Car fuel intensity has declined, but at a slowing rate

Figure 7-10

Car Stock-average Fuel Intensity



How have declines in fuel intensities kept up with increases in car travel? The results are mixed. Outside of North America, the average fuel intensities of all cars (the total stock) increased in most countries throughout the 1970s before the trend turned and intensities fell everywhere until the early 1990s. Car fuel intensity did fall significantly in the United States in the 1970s and 1980s, along with Canada, due to strong fuel economy improvement programmes, resulting in fuel use per vehicle-kilometre levels reaching a par with Australia (and Canada with Japan) by the early 1990s. However, after 1991 the fuel intensity in these four countries was on the rise, while European countries continued to experience intensity declines. By the late 1990s two "clusters" of countries had developed: European countries in the range of 7-9 litres per 100 km; and non-European countries in the range of 11-12 litres/100 km. Overall the net intensity decline in IEA-11 between 1973 and 1998 has been about 16%.

Many factors have influenced these trends. The high oil prices in the early 1980s, along with the energy-saving policies that the oil price shocks of the 1970s helped trigger, had the effect of reversing an increasing average energy intensity (outside North America) into a dropping one through the 1980s. After 1986, oil prices fell and by 1990 the rate of improvement in many countries had slowed.

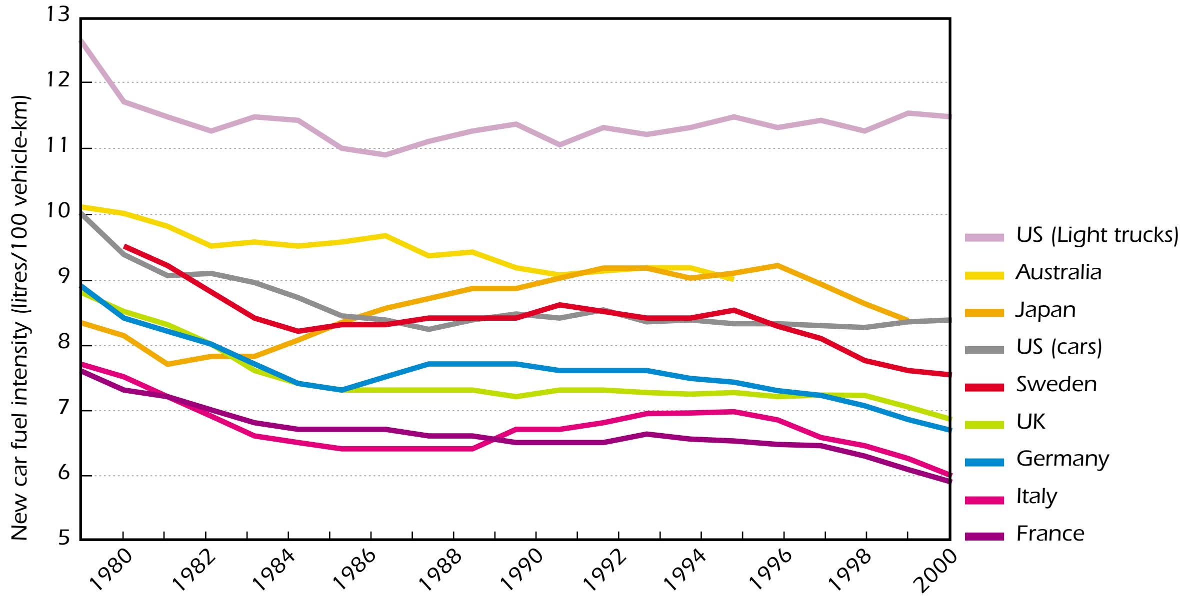
Since this graph shows stock-average fuel intensity, there is a "lag" effect of several years following changes to the characteristics of new vehicles sold during these periods (new car fuel intensity is shown in Figure 7-11). But one factor not related to new car characteristics is the effect of driving conditions on vehicle "in-use" fuel intensity. Increased urban traffic congestion, higher speeds on highways and more amenities like air conditioning have all contributed to an increase in the gap between vehicle tested fuel economy rating and actual on-road performance.

New Car Fuel Intensity

Changes in new car fuel intensity have driven the trends in fleet-average fuel intensity

Figure 7-11

Trends in New Car Fuel Intensity



Underlying reasons for the trends in fleet-average fuel intensity become apparent when observing the trends in new car intensity. Most countries had a downward trend in this intensity through the mid to late 1980s, followed by a period of flat or even rising intensity until the mid 1990s. Except for the United States, the trend in new vehicles shifted again towards intensity declines around 1996. New policies appear to be the main reason. Those countries experiencing the biggest gains also have had strong fuel efficiency improvement policies, namely Europe's auto-industry voluntary commitment to improve fuel economy, and Japan's "Top Runner" programme, which encourages manufacturers to improve all vehicles to the level of the best performer in each market segment. In contrast, the US "CAFE" fuel economy regulation has not changed its fleet-average fuel economy requirement significantly in recent years.

Data in Figure 7-11 for the United States have been broken into two parts: cars and "light trucks" (those light-duty vehicles that are not cars – mainly minivans, sport utility vehicles and pickup trucks). While the fuel intensity of *new* cars in the United States is within the range for most other countries, US light truck fuel intensity is much higher. Since the United States has a much higher share of light trucks than any other country (except perhaps Canada), the result is that average new (and fleet) fuel intensity for LDVs (cars and light trucks) in the United States is still the highest of any IEA country. Currently no country outside North America has a light truck share much above 5% of LDV sales. If this share begins to rise significantly, clearly the average fuel intensity would follow.

Apart from growth in the use of light trucks, vans and SUVs as passenger vehicles (essentially large, heavy cars), there have been steady trends toward increases in the size, weight and power of cars in nearly every country since the mid-1980s. Previous IEA work has tracked these trends and shows that car fuel consumption per unit weight and per unit engine power has declined quite steadily, but this has been largely offset by steady increases in average weight and power.[2] Thus, if the efficiency improvement trends continue, and vehicle weight and power were to stop increasing (either through market "saturation" or through policies discouraging shifts toward heavier, more powerful vehicles), then fuel intensity improvements in the future could be much greater than they have been over the past 15 years.

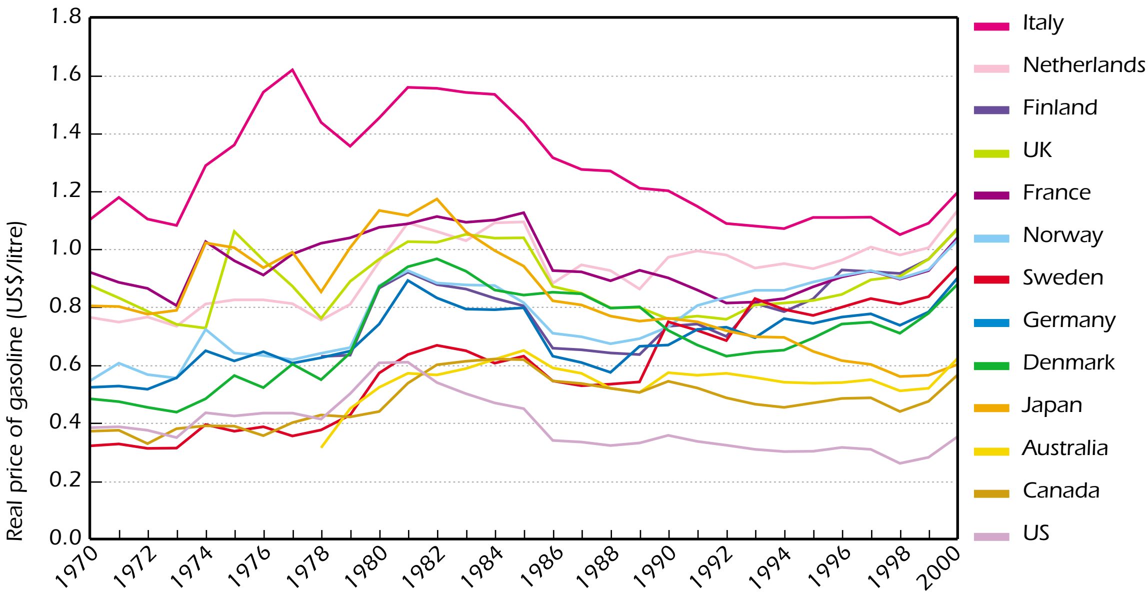
2. Saving Oil and Reducing CO_2 Emissions in Transport: Options and Strategies, *IEA/OECD, Paris, 2001.*

Gasoline Prices

Gasoline prices have varied considerably both over time and across IEA countries

Figure 7-12

Trends in Retail Gasoline Prices in Real Terms, Including Taxes



Fuel prices for passenger transport are an important driver of travel demand, mode choice and fuel intensity. Fuel prices have varied considerably across IEA countries and continue to do so, particularly when fuel taxes are taken into account. In 2000 prices ranged from a low of about 0.35 cents per litre in the United States to $1.20 per litre in Italy (adjusted using a PPP-weighted exchange rate).

Fuel taxes have also varied considerably over time (not shown separately). Oil prices peaked in the early 1980s, and generally have been declining in real terms for the past 20 years. Price trends for countries such as Japan and the United States reflect this, since these countries have not substantially increased fuel taxes, and real gasoline prices in 2000 were comparable or lower than in the mid 1970s. On the other hand, most European countries offset much of the oil price decline by raising fuel taxes. In some cases, such as Germany and Finland, taxes have been increased at a greater rate than the oil price decline, yielding a steady rise in retail fuel prices since the mid 1980s.

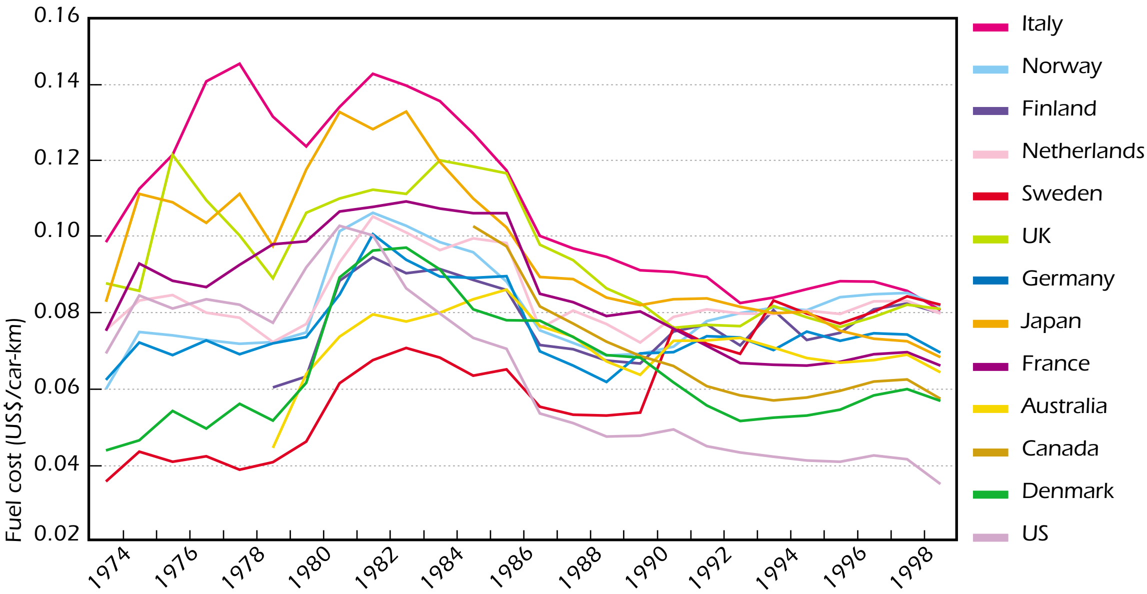
Between 1998 and 2000, fuel prices increased significantly in many countries, particularly in Europe. This was due both to increases in world oil prices and, in a few countries, increases in fuel taxes, such as in the United Kingdom and Germany. While these represent relatively minor changes compared to historical price fluctuations, for a number of European countries the recent increases have put fuel prices, in real dollar terms, near all-time highs, and led to protests in Europe during 1999.

Fuel Costs per kilometre Driven

Car fuel costs per kilometre generally have fallen since the early 1980s

Figure 7-13

Fuel Cost per Vehicle-km for Cars (Real Terms, Including Taxes)



By combining fuel price information with data on stock-average fuel intensity of cars, the average cost per kilometre of driving is derived. The cost of driving shows a somewhat similar pattern of variation by country and over time as for gasoline prices, with peak costs occurring in the early to mid-1980s. However, there are two noticeable effects related to vehicle fuel intensity. First, fuel costs ($ per car-km) have declined more during the late 1980s and 1990s than fuel prices, reflecting the impact of reduced fuel intensity on lowering travel costs (note that this figure represents data to 1998 while the price figure (7-12) extends to 2000).

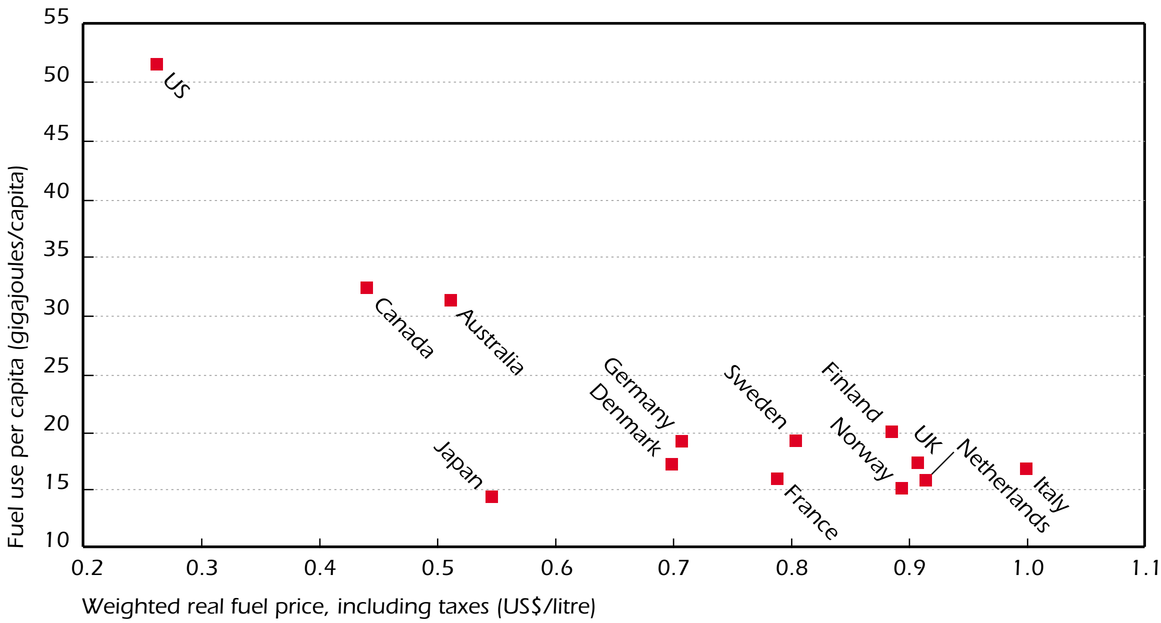
Second, apart from the United States, the range between countries in fuel cost per kilometre narrowed considerably during the 1990s, with a slight "convergence" toward $0.06-$0.08 per kilometre driven. This may reflect that over time, drivers have responded to fuel price changes by buying types of vehicles that bring their driving costs into an acceptable range that does not vary too much by country. However, the United States has moved away from this emerging convergence, with a cost per kilometre declining steadily through the 1990s and below $0.04 by 1998. Thus, despite the relative high fuel intensity of US cars, prices in the late 1990s were low enough for driving to be far cheaper than in other countries. On the other hand, without the significant drop in car intensities during the 1970s and 1980s the cost of driving in the United States today would have been more comparable to other IEA countries.

Fuel Use per Capita versus Fuel Prices

Energy use for cars is much higher in countries with low fuel prices

Figure 7-14

Car Fuel Use per Capita versus Average Fuel Price, 1998



The relationship between fuel price and fuel use is examined further in Figure 7-14 by plotting car energy use against average fuel price using 1998 data. This results in a clear separation of the countries into three groups. The United States is by itself, with almost twice the car fuel use per capita and half the average fuel price of any other country. Japan and the European countries, with fuel prices two to three times higher, use around two-thirds less fuel per capita than the United States. Canada and Australia fall into a middle group, both in terms of fuel price and fuel use per capita.

Looking at the Japan and Europe grouping, there is no clear relationship between fuel prices and fuel use. Other factors explain most of the variation: country size, income, vehicle prices, taxes, ownership levels, and availability and extent of mass transit. For example, Japan, with the lowest average fuel price and lowest energy use of the countries in the Europe/Japan group, is also one of the smaller countries and the one with the highest rail transit availability and use.

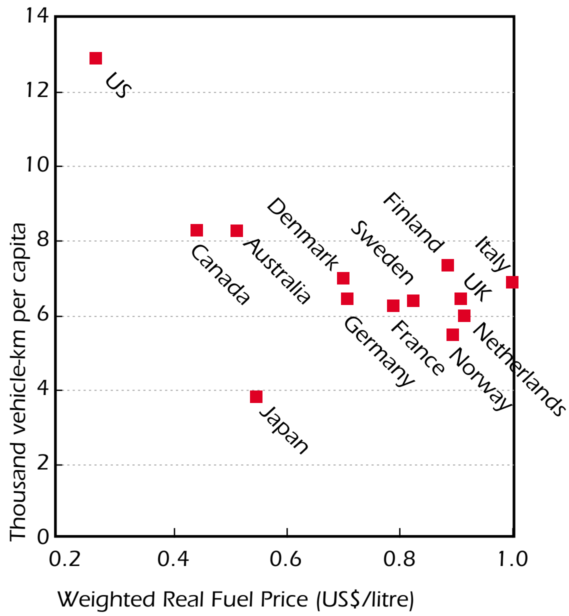
The United States, Canada and Australia are geographically the three largest countries, which partially explain why their energy use per capita is higher. But size does not explain the difference between the United States and Canada/Australia. This difference is clearly influenced by lower energy prices in the United States, and also higher incomes.

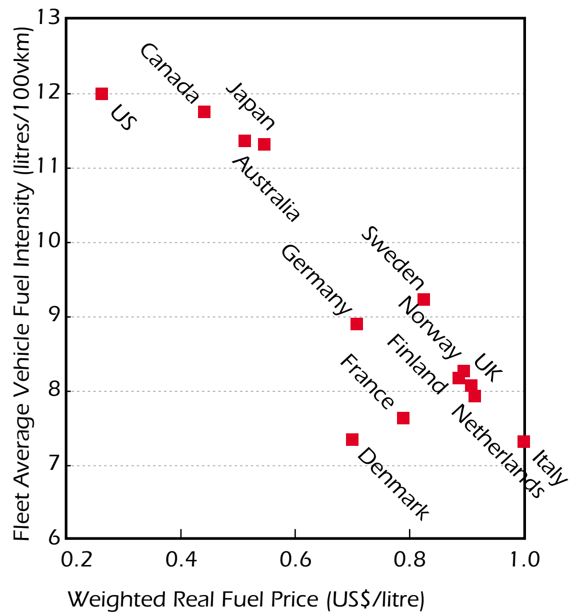
Vehicle Travel and Intensities versus Fuel Prices

Higher fuel prices correlate with lower vehicle fuel intensity and lower travel per capita, though the travel effect is fairly weak

Figure 7-15

Passenger Car Travel per Capita and Car Fuel Intensity versus Average Fuel Price, 1998





Breaking car fuel use per capita into car travel per capita and energy intensity offers some explanation for the relationship between fuel use and fuel price. The left hand part of Figure 7-15 indicates a weak correlation between low fuel prices and high car travel rates (the United States, Canada and Australia). The European countries have relatively similar levels of car travel per capita, despite that real fuel prices vary significantly.[3] In Japan travel rates are the lowest of all countries, even if the fuel price is relatively low. This underscores the impact of Japan's small geographical size and well developed mass-transit system on car fuel use (refer to discussion of Figure 7-14).

The right hand part of Figure 7-15 shows a relatively clear correlation between higher fuel prices and lower car fuel intensity, also within the group of European countries. Interestingly, in this case Japan is no longer an outlier of the general trend: its relative high fuel intensity and low fuel price bring it into the same range as Australia and Canada. Thus the low car fuel use per capita relative to fuel price in Japan (Figure 7-14) is a result of modest car use, not low fuel intensity. Similarly, Australia and Canada, which represent mid-case countries for per capita car fuel use, are close to the United States in fuel intensity, but closer to European countries in terms of car travel per capita.

*3. In fact many studies have shown that the relationship between car travel and fuel price is fairly weak, with a 10% change in fuel prices causing only and 1-3% change in travel (*Saving Oil and Reducing CO_2 Emissions in Transport: Options and Strategies, *IEA/OECD 2001).*

Decomposition of Car Energy Use

Rising car ownership explains most of the increase in car energy use

Figure 7-16

Decomposition of Changes in Car Energy Use per Capita, 1973-1998

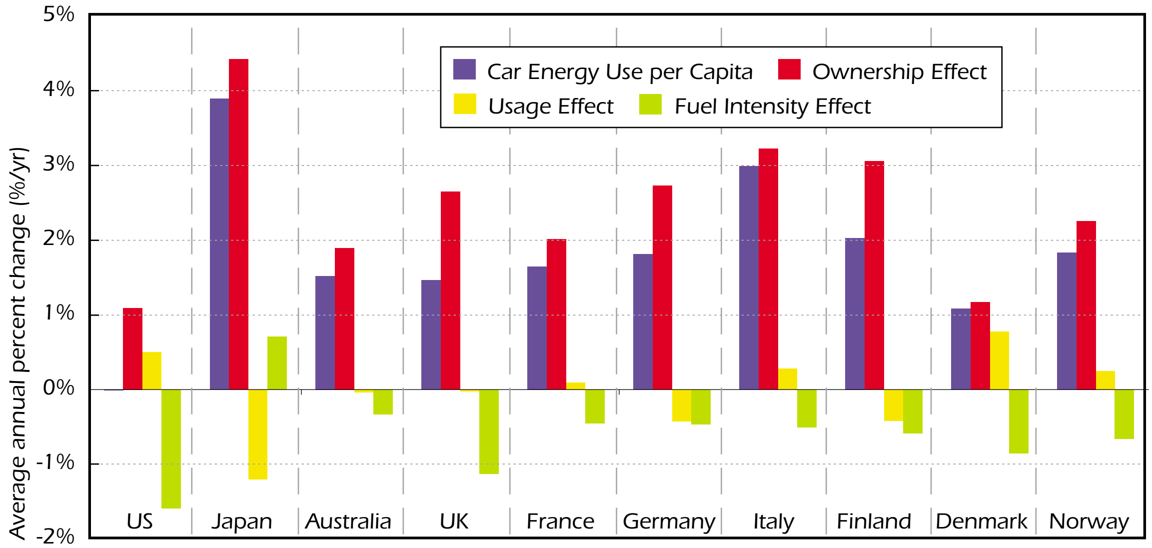


Figure 7-16 shows the relative impact of three components that multiply through to changes in total per capita energy use for cars: changes in ownership levels; vehicle use (average travel per vehicle); and average fuel intensity. (See box on car energy use decomposition.)

Increased car ownership levels have by far been the most important driving force behind increases in car energy use per capita. At the lower end of the scale, vehicle ownership increased 30% in the United States between 1973 and 1998 and about 300% in Japan at the higher end, (see Figure 7-6). On the other hand, the average distance driven by each car has changed little in most countries, and energy intensity has generally gone down, but by far less than ownership rates have gone up. As a net result per capita energy use for cars increased substantially in all countries, except the United States, where the significant decline in fuel intensity exactly offset the impact of increased car ownership and use over the 1973 to 1998 period. The United States started the period with the highest car ownership levels and highest energy intensities and, partly as a result, had the slowest growth in car ownership and the greatest average reduction in energy intensity. In contrast, Japan began the period with far lower car ownership and therefore experienced a much higher percentage increase. The size and weight of vehicles in Japan have increased substantially from the very small cars that it built 30 years ago. As a result, Japan has had a net increase in its vehicle energy intensity.

Decomposition of Energy Use – All Modes

Across all modes, energy intensity reductions have slowed while passenger travel growth remains robust

Figure 7-17

Decomposition of Changes in Passenger Transport Energy Use, IEA-11

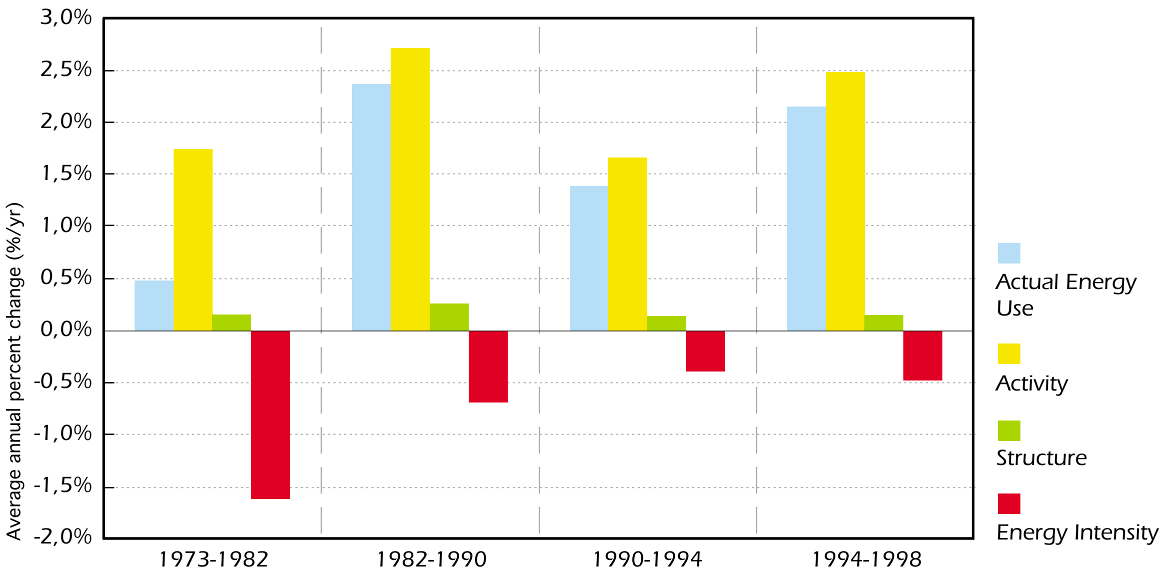


Figure 7-17 decomposes changes in energy use for passenger travel across all modes into changes in activity, changes in modal structure, and changes in modal intensities, as described in Chapter 2. Though energy use has increased in each period, the rate of increase has varied considerably, due to differences in the rates of growth in travel activity and in the reductions of travel energy intensity. Intensity reductions were strongest from 1973 to 1982 and although intensity has declined since then, the rate of decline has slowed considerably. Between 1973 and 1982 the intensity fell more than 1.5% per year, compared to less than 0.5% per year on average after 1990. While there have been changes in the modal structure of travel, such as a greater share of air travel, this has had a relatively small effect on energy use compared to the impact of overall increases in passenger travel activity. The structure effect has pushed up travel energy use at a rate of about 0.2 - 0.3% per year from 1973 to 1998.

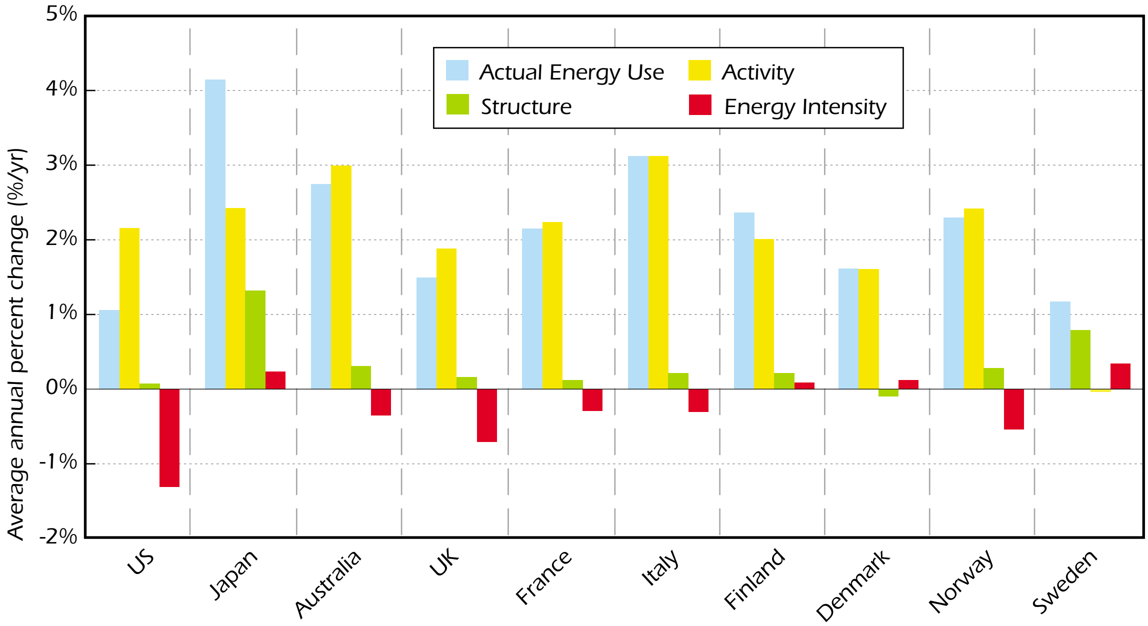
The IEA-11 intensity reductions until 1982 were led by declines in aircraft intensities in most countries, and further by reduced car intensity in the United States. The United States is significant in the weighted average. Therefore for the group of IEA-11 countries intensity did decline notably despite modest reductions in car intensity outside the United States. (See Figure 7-10). Between 1982 and 1990, travel grew rapidly and the rate of reduction in energy intensity slowed, leading to strong increases in energy use. In 1990-94, intensity reductions slowed further, but so did travel growth, leading to a more moderate energy use increase. Between 1994 and 1998, a strong global economy stimulated faster growth in travel activity and energy use. Relatively low fuel prices in the 1990s have also certainly played an important role, encouraging travel growth and discouraging intensity reductions.

Decomposition of Travel Energy Use – By Country

Energy intensity reductions activity have not kept up with growth in travel

Figure 7-18

Decomposition of Changes in Passenger Transport Energy Use, 1973-1998



While most IEA countries saw a net reduction in travel energy intensity from 1973 to 1998 it was not enough to offset growth in travel activity in any of them. In many countries, reductions in energy intensity have barely kept up with the impacts of changes in modal structure, i.e., increases in the share of car and air travel have offset the effect of declining intensities for those (and other) modes. As a result, total energy use has increased about as much as total travel activity in these countries.

It is important to recall that countries had different starting points. Growth in energy use was much lower in the United States than in Japan but this must be considered in the context that travel energy use in the United States was, and still is, much higher, yet Japan is clearly catching up. Japan, which had the largest travel share by public modes (bus and rail), also had the biggest shift away from these modes since 1973.

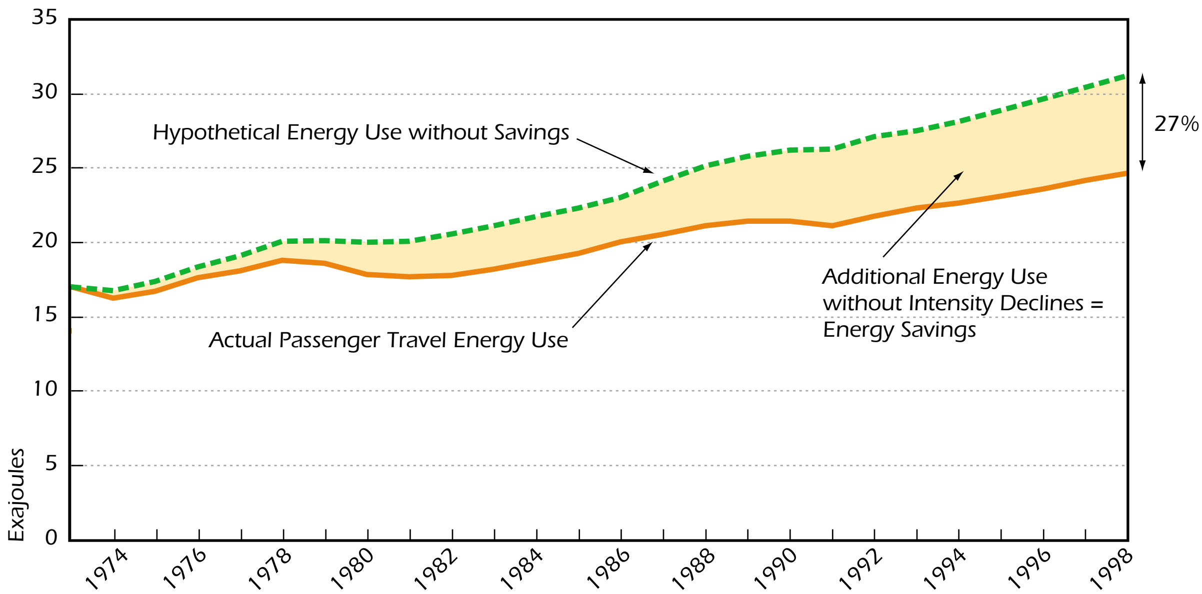
If IEA countries aim to curb passenger transport energy growth in the future, and shift current trends to lower energy use in transport, they will have to close the large gap between rates of reductions in fuel intensity and increases in passenger travel. This is clearly not an easy task, as evidenced by the fact that none of the IEA-11 countries were able to achieve this over three decades.

Energy Savings

Fuel intensity declines yielded fuel savings equivalent to 27% of 1998 fuel use

Figure 7-19

Actual Energy Use and Hypothetical Energy Use without Intensity Reductions, IEA-11



Despite the fact that fuel intensity declines have not kept up with activity growth, they have contributed to a significant reduction in energy use compared to what would have occurred if intensities had remained at 1973-levels. Without the declines in energy intensities energy use for passenger transport would have been 27% higher in 1998. This is illustrated by the difference between the two lines shown in Figure 7-19. The upper line represents the hypothetical energy use that would have occurred if no changes in fuel intensities had taken place, while the lower line shows actual energy use for passenger travel (see equation 5 in Chapter 2 and Chapter 3, Figure 3-16).

Though fuel intensity declines saved about a quarter of 1998 actual fuel use, they have not at all been sufficient to “bend the curve” of consumption. Energy use for travel in 1998 was around 45% higher than in 1973. This increase has been the major driver of increased oil demand in the IEA-11 countries.

Chapter 8. FREIGHT TRANSPORT

Highlights

- Energy use in "surface" freight (excludes air freight) has increased by 80% in a group of eleven IEA countries (IEA-11) since 1973, which compares to 45% growth in passenger transport energy use. All the growth has been in trucking; energy use in rail and shipping has declined.

- Total freight haulage (measured in tonne-kilometres) has increased on a per capita basis, but not significantly on a per unit of GDP basis, in most IEA countries. In fact, it declined relative to GDP in several countries, particularly the United States and Japan. In most European countries, freight haulage continues to grow at about the same pace as GDP.

- Few countries have seen reductions in aggregate freight energy intensity (total freight energy per total freight tonne-kilometre) since 1973, though energy intensities of the individual modes fell somewhat in most countries. This apparent contradiction reflects an increasing share of trucking in overall freight haulage, which is much more energy-intensive than rail or shipping.

- Trucking energy intensity has declined significantly in just a few countries since 1973. In other countries, individual truck efficiencies have likely improved, but this effect may have been offset by changes in the size-mix of trucks and the nature of the loads they carry. For example, in the United States the average weight of truck shipments has declined, perhaps due to moving more light-weight products. This can result in an increase in energy use per tonne (and tonne-kilometre) shipped. On the other hand, in Australia, where trucking intensity did fall significantly, there has been strong growth in very large long-haul trucks that carry heavy loads very efficiently.

- Across countries, there have been large variations in freight activity growth, changes in modal structure, and intensity declines. Some countries have seen much more rapid growth in tonne-km than others (ranging from less than 1% to nearly 3% per year between 1973 and 1998); some have seen much bigger shifts to trucking and some have experienced much greater intensity reductions (ranging from a 2% annual decline to nearly a 1% increase averaged over the 1973 to 1998 period).

- On average across the IEA-11 group, growth rates in freight energy use have slowed in recent years, mainly due to lower growth in freight activity. Freight haulage grew on average by 2.5% per year in the 1980s, compared with under 2% per year between 1994 and 1998.

Definitions and Data Used in this Chapter

Sectors

This analysis covers domestic surface freight. Air freight has been excluded due to a lack of data separating domestic and international air freight. The three main sectors analysed are: heavy and light freight trucks, rail and domestic shipping and barges. Pipelines are excluded.

Activity

Freight haulage measured in tonne-kilometres, which indicates both the weight of freight and the distance it is moved.

Mode

Means of transport, e.g., ship, rail, truck.

Structure

The share of total freight haulage by each mode.

Intensity

Modal intensity is energy use per tonne-kilometre. For trucks, vehicle energy intensity measured as energy use per truck-km is also analysed.

Decomposition

Changes in freight energy use are decomposed into changes in activity, modal structure, and intensity using the general decomposition method described in Chapter 2.

Data

Data are generally from national sources (see Chapter 2).

Country coverage

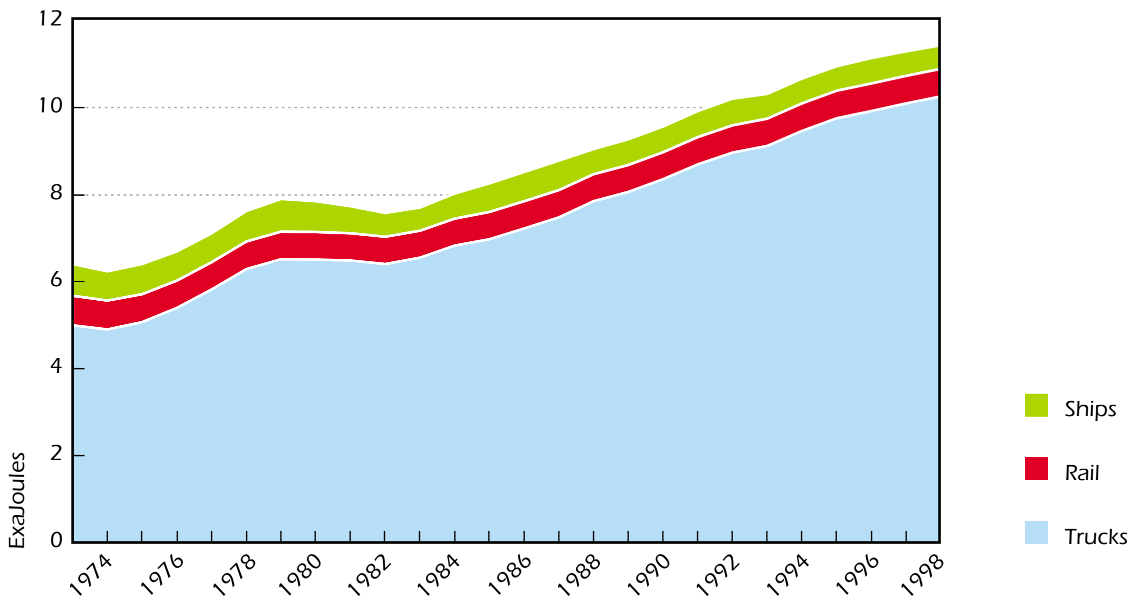
IEA has consistent time series with energy and activity data from 1973 through 1998 and in some cases 1999 and 2000 for eleven IEA countries. This includes Australia, Denmark, Finland, France, Germany, Japan, Italy, Norway, Sweden, the United Kingdom and the United States. When the aggregate results of this group are presented the group is referred to as IEA-11. The group of eight European countries within the IEA-11 is sometimes referred to as EUR-8 and includes Denmark, Finland, France, Germany, Italy, Norway, Sweden and the United Kingdom. In addition, IEA has complete time series with freight sector data but for shorter periods for the Netherlands and Canada.

Energy Use in Freight Transport by Mode

Freight transport energy use was 80% higher in 1998 than in 1973, driven by growth in trucking

Figure 8-1

Energy Use in Freight Transport by Mode, IEA-11



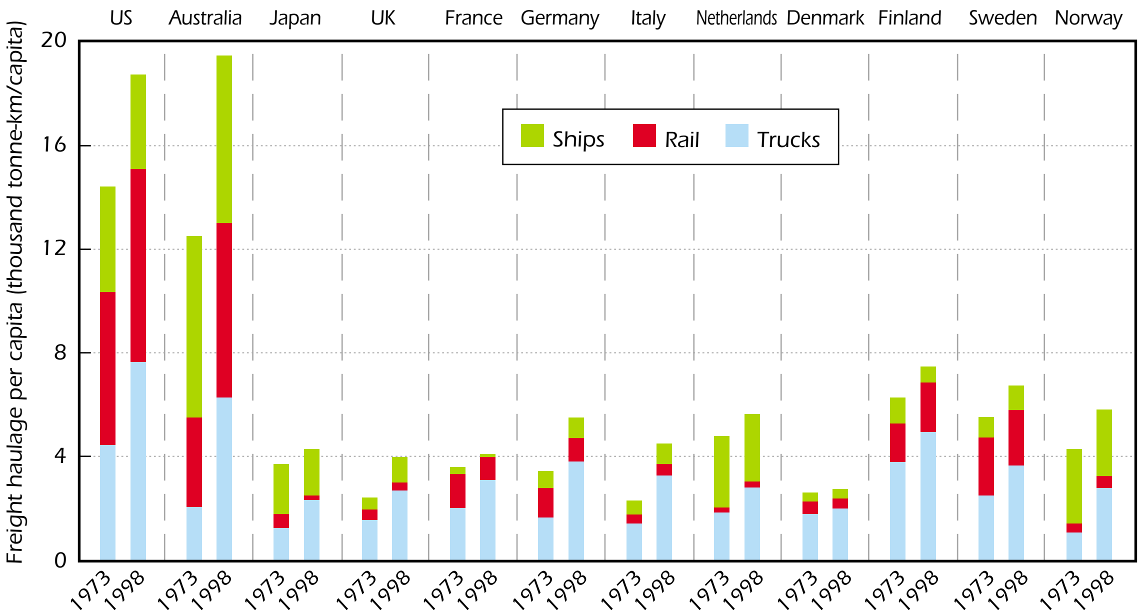
Energy use for freight transport in the IEA-11 countries has increased on a percentage basis far more than passenger transport since 1973. The strong growth in freight energy use is due entirely to growth in trucking, where energy use has more than doubled. In contrast, energy use in rail and shipping has declined slightly. Trucks accounted for more than 94% of total surface freight energy use in 1998, up from 88% in 1973.

Freight Transport per Capita

Freight haulage has increased in every country, as has the share of trucks

Figure 8-2

Freight Transport Tonne-kilometres per Capita and by Mode



Freight transport, measured in tonne-kilometres, per capita, increased between 1973 and 1982 in all the IEA countries shown in Figure 8-2. Freight haulage in the United States and Australia started at much higher levels in 1973 than other IEA countries, as well as experiencing high growth over the period. This reflects their large physical size and strong growth in the production and long-distance transport of raw materials. However, growth rates in freight haulage were similar in several European countries, e.g., Germany and Norway. Italy had the highest growth rate among the IEA-11, where domestic freight movement doubled over the period but from a small basis.[1] In all these countries, trucking exhibited the strongest growth of the three modes, with increases in per capita haulage ranging up to 200% in Australia betwen 1973 and 1998.

Growth in rail freight per capita varies considerably across countries, with significant increases in Australia and Finland; and declines in Japan, the United Kingdom, France and Germany. (Total rail freight haulage did not actually decline: it only grew more slowly than population.) Still, rail lost market share to trucking in all countries except Finland.

Water-borne shipping is important in domestic freight movement in the United States, Australia, Norway, and Japan, and less so for continental Europe. However, shipping's share of freight haulage has declined in IEA-11 countries since 1973.

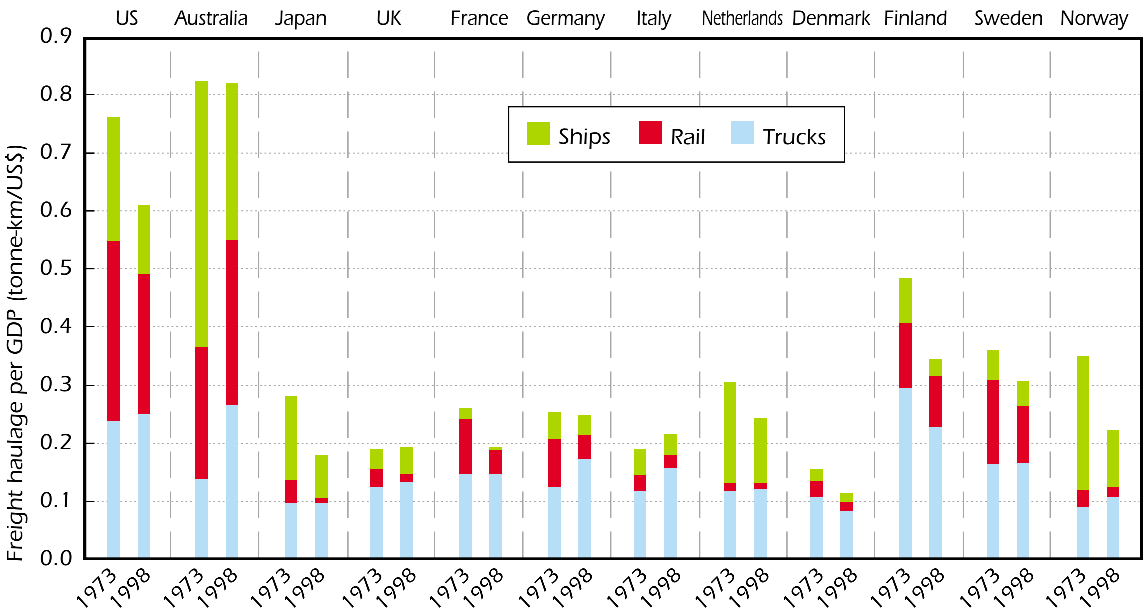
1. European domestic freight movement is generally much smaller than international movement within Europe. International freight transport is not included in this study.

Freight Transport per GDP

Total freight haulage roughly follows GDP in most countries

Figure 8-3

Freight Transport Tonne-kilometres per Unit of GDP and by Mode



Although freight transport per capita has increased substantially in the last three decades, on a per unit of GDP basis it has been flat or has declined in most IEA-11 countries. On average, across the countries shown in Figure 8-3, economies have become slightly less freight-intensive. In countries where there was a decoupling of freight haulage and GDP, this reflects faster growth in service sector GDP than in goods sectors such as manufacturing, and greater average value per unit weight of the goods moved (e.g., more computers shipped, less coal).

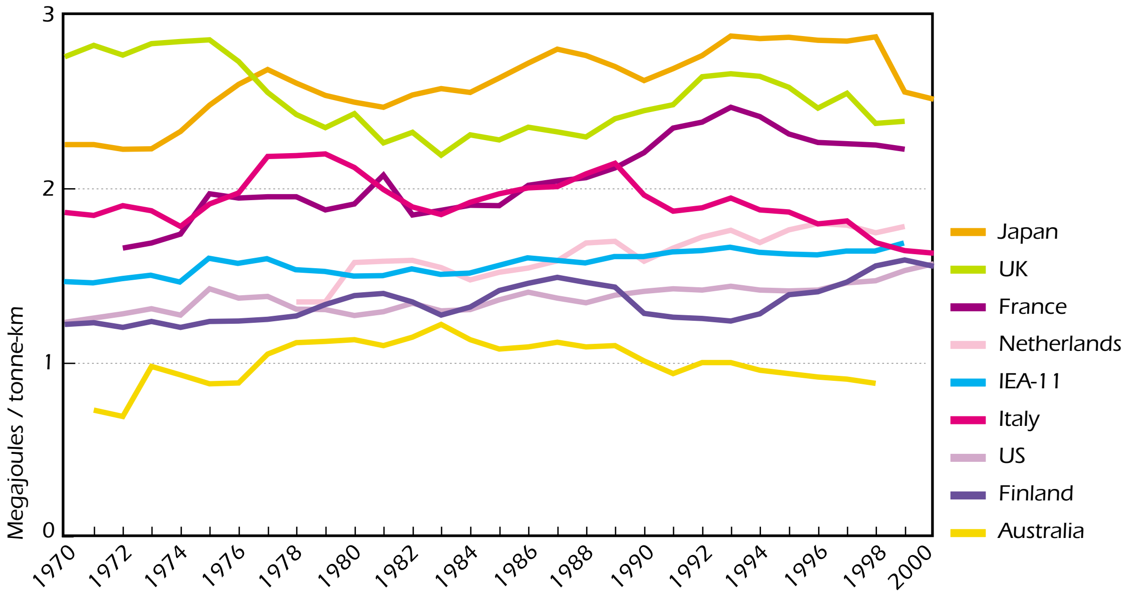
Freight transport by truck per unit of GDP increased in most countries, while there were strong decreases in the GDP intensity of rail and shipping. This underscores the fact that trucking gained market share at the expense of rail and shipping.

Aggregate Freight Energy Intensity

Small changes in energy per tonne-km over time, but levels vary widely

Figure 8-4

Freight Transport Energy per Tonne-kilometre Aggregated for all Modes



Aggregate energy intensity of total freight haulage across IEA countries varies by a factor of nearly three, though there has been a convergence in intensity among a number of countries in recent years at around 1.5 megajoules per tonne-kilometre. The aggregate energy intensity for the IEA-11 has been remarkably stable, though it shows a slight upward trend, indicating that, on average across country and mode, freight transport is not becoming less energy intensive.

Two countervailing trends affect the aggregate intensities: the energy intensity of individual modes (trucking, rail, shipping) has declined, though not by much; but the declines have been offset by a larger share of trucks in the modal mix. As shown in the next figure, trucks are much more energy intensive per tonne-kilometre than rail or shipping.

The large differences in absolute levels among countries reflect many factors, particularly the relative importance of trucking versus rail freight. Australia and the United States, with considerable low-energy-intensity rail freight, are at the lower range of the energy intensity spectrum, while Japan, with very little, is at the high end.

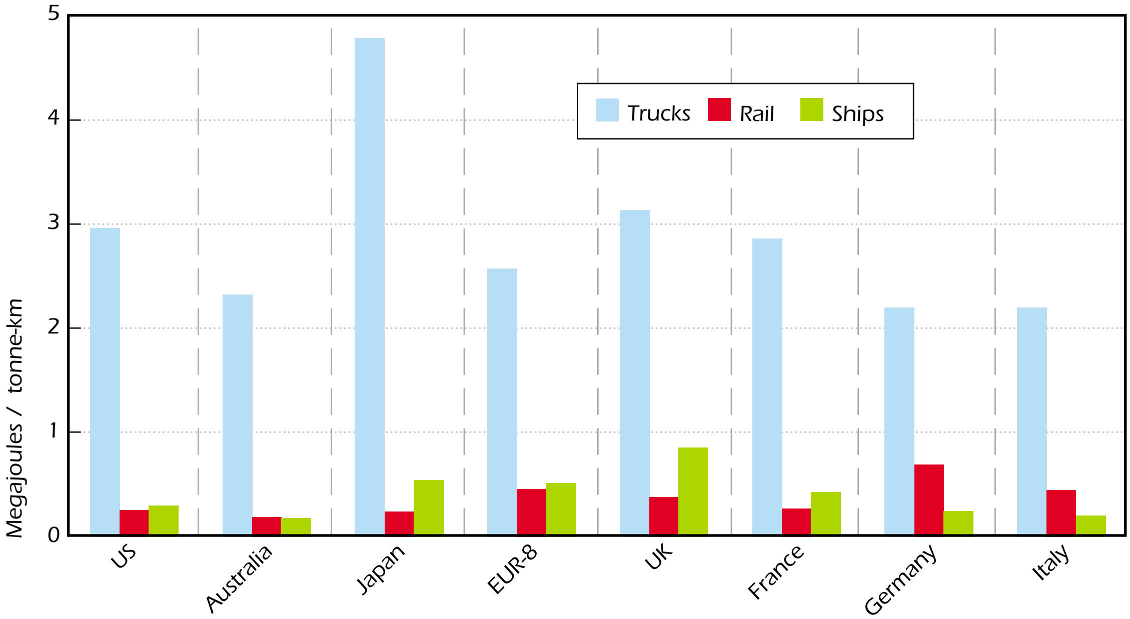
In some countries, for example in France, strong growth in truck freight movement relative to rail has increased aggregate freight energy intensity over much of the period. On the other hand, reductions in modal energy intensities have helped reduce growth in energy use, particularly since 1990. The net effect of increased trucking share and reduced modal intensities results in little change in aggregate energy intensity since 1973 in most countries and overall for the IEA-11.

Modal Energy Intensities

Trucks use far more energy per tonne-kilometre than rail or ships

Figure 8-5

Freight Transport Energy per Tonne-kilometre by Mode, 1998



*EUR-8 includes: Denmark, Finland, France, Germany, Italy, Norway, Sweden and the United Kingdom

Big differences in the energy intensity of trucks, ships and rail help account for the strong variation in aggregate energy intensity of freight. On average trucks use from four to twenty times more energy to move a tonne of goods one kilometre than does rail in IEA countries. This large range relates to differences in factors such as the type of goods moved and the split between urban delivery trucks and much larger and less energy-intensive long-haul trucks. Reflective of its size and density of settlement, Japan has the highest trucking intensity as it has a large share of short-haul and delivery freight activity and relatively little long-haul trucking. Rail and shipping energy intensities also vary by up to a factor of three across countries, yet in each, both intensities are much lower than for trucking.

There are two important messages here. First, mode shifting from truck to rail or water can have a large impact on energy use (though it must be remembered that the difference in energy intensity, at the margin and for particular types of goods, may not be nearly as large as the averages suggest; further, the far greater flexibility of trucking, its "just-in-time" service, and limitations to freight rail capacity in many countries restrict the opportunities for truck-to-rail substitution). Second, intensity reductions in rail and shipping are not nearly as important as for trucking, since they use so little fuel per tonne-kilometre to begin with.

Energy Use by Trucking: A Decomposition Model

To better understand why energy use in trucking is changing over time and how it varies among countries, it is useful to look at the different components that affect it.

How much energy trucks use depends on several factors. The two most important are: how many tonnes of freight are moved and over what distance (together measured as tonne-kilometres); and how much energy is used per tonne-kilometre. This can be expressed by the following identity that decomposes changes in freight energy use into changes in tonne-km hauled by trucks and trucking energy intensity:

$$\text{Final energy for trucks: } FE_t = \text{tonne-km} * FE_t / \text{tonne-km};$$

Changes in energy use per tonne-kilometre can be further broken down into changes in tonne-kilometres per vehicle-kilometre and changes in vehicle energy intensity (energy use per vehicle-kilometre):

$$FE_t / \text{tonne-km} = \text{vehicle-km} / \text{tonne-km} * FE_t / \text{vehicle-km}$$

Note that vehicle-km per tonne-km is simply the inverse of load factor (tonne-km/vehicle-km), reflecting that energy use per tonne-km goes up when the load factor is reduced.

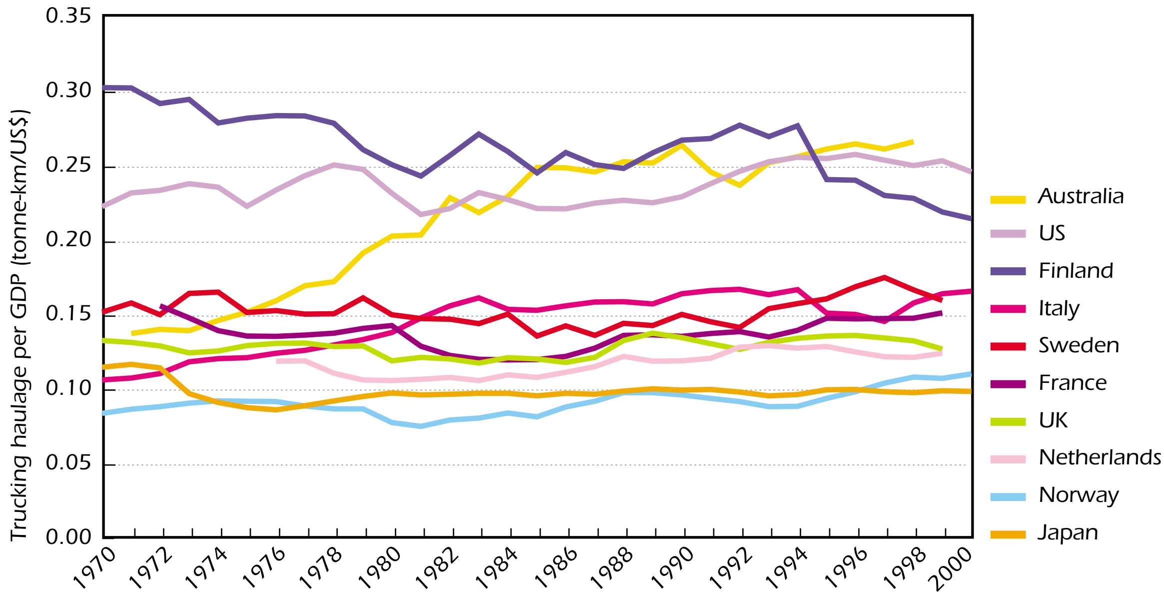
The following pages illustrate the development of some of these factors for selected IEA countries, and then summarises how each factor has affected energy use for trucking in Figures 8-10 and 8-11.

Truck Freight Transport

Truck haulage follows GDP growth in most countries

Figure 8-6

Truck Freight Tonne-kilometres per GDP



While the share of domestic freight movement by trucks has expanded, the overall increase in truck tonne-kilometres generally has been in line with GDP growth. The relative flatness of most of the lines in Figure 8-6 reflects a near unitary long-term elasticity between economic growth and trucking growth. The major exceptions are Australia, which has experienced far more rapid growth in trucking than in GDP, and Finland, which has experienced a decline.

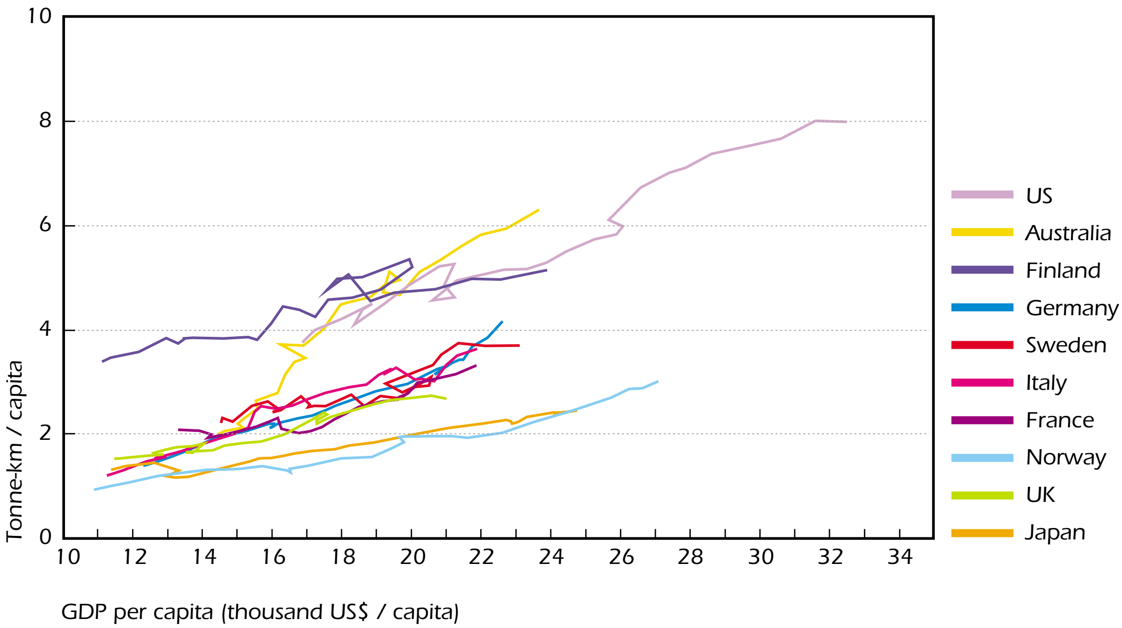
The figure also illustrates the large differences in trucking per unit of GDP among countries. The geographically larger countries such as the United States and Australia have relatively high levels compared with smaller ones such as Japan and the Netherlands. The relatively low levels in Sweden and Norway are in contrast to Finland, which is among the most trucking-intensive economies. Variations among the Nordic countries may reflect differences in the composition of freight and how it is moved, with more coastal shipping of heavy freight in Norway and Sweden than in Finland. The situation in Norway is also related to the dominance of the petroleum sector in the Norwegian economy, which has boosted GDP, but not resulted in much increased trucking as the oil and gas are mainly transported via pipelines and international tankers.

Truck Freight Transport and GDP

Truck average haulage per capita increases steadily with GDP per capita, but is on a higher plane in some countries

Figure 8-7

Truck Freight Tonne-kilometres per Capita versus GDP per Capita, 1973-2000



Truck haulage is clearly aligned with GDP growth, with tonne-kilometres per capita increasing steadily as GDP grows over time, and in some cases dropping as GDP declines, as in Finland during the early 1990s. For most countries the relationship appears to be quite stable and there is little sign of a slowing in truck freight movement per unit of GDP growth in recent years, as might be suggested by the shift towards more service-oriented economies. A few countries, however, show signs of "bending" the curve. These include the Nordic countries and the United States where the growth in tonne-kilometres per capita has slowed in recent years. The fastest truck freight growth by far, relative to GDP growth, has been in Australia, which is now at a significantly higher level of tonne-kilometres per capita than the United States was when it was at a similar income level.

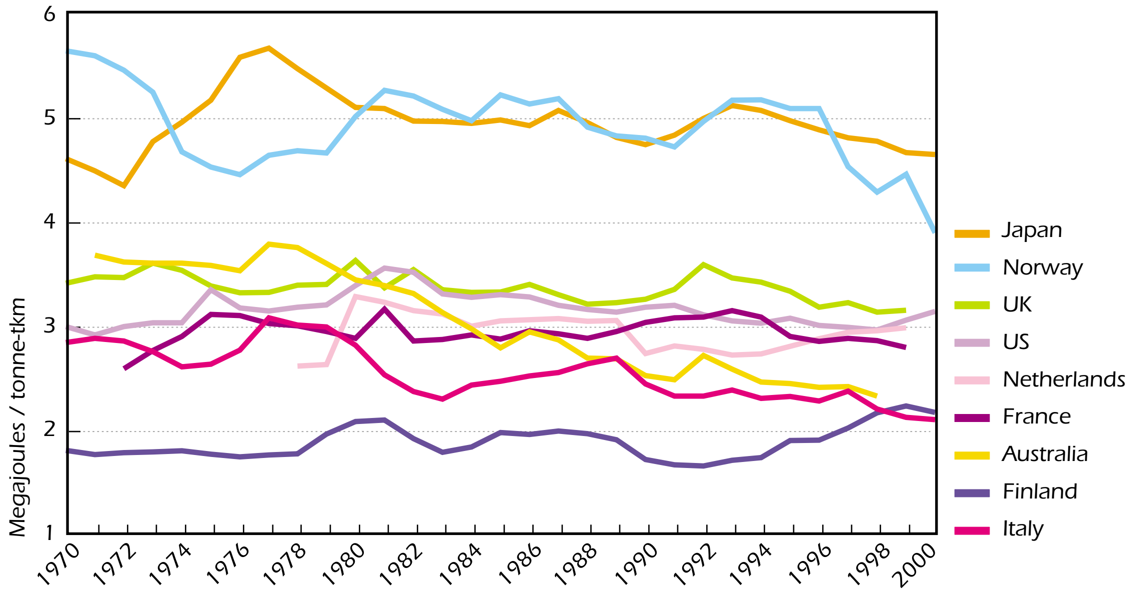
The differences in truck freight movement per GDP evident in Figure 8-6 are also apparent here: it shows that most countries with lower levels of freight movement do not seem to be on a particularly faster growth trajectory than those with high levels; rather, there appear to be different "planes" of trucking per capita, with some countries (e.g., Japan, Norway) appearing unlikely to ever reach levels already seen in the United States and Australia. These reflect inherent differences in the countries' physical and economic structure.

Truck Energy Intensity

In most countries, trucking energy intensity has not declined significantly

Figure 8-8

Energy Intensity for Trucks



Most IEA-11 countries have seen only modest reductions in trucking energy intensity over the last two to three decades, with a few exceptions (Australia, Italy). While energy intensities have been relatively stable over time within countries, they vary considerably across countries, reflecting differences in the average length of haul, size of vehicle, and characteristics of the average load. These structural factors yield a large and enduring spread. Japan, with short-hauls and small trucks is at the high end. At the low end is Finland, with a relatively high percentage of domestic freight with large truck shipments of raw materials. By far, Australia shows the most reduction in truck freight energy intensity, related to the rapidly increasing use of large, long-haul trucks moving freight great distances across the country (including three-trailer “truck-trains”).

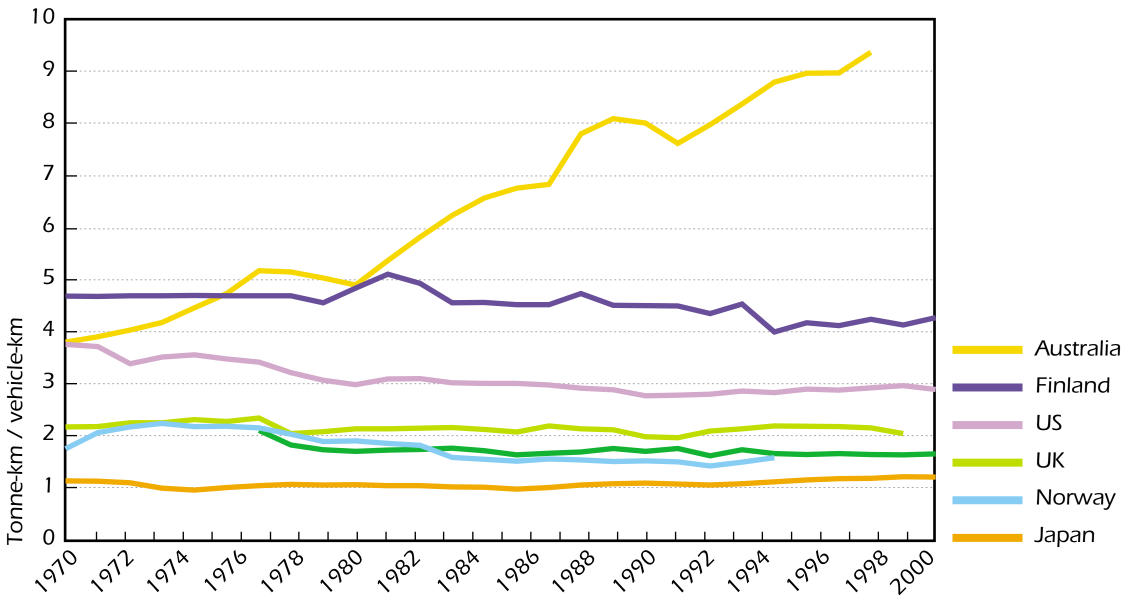
There is no question that there have been significant efficiency improvements to trucks over the past 30 years, e.g., more efficient engines, better cab design, and lower rolling resistance tires. However, these improvements are mostly overshadowed by the trends related to truck size, urban versus highway driving, and load characteristics. One general trend working against intensity reductions, as measured by energy per tonne-kilometres, is the increasing haulage of relatively lighter, but often higher value, manufactured goods, rather than heavier raw materials. When trucks “cube out” rather than “weigh out”, that is, when they fill to capacity before they reach their weight limit, they run fewer tonnes per load, and their energy intensity rises. This trend has occurred in all IEA countries since the 1970s, and is an important factor that has offset improved vehicle efficiency. Data on energy use per unit value of goods moved by trucking (as opposed to unit weight) are not widely available. Though this indicator would also be useful to consider, and would no doubt show that energy intensity measured per unit value of goods transported has declined since the 1970s.

Truck Average Load Per Vehicle

Truck average load factors have been fairly constant, with one notable exception

Figure 8-9

Truck Average Load per Vehicle



Most IEA countries have experienced fairly stable truck loads, measured as tonne-kilometres per vehicle-kilometre. The one notable exception is Australia, where average loads have more than doubled since 1973. As mentioned for Figure 8-8, Australia has experienced strong growth in large, long-haul trucking relative to short-haul (e.g., delivery) activity. Other countries have either had more balanced growth between these two types of trucking, or in some cases a trend to larger trucks may have been offset by shifts to lighter, lower density loads (e.g., more electronics, fewer bricks).

It is also noteworthy that there are large differences in the average load factor for different countries, ranging from about one tonne per load in Japan to nine in Australia (in 1998). This reflects both the size of trucks and composition of the loads. Japan is both small geographically and heavily urbanised, so relatively few large, long-haul trucks are used there. Urban deliveries make up a much higher share of total trucking in Japan than in big countries like the United States and Australia. Finland's low energy intensity levels, shown in Figure 8-8, are also reflected here as high load factors: truck haulage is dominated by large trucks moving bulk goods such as timber resulting in low energy use per tonne-kilometre.

Truck Energy Use Decomposition

Trucking energy use has increased, as intensity reductions have not nearly offset growth in tonne-kilometres

Figure 8-10

Decomposition of Changes in Truck Energy Use, 1973-1998

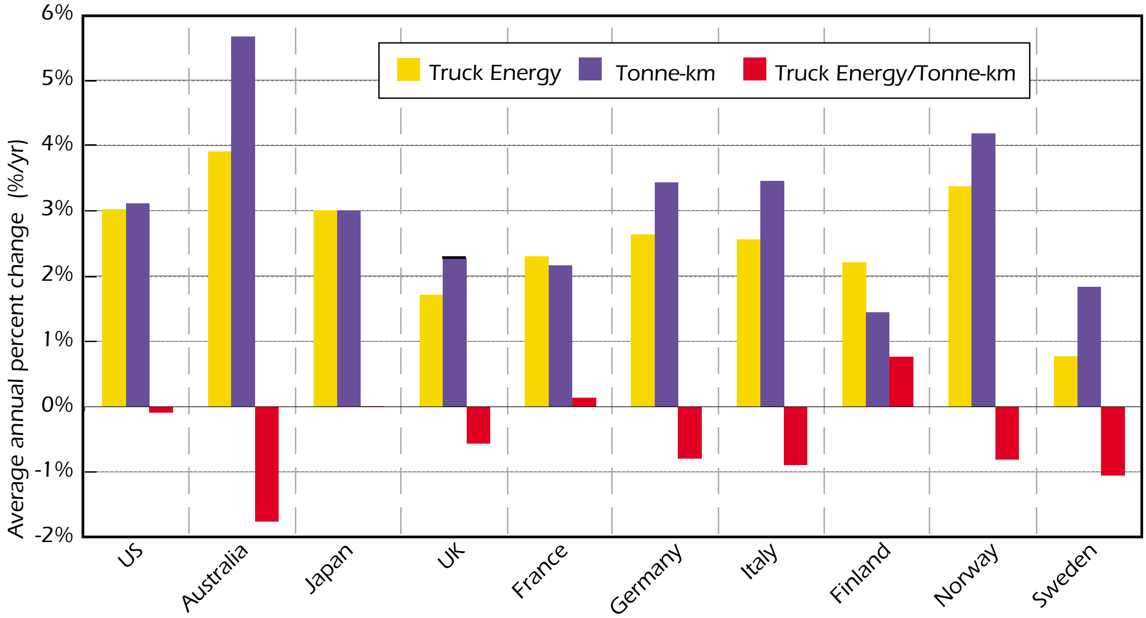


Figure 8-10 shows how changes in activity (tonne-km) and intensity (energy per tonne-km) each have affected changes in trucking energy use between 1973 and 1998 using the approach described in the box on truck energy use decomposition. Growth in trucking activity has driven rapid increases in energy use. Australia is the only country with a significant decline in trucking intensity, but since it is also the country with the strongest growth in activity, trucking energy use increased more in Australia than in any other country shown in the figure.

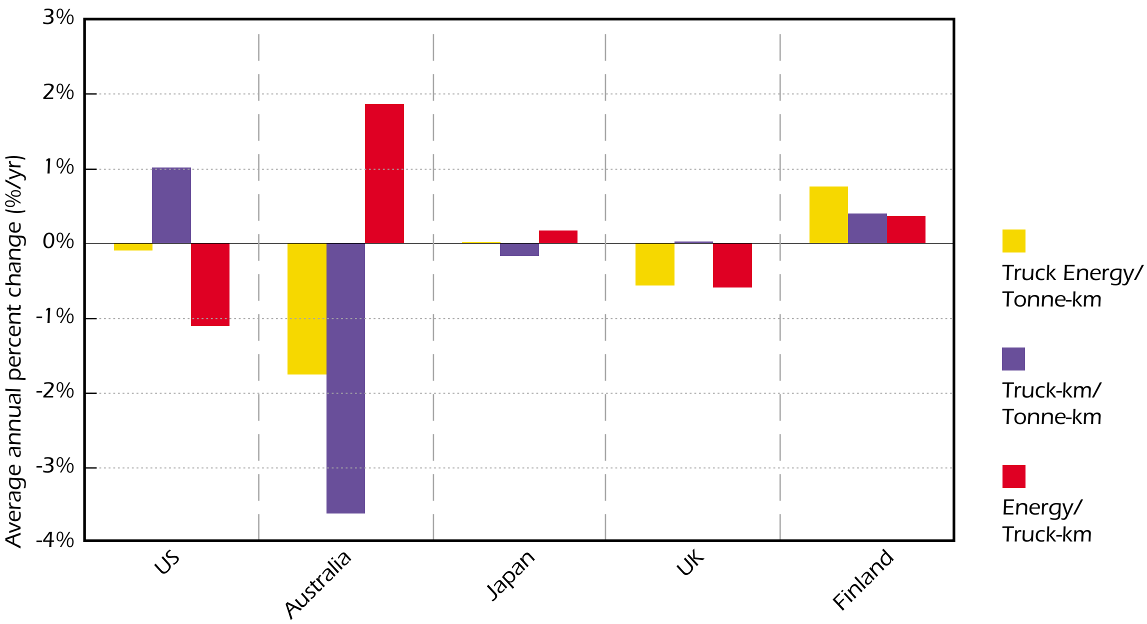
In most European countries trucking intensity fell by between 0.5% and 1% per year on average between 1973 and 1998. Sweden had the lowest growth in trucking energy use, a result of both a modest increase in trucking activity and a slightly more than 1% per year decline in intensity. In Japan and the United States the change in trucking energy intensity between 1973 and 1998 was close to zero, with the result that trucking energy use grew on a par with trucking haulage.

Truck Energy Intensity Decomposition

Trucking energy intensity is heavily influenced by load factor

Figure 8-11

Decomposition of Changes in Truck Energy Intensity, 1973-1998*



* Note that this figure shows the inverse of load factor, i.e., truck-kilometres per tonne-kilometre, since an increase in load factor will yield a decrease in trucking energy intensity.

The changes in trucking energy intensity depicted in Figures 8-8 and 8-10 are shown here as the product of changes in load factor (how many tonnes of freight trucks move at a time) and vehicle energy intensity (how much energy trucks use per vehicle-kilometre in moving the freight). For those few countries where sufficient data are available, the trucking tonne-kilometre energy intensity developments have been heavily influenced by trends in load factors.

Australia achieved its large reduction in average trucking energy intensity not by making trucks individually more efficient (though this may also have occurred), but by moving far more freight per truck-kilometre (that is, using far fewer truck-kilometres per tonne kilometre). Energy use per truck-kilometre in Australia actually increased substantially over the period. Both of these trends probably relate to the increased use of very large trucks.

The trends have varied in other countries. In the United States, truck load factors actually decreased (truck-kilometres per tonne-kilometre increased), offsetting most of the significant reduction in energy use per truck-kilometre. In the United Kingdom, average load factors changed very little while energy use per truck-kilometre declined, resulting in a net reduction in energy per tonne-kilometre over the period.

Freight Energy Decomposition – All Modes

Reductions in energy intensity have not kept pace with shifts in modal structure

Figure 8-12

Decomposition of Changes in Freight Energy Use, all Modes, IEA-11

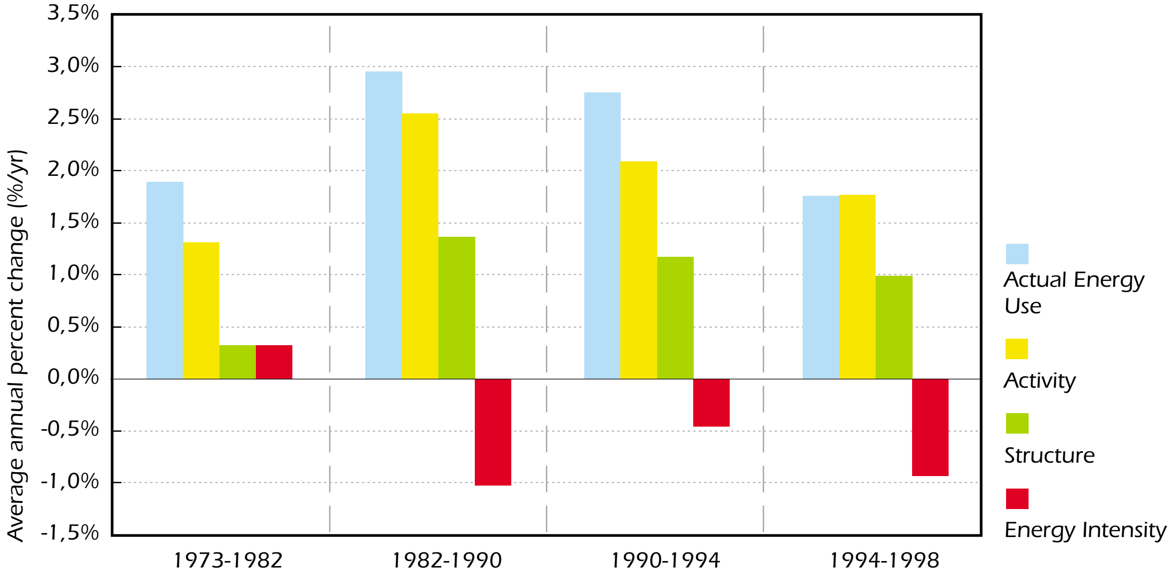


Figure 8-12 shows how changes in total freight energy use for IEA-11 are decomposed into changes in total freight haulage (activity), modal structure and energy intensities of the three freight modes included (refer to decomposition approach described in Chapter 2). Between 1973 and 1982 growth in freight energy use was relatively modest, despite increases in energy intensities and shifts to more energy-intensive modes (trucking). Moderating the growth in energy use was relatively slow growth in freight haulage, a result of the economic recessions in the mid-1970s and the early 1980s, and a lower impact on energy use from structural shifts to trucking than seen after 1982.

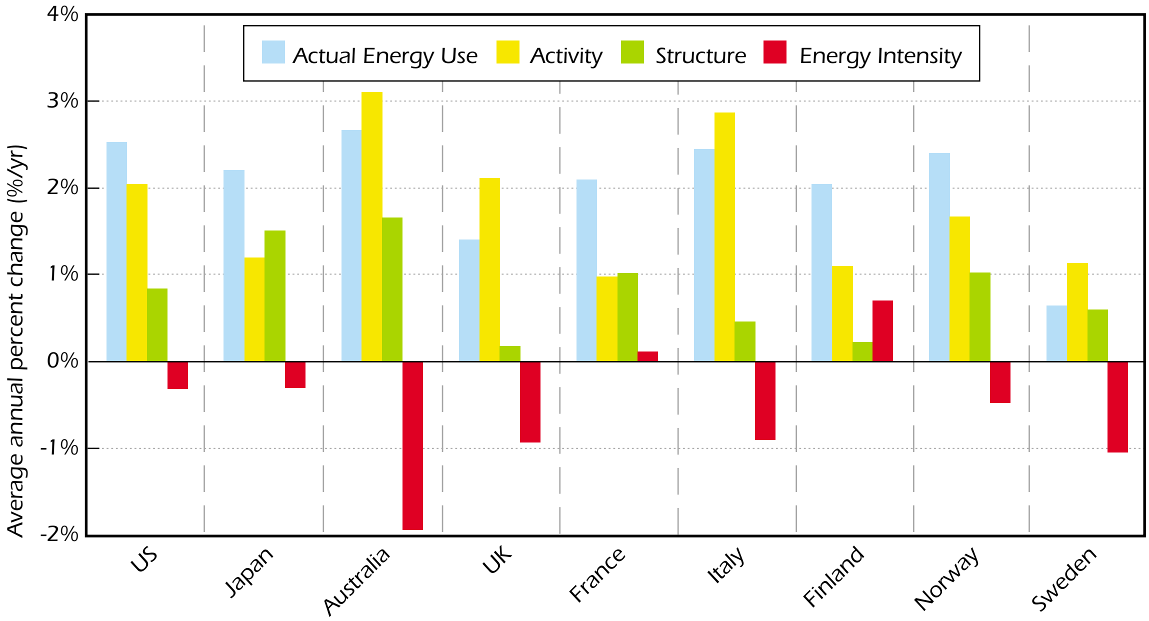
Things changed during the 1980s. Overall freight activity growth rates increased, as did modal shifts to trucking. One percent per year reduction in modal energy intensities was far too to little to prevent rapid increases in energy use. During the early 1990s, intensity declines slowed, but so did the growth in freight activity and the shift to trucking in the modal structure. As a net result, freight energy use grew a little less than in the 1982-1990 period. After 1994 energy intensities again fell by 1% per year, while activity and modal shifts continued to slow somewhat. Still, the intensity reductions were only just enough to offset changes in modal structure, and energy use grew at the same rate as activity. Overall, between 1973 and 1998 the average decline of 0.4% in energy intensity only offset about half of the increase in energy use due to the shift in modal structure. Consequently, energy use grew faster than freight activity, at 2.4% on average per year compared to 1.9% per year growth in activity.

Freight Energy Decomposition – By Country

Large variations in activity growth, changes in modal structure and intensity declines across countries

Figure 8-13

Decomposition of Changes in Freight Energy Use, 1973-1998



Though aggregate freight energy use has increased in every country included in Figure 8-13 since 1973, the underlying reasons vary considerably. Freight activity growth ranges from about 0.1% per year in France to more than 3% per year in Australia; impacts from shifts in modal structure range from a 0.2% annual energy increase in the United Kingdom to a 1.7% increase in Australia; and changes in energy intensity range from a 2% per year decline in Australia to a 0.7% per year increase in Finland.

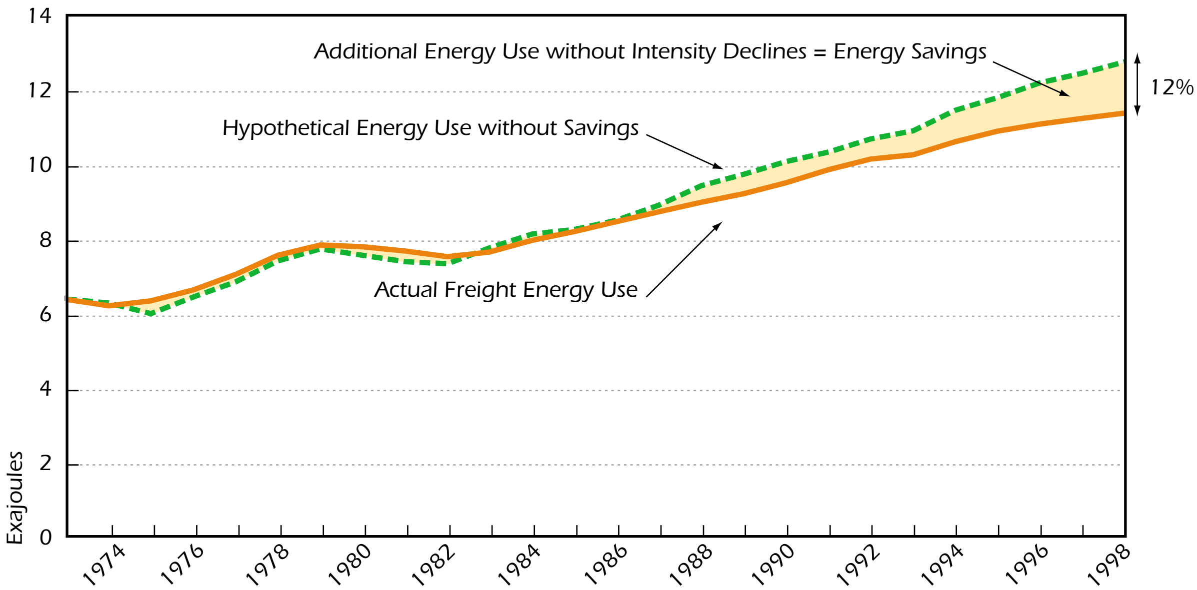
Structural changes – more trucking, less rail – more than offset reductions in energy intensity for the IEA-11 as a group (Figure 8-12). However, in several countries decreases in energy intensity have been greater than the impact of structural change, such as in Australia, the United Kingdom, Italy and Sweden. On the other hand, freight activity in these countries, except for Sweden, also grew the fastest. With the lowest overall growth rate in freight energy use, Sweden experienced low activity growth, low structural change, and a relatively strong reduction in intensity.

Energy Savings

Without energy savings from reduced fuel intensities freight energy use would have been 12% higher in 1998

Figure 8-14

Actual Energy Use and Hypothetical Energy Use without Intensity Reductions, IEA-11



Energy intensity reductions in freight transport have been relatively modest since 1973. The savings from the decline in energy intensities between 1973 and 1998 only amounted to 1.4 EJ, which corresponds to 12% of the 1998 actual freight energy use level. These savings are calculated as the differences between the two curves in Figure 8-14, using the same methodology as described by equation 5 in Chapter 2 (see also Chapter 3, Figure 3-16).

The savings due to fuel intensity declines have not been anywhere near sufficient to "bend the curve" of consumption. Energy use for freight in 1998 was nearly 80% higher than in 1973. This increase has been an important driver of increased oil demand in the IEA-11 countries.

Chapter 9. TRENDS IN CO_2 EMISSIONS

Highlights

- CO_2 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 CO_2 emissions per unit of GDP between 1973 and 1990. After 1990, however, only a few continued to exhibit significant decoupling of CO_2 emissions from economic growth. While total IEA-11 CO_2 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.
- Detailed data show that the primary reason for the slowing decline in CO_2 emissions per unit of GDP since 1990 is that rates of energy intensity reductions in most sectors have slowed. This is a uniform trend among the IEA-11 countries. In addition, switching to less carbon-intensive fuels for electricity and district heat production contributed less to overall CO_2 emission reductions in most countries after 1990 than before.
- 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 CO_2 intensity of electricity supply and a shift to a less energy-intensive manufacturing 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 CO_2 emissions.
- Growth in CO_2 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, the reduction in CO_2 emissions per unit of electricity generated has 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 varied. 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 service 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, CO_2 emissions from IEA-11 households would have accelerated even more.

1. IEA-11 includes 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 CO_2 emissions in 2001.

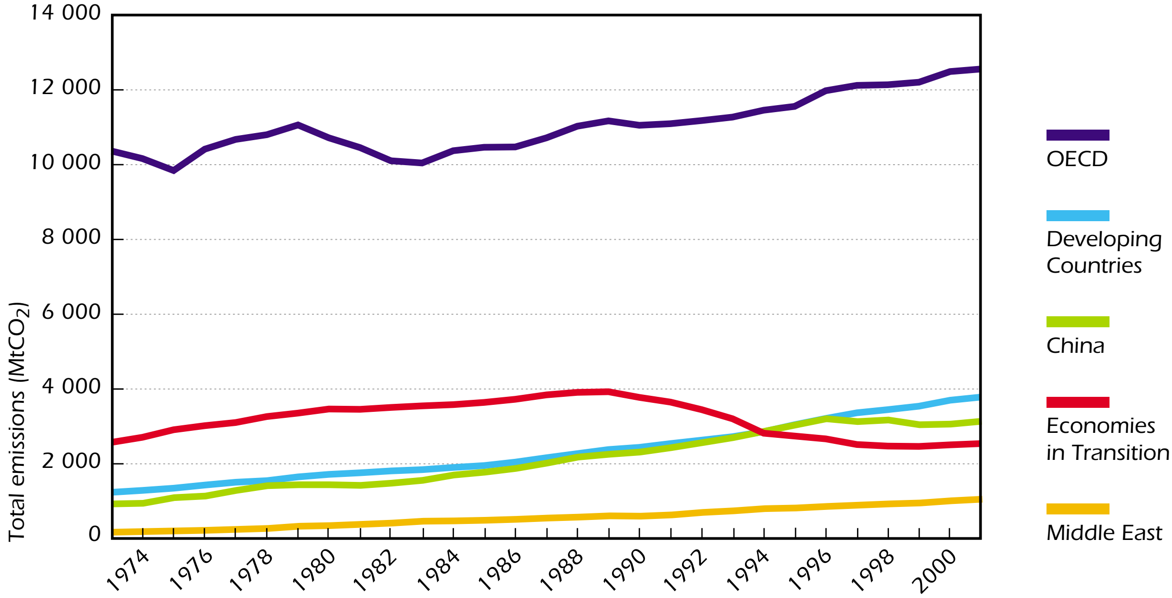
- CO_2 emissions from the passenger transport sector have increased steadily since 1973, driven by increased travel activity and a shift towards more cars and aircraft in the modal mix. Emission growth accelerated in the United States and Japan after 1990, as the decline in fuel intensities slowed. In Europe, a somewhat more rapid decrease in intensities after 1990 led to lower CO_2 emissions growth rates.
- Freight transport showed the highest relative growth in CO_2 emissions since 1973 among all sectors in the IEA-11 countries. 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.

Global CO_2 Emissions from Fuel Combustion

Global CO_2 emissions continue to increase

Figure 9-1

Global CO_2 Emissions



Global CO_2 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.[2]

The OECD countries account for the overwhelming majority of total CO_2 emissions. The trend shows dips in emission levels corresponding to the oil price shocks of the 1970s and the 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 CO_2 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.

In developing countries as a group (excluding China), CO_2 emissions have increased rapidly since the mid-1980s as total primary energy supply (TPES) and GDP have grown. The link between energy use and CO_2 emissions remains strong in most developing countries because of the predominance of fossil fuels in the commercial energy supply.

The sharp downturn in CO_2 emissions in the Economies in Transition countries (EITs) reflects the collapse of the formerly centrally-planned economies. Emission levels have increased slightly in the last two years, but remain some 30% below 1990 levels.

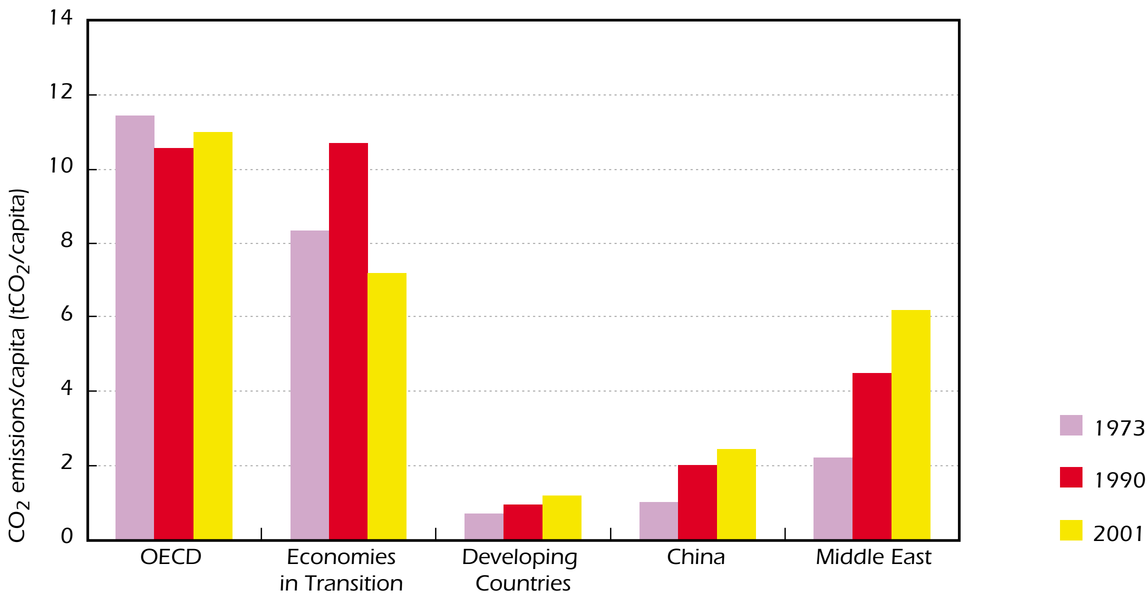
2. Data for Figures 9-1, 9-2, 9-3, 9-5 and Table 9-1 are from IEA CO_2 Emissions from Fuel Combustion.

Global CO_2 Emissions per Capita

***OECD** countries emit about three times as much CO_2 per capita as the world average*

Figure 9-2

CO_2 Emissions per Capita



Historically, CO_2 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 CO_2 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 CO_2 emissions.

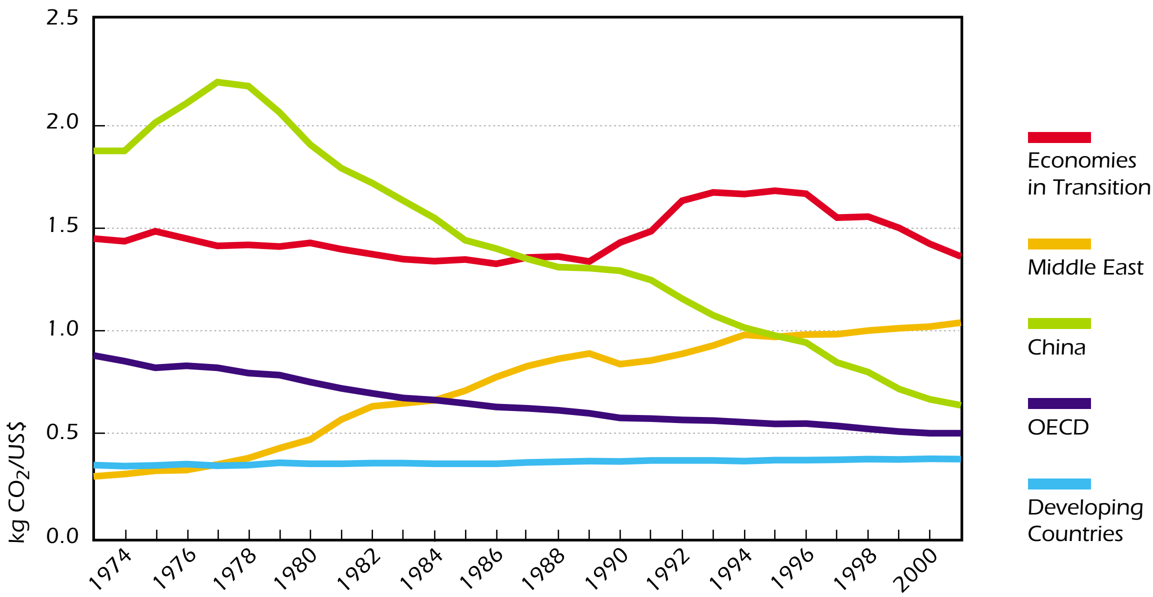
In the Economies in Transition countries, the dramatic decline in CO_2 emissions through the 1990s reflects economic restructuring and an almost 3% population decline. China, on the other hand, experienced enormous GDP growth (174%) and a 12.1% surge in population. Increased oil and gas production in the Middle East led to increased emissions in this region.

Global CO_2 Emissions per GDP

China's CO_2 emissions per GDP appear to have declined dramatically

Figure 9-3

CO_2 Emissions per GDP



China has seen one of the most dramatic declines in CO_2 emissions per unit of GDP of any country over the past three decades. Its CO_2/GDP ratio declined 50% between 1990 and 2001, while China's overall emissions, due to high coal consumption levels and a dramatic increase in vehicle traffic, have risen over most of this period. Some experts question the dramatic decrease in reported Chinese coal supply in recent years, and existing data may well underestimate CO_2 emissions.

The increase in CO_2 emissions per GDP in the Economies in Transition countries is caused by the rapid decline in economic output since 1990.

In the Middle East, increasing extraction of oil and gas (an energy and CO_2 - intensive activity) and the important contribution this activity makes to the region's economic output explain the growth in CO_2 emissions per unit of GDP since the late 1970s.

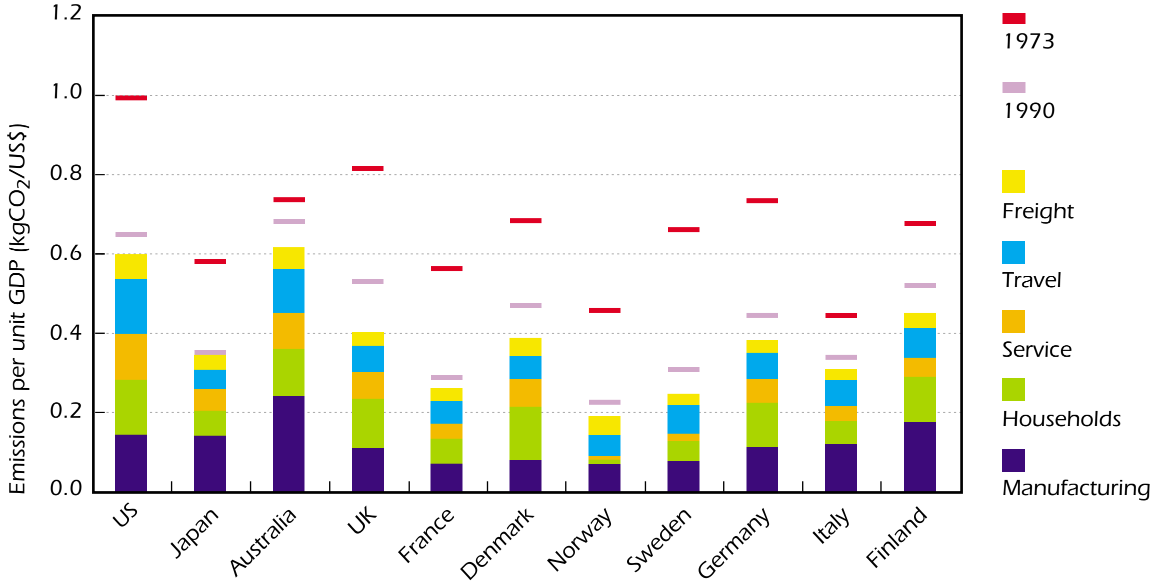
The partial decoupling of GDP from CO_2 emissions in OECD countries reflects a number of factors. Countries responded to the first oil price shock in 1973 by reducing their use of oil in power generation, developing non-fossil-fuel energy sources such as nuclear and renewable energy, and increasing energy efficiency.

CO_2 Emissions per GDP and Sector

Emission levels per GDP vary considerably among IEA countries

Figure 9-4

CO_2 Emissions per GDP and Sector, 1998[3]



In 1998 CO_2 emissions per unit of GDP varied by more than a factor of three across the countries shown in Figure 9-4, 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 CO_2 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 CO_2 intensive among the IEA-11. While the high share of low carbon electricity in the Norwegian space heating results in almost no emissions from the two buildings sectors, Finland, which also has a very cold climate, has among the highest emission levels from household and services buildings. 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.

3. Emissions from electricity and district heat are allocated to end-use sectors using average yearly CO_2 emission coefficients for electricity and district heat, respectively. This approach is used throughout this publication.

The passenger and freight transport sectors are almost entirely based on oil products and the more modest variations in CO_2 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. Relatively high energy intensities for cars, combined with long driving distances, the latter at least partly due to geography, explain why the United States and Australia have the highest CO_2 emissions per GDP from passenger travel.

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 CO_2 emissions and GDP. With 1990 as the base year for the Kyoto targets, this poses concern for many IEA governments.

Climate Change Challenge

Current climate change actions being undertaken by the world community are largely based on the agreement set out in the United Nations Framework Convention on Climate Change. The ultimate objective of the UNFCCC is the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". As a first step towards this goal, Parties to the Convention agreed to mitigate emissions and to promote removals by sinks of all greenhouse gases. The developed countries and economies in transition (known as "Annex I" Parties) were called upon to adopt policies and measures with the aim of returning their greenhouse gas emissions to 1990 levels by 2000.

Responding to the evidence of continuing increases in emissions in part, as well as to more robust science on climate change, the Conference of the Parties to the UNFCCC agreed that additional actions were needed to combat the climate change challenge. In 1997, the Parties adopted the Kyoto Protocol. It establishes a *legally binding obligation* on most developed countries to reduce their emissions of six greenhouse gases; the aggregate reduction is to be at least 5% below 1990 levels in the commitment period 2008-2012. There are no such obligations on developing countries.

Emissions targets under the Kyoto Protocol were differentiated to take into account national circumstances such as climate, geography, demographics, development patterns and available energy resources. The European Union (EU) member countries reallocated their collective 8% reduction among themselves.

To enter into force, the Protocol requires ratification by at least 55 Parties to the Convention, and these Parties must account for no less than 55% of total Annex I carbon dioxide emissions in 1990. As of January 2004, the Kyoto Protocol had been ratified by 120 countries, representing 44.2% of Annex I Party emissions. The United States, representing 36.1% of Annex I Party emissions, announced its intent not to ratify in 2001. Australia also has announced its intent not to ratify. This means that entry into force of the Kyoto Protocol now hinges on ratification by Russia to achieve the necessary threshold. Russia, representing 17.4% of Annex I emissions, has not yet taken a decision to ratify.

Kyoto Targets and Trends in CO_2 Emissions

CO_2 emissions have been on the rise in most countries since 1990

Table 9-1

Changes in CO_2 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 CO_2 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 CO_2 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, CO_2 emissions declined or grew only modestly in most countries. In the IEA as a whole, CO_2 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.

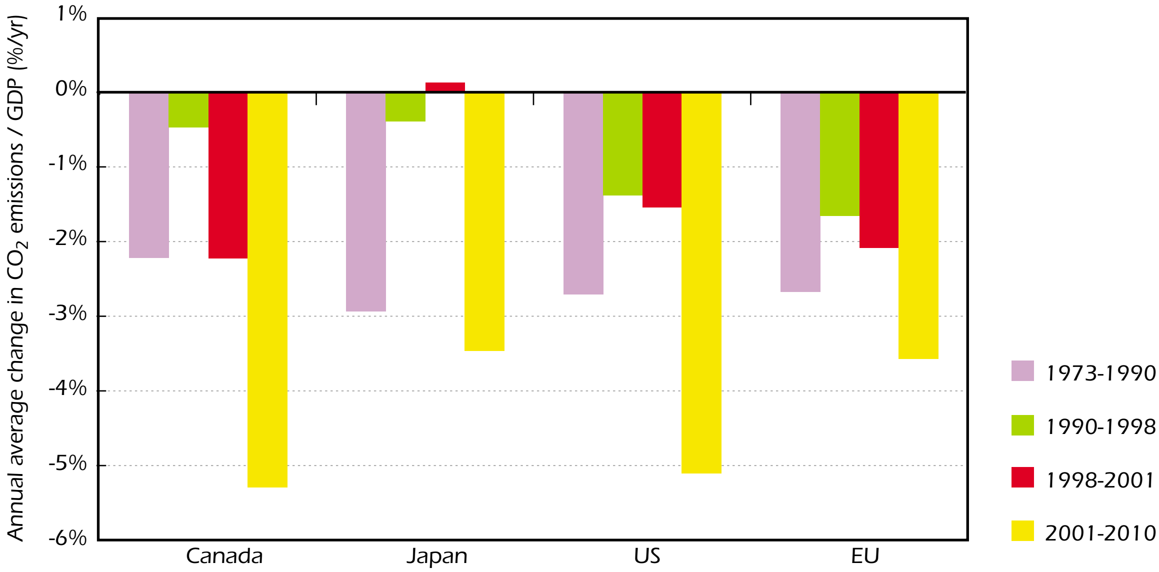
The developments during the 1990s paint a gloomy picture of the prospects of reducing CO_2 emissions to the levels called for by the Kyoto targets by 2010. With few exceptions, emissions will have to be reduced at significantly higher rates than have been seen in previous periods.

CO_2 Emissions/GDP and Kyoto Targets

Slowdown in the decline of CO_2 emissions per GDP since 1990 is in stark contrast to the reductions implied by the Kyoto targets

Figure 9-5

Average Annual Change in CO_2 Emissions per GDP, Historical and as Implied by the Kyoto Targets



Economic growth is the primary driver behind increases in energy-related CO_2 emissions. Figure 9-5 shows that CO_2 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 in part 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, CO_2 emissions per GDP actually increased between 1998 and 2001, although only very marginally.

The figure also illustrates what the annual average decline in CO_2 emissions per GDP would need to be if each country's Kyoto targets are to be met.[4] In all cases, CO_2 emissions will need to be decoupled at a much stronger pace than what is indicated by recent trends.

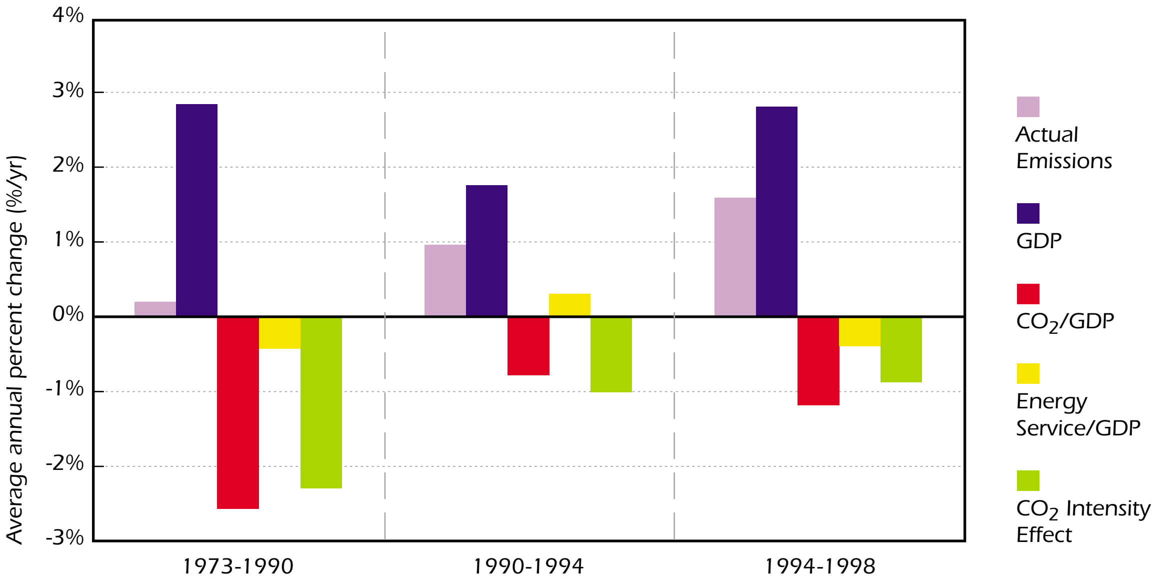
4. The GDP developments between 2001 and 2010 are based on assumptions made for the IEA World Energy Outlook 2002. *According to these, annual GDP growth will average 2.5% in the United States and Canada, 2.3% in the EU and 1.6% in Japan between 2000 and 2010.*

Factors behind Changes in CO_2 Emissions per GDP

CO_2 emissions are increasing as rates of decline in CO_2 intensity have slowed

Figure 9-6

Decomposition of Changes in CO_2 Emissions per GDP, IEA-11[5,6]



Why did the rate of decline in CO_2 emissions per GDP slow so markedly after 1990? To answer this, changes in CO_2 emissions per GDP are decomposed into changes in energy service levels per unit of GDP and changes in CO_2 intensities. This is analogous to the way energy per GDP developments were analysed in Chapter 3. Recall that the energy service effect is calculated from the activity and structure components in each sector and thus 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. The carbon intensity element combines the effects of changes in CO_2 emissions per unit of electricity or district heat produced (the utility CO_2 intensity), changes in end-use fuel mix and changes in sub-sectoral intensities, see Chapter 2.[7]

Thus changes in CO_2 emissions per GDP can be viewed as the product of changes in energy service demand per GDP and changes in CO_2 intensity. The results of this decomposition are shown in Figure 9-6 along with changes in actual CO_2 emissions and GDP. Between 1973 and

5. Figure 9-6 and all the remaining figures and tables in this chapter are based on data from the IEA Energy Indicator database. These data differ somewhat from data used for Table 9-1 and Figure 9-5, which are from IEA CO_2 Emissions from Fuel Combustion.

6. Space heating in households in this figure and in all the following figures and tables in this chapter is corrected for year-to-year variations in climate using the ratio of degree-days (DD) in a given year to the average 30-year DD number (see Chapter 5.)

7. The effect that changes in energy services and energy intensities have had on emissions may differ from the effect they have had on energy use since in the CO_2 decomposition these effects are weighted according to sector and sub-sectoral shares of CO_2 emissions and not shares of energy use.

1990 CO_2 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 CO_2 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 CO_2 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 is due both to energy service demand growing faster than GDP in this period and the slow rates of reduction in CO_2 intensity. After 1994 economic growth recovered, but still with a modest decline in CO_2 intensities. Even if decoupling of energy services from GDP helped to bring down CO_2 emissions per unit of GDP, this was by far not enough to offset the growth in GDP, with 1.6 % annual growth in emissions as a net result.

The slowdown in the decline of CO_2 intensities is apparent for most individual countries as well (Table 9-2). In all but Finland and the United Kingdom, the intensity fell less after 1990 than in previous periods. These two countries also saw CO_2 emission per unit of GDP decline more after 1990. The latter holds for Australia as well, despite no decline in CO_2 intensity after 1990. Hence the 1.3% per year drop in Australian CO_2 emissions per unit of GDP was caused by a considerable decoupling of energy service demand relative to GDP.

Table 9-2

Decomposition of Changes in CO_2 Emissions per GDP

Annual Average Percent Change (%/yr)

	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	-2.3	0.0	-2.2	-2.3	-0.7	-1.6
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	-4.4	-0.5	-4.0	-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[8]	-2.8	-0.1	-2.9	-2.0	-0.1	-1.9
IEA-11	-2.6	-0.4	-2.3	-1.0	0.0	-0.9

8. EU-7 includes the European Union countries: Denmark, Finland, France, Germany, Italy, Sweden and the United Kingdom, i.e., EUR-8 less Norway.

Factors behind Changes in CO_2 Emissions

Changes in the CO_2 intensity components since 1990 have not been enough, by far, to offset emission increases driven by growing energy service demand

Figure 9-7

Decomposition of Changes in CO_2 Emissions, IEA-11

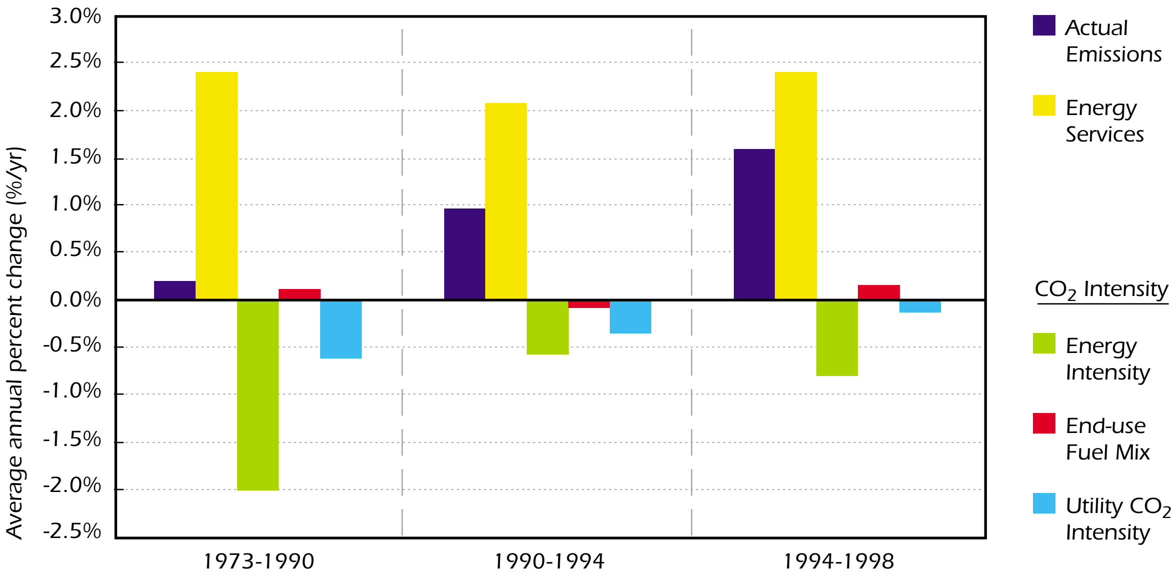


Figure 9-7 shows how the three components of the CO_2 intensity effect compare to the growth in energy service demand levels and how all four factors add up to changes in IEA-11 total CO_2 emissions. Increased demand for energy services has driven up emissions almost at the same rate over the three periods. Note from Figure 9-6 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 CO_2 intensity before 1990 was almost enough to offset growth in energy service demand. Roughly four-fifths of the decline in CO_2 intensity was caused by falling end-use energy intensities, with the rest being lower utility CO_2 intensity. 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 CO_2 intensive.

The slowing rate of decline in CO_2 intensity after 1990 came both as a result of lower energy saving rates and more modest reductions in the utility intensity. In sum, the restraining forces from reductions in the CO_2 intensity components by far were not enough 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 9-3). 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 CO_2 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 CO_2 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 as the nuclear expansion stagnated, while in others the sector contributed significantly to overall lower emissions. This was particularly the case in Denmark, Germany and the United Kingdom, where the increased use of natural gas at the expense of coal for electricity generation played an important role.

Table 9-3

Decomposition of Changes in CO_2 Emissions

Annual Average Percent Change (%/yr)

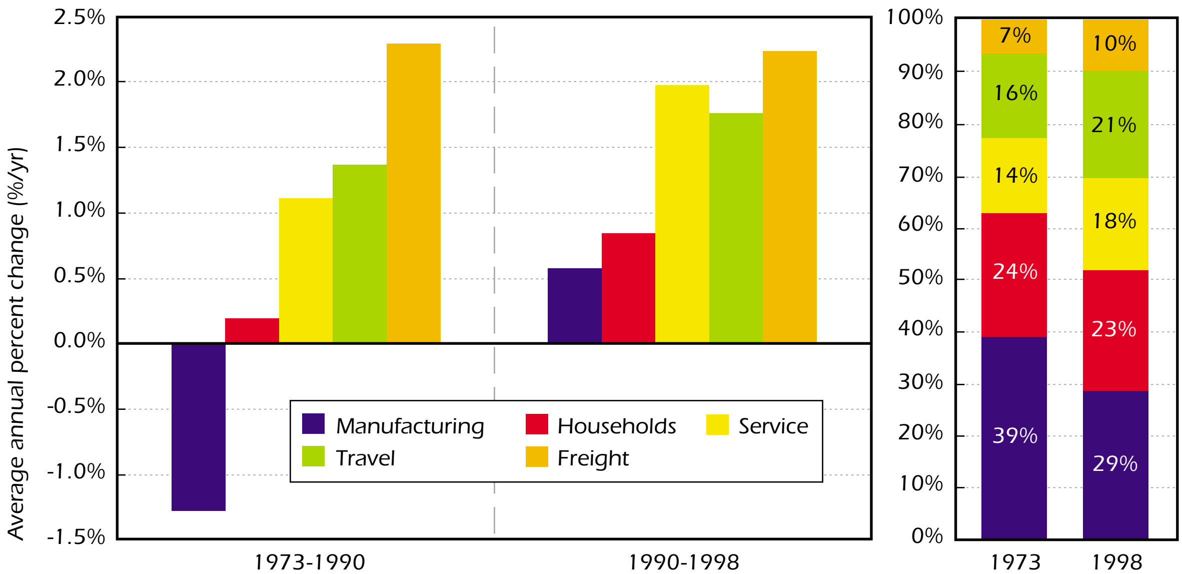
	1973-1990					1990-1998				
	Emissions	Energy Services	Energy Intensity	End-use Fuel Mix	Utility Intensity	Emissions	Energy Services	Energy Intensity	End-use Fuel Mix	Utility Intensity
Australia	2.5	3.2	-0.6	0.4	-0.4	2.4	2.4	-0.3	0.0	0.3
Denmark	-0.8	1.5	-2.2	0.5	-1.1	-0.1	1.5	-0.4	0.3	-1.3
Finland	1.4	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	-0.8	-2.0	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	-2.5	1.4	-1.4	-1.9	-1.2	-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	-1.8	0.2	-0.3	2.0	2.8	-1.0	0.1	0.1
EU-7	-0.5	2.2	-2.1	-0.1	-1.0	-0.4	1.5	-0.8	-0.2	-1.0
IEA-11	0.2	2.4	-2.0	0.1	-0.6	1.3	2.2	-0.7	0.0	-0.2

Changes in CO_2 Emissions by Sector

Emissions growth has accelerated since 1990 in all sectors

Figure 9-8

Changes in CO_2 Emissions by Sector and Emission Shares by Sector, IEA-11



Manufacturing was the only sector where CO_2 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 reduction 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 still the sector with the highest share of total IEA-11 emissions in 1998.

The household sector maintained its share of roughly a quarter 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 household 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 service demand pushed up emissions everywhere, but to a varying degree; and the decline in energy intensities helped to bring down emissions in most countries, but again with great variations from country to country.

The service sector's share of 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 the passenger transport 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, CO_2 emissions grew at a higher rate than in previous periods in all sectors, except freight where emissions kept growing at the same high average annual rate.

Manufacturing CO_2 Emissions per Value-added

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

Figure 9-9

CO_2 Emissions per Total Manufacturing Value-added

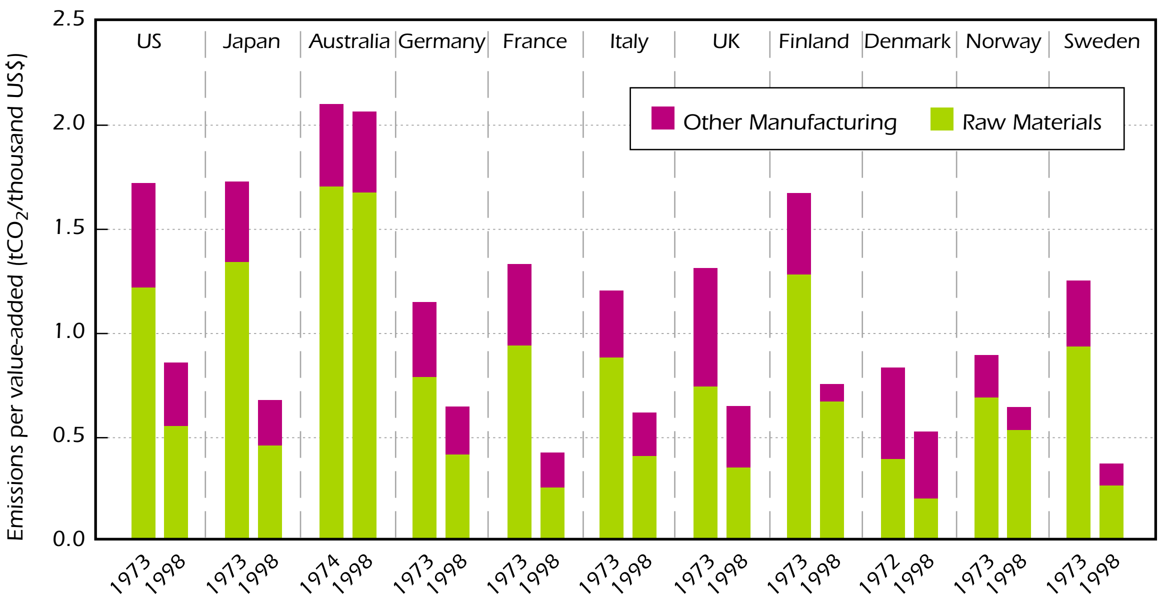


Figure 9-9 shows considerable variation in manufacturing sector CO_2 emission levels across countries. Interestingly, emission levels showed more variation among the extreme high and low in 1998 than in 1973. In 1973 there was a factor of 2.5 between Denmark at the low end and Australia at the high, 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 from manufacturing 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.

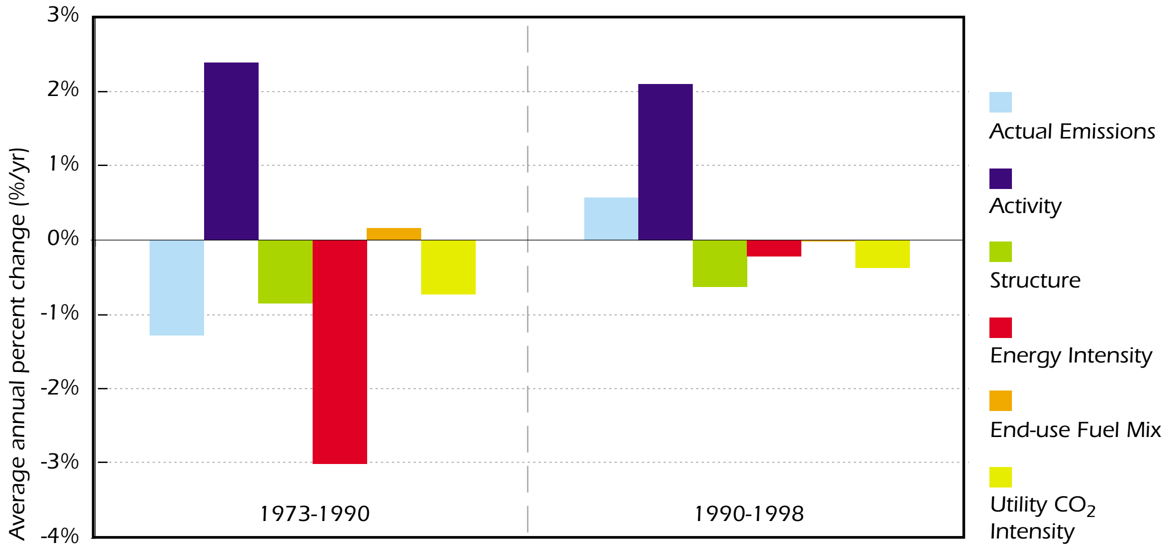
Why are there such big variations in emissions in both absolute levels and over time? First of all, differences in fuel mix play an important role. In some countries the manufacturing end-use fuel mix has a high share of coal, which results in higher CO_2 emissions levels than other fuels. Furthermore, CO_2 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.

Factors behind Changes in Manufacturing CO_2 Emissions

With reductions in energy intensities almost coming to a halt, manufacturing emissions have been growing since 1990

Figure 9-10

Decomposition of Changes in Manufacturing CO_2 Emissions, IEA-11



Despite output (value-added) growing at almost 2.5% per year on average, CO_2 emissions from manufacturing in the IEA-11 fell by more than 1% per year between 1973 and 1990. The main reason behind this dramatic de-carbonisation is the strong decline in energy intensities, which averaged 3% per year. But also a less energy-intensive (and CO_2-intensive) manufacturing structure and lower emissions from the utility sector contributed to lower emissions in this period. There was a very minor upward effect on emissions from a more carbon-intensive end-use fuel mix. In sum, the restraining forces - structure, energy intensity and utility CO_2 intensity - resulted in a dramatic decline in CO_2 emissions relative to value-added between 1973 and 1990.

After 1990 the picture looks very different. Value-added kept growing at almost the same rate, but this time with an increase in CO_2 emissions averaging about 0.5% per year. This resulted in a much more modest decline in emissions relative to value-added. The most important factor behind the decline was structural change and not reductions in energy intensities or utility sector emissions. In other words, the limited de-coupling of CO_2 emissions from manufacturing output came more as a result of the manufacturing product mix becoming less energy-intensive than as a result of improved energy efficiency or shifts towards lower-carbon fuels.

As indicated in Figure 9-9, manufacturing emissions per value-added fell in all countries between 1973 and 1990. The greatest drop occurred in Sweden, led by fuel switching at the end-use and utility levels and bolstered by lower energy intensities. Shifts in the end-use fuel mix were also the most important component behind CO_2 emission reductions in Finland and Norway. The shift in these three countries came as biomass and low-carbon electricity (especially in Norway and Sweden) increased their share in the manufacturing sector fuel mix. In all other countries, falling energy intensities had the largest downward effect on emissions (Table 9-4). Structural change reduced emissions further in all countries except Australia, Italy and Norway, although outside the United States and Japan, the impact was relatively minor. Changes in the utility CO_2 intensity also contributed to lower emissions as oil and coal were gradually replaced with natural gas, but the largest reductions occurred in Sweden and France where nuclear power became particularly prevalent. Changes in the end-use fuel mix had varied effects because some countries favoured coal as a substitute for oil, while for others gas was the favoured alternative.

Since 1990 the rate of decline in CO_2 emissions relative to value-added has slowed in all countries except Australia, Finland and the United Kingdom. The main reason is that energy intensities are falling less than in the previous period. They have even increased in a couple of cases. Fuel switching in both end-use and the utility sector has also contributed less to CO_2 emissions reductions since 1990 in most countries. Important exceptions are Denmark and the United Kingdom where a decline in coal use for power generation in the early 1990s helped drive down manufacturing CO_2 emissions.

Table 9-4

Decomposition of Changes in Manufacturing CO_2 Emissions

Annual Average Percent Change (%/yr)

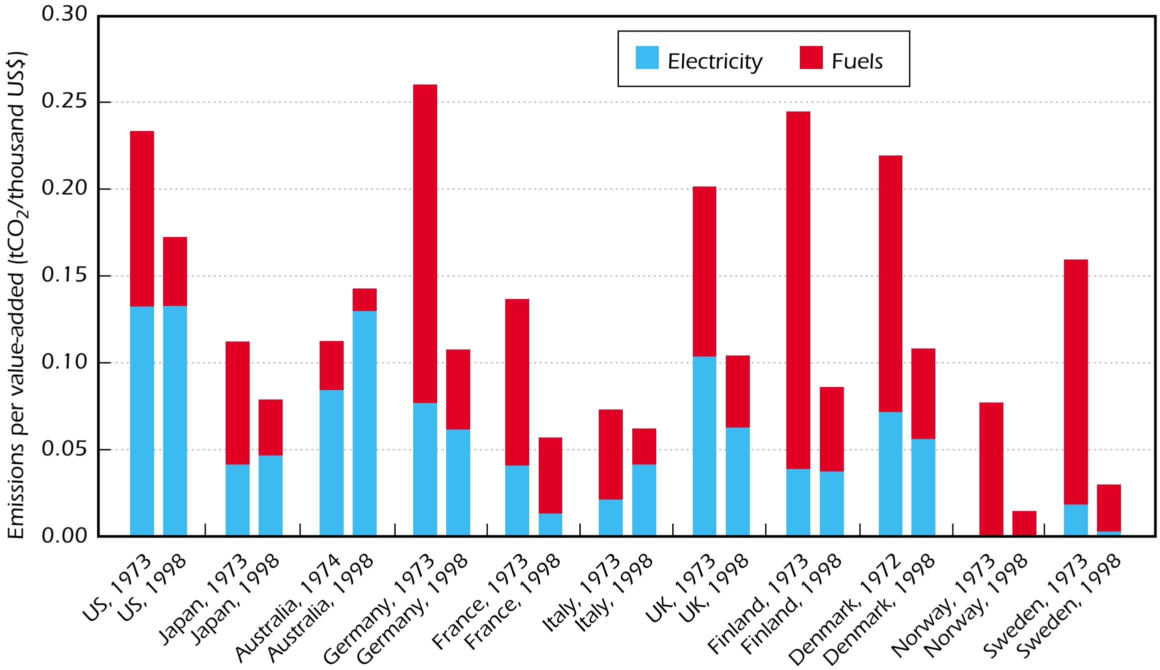
	Actual Emissions	Activity (Value-added)	Structure	Energy Intensity	End-Use Fuel Mix	Utility CO_2 Intensity
1973-1990						
Australia	1.5	1.5	1.0	-1.0	0.6	-0.4
Denmark	-1.3	1.3	-0.5	-2.8	1.0	-1.1
Finland	0.3	3.2	0.0	-0.4	-1.7	-1.1
France	-3.7	2.0	-0.2	-3.5	-0.8	-2.6
Germany	-1.8	1.4	-0.2	-2.4	0.4	-1.4
Italy	0.8	3.0	0.4	-4.1	0.3	0.9
Japan	-1.0	4.4	-0.8	-4.4	0.4	-1.0
Norway	-2.6	-0.3	1.0	-1.4	-2.4	0.0
Sweden	-4.4	1.4	-0.4	-2.0	-2.8	-1.9
UK	-2.3	0.3	-0.3	-2.8	0.8	-0.7
US	-1.1	2.3	-1.4	-2.1	0.1	-0.4
EU-7	-1.9	1.6	-0.2	-3.4	0.2	-1.1
IEA-11	-1.3	2.4	-0.8	-3.0	0.2	-0.7
1990-1998						
Australia	1.7	2.0	-0.8	0.1	0.1	0.3
Denmark	-0.3	1.5	0.5	0.0	0.2	-1.8
Finland	0.3	4.3	-0.3	-2.2	-1.2	-0.3
France	-0.5	1.8	-0.7	-0.3	-1.0	-0.2
Germany	-1.9	0.3	0.3	-1.2	-0.1	-1.2
Italy	-0.1	1.3	0.2	-1.0	0.2	-0.6
Japan	-0.4	0.3	-1.1	1.3	0.0	-0.5
Norway	1.7	2.1	-0.8	-0.6	0.7	0.0
Sweden	0.8	3.7	-1.1	-0.7	-0.2	-0.2
UK	-2.7	0.5	-0.3	-0.6	-0.1	-2.0
US	2.0	3.5	-0.8	-0.5	0.1	0.1
EU-7	-1.3	1.0	0.0	-0.9	-0.2	-1.1
IEA-11	0.6	2.1	-0.6	-0.2	0.0	-0.4

Service Sector CO_2 Emissions per Value-added

Relative to value-added, emissions from fuel use have fallen dramatically, while the results for emissions from electricity use are more mixed

Figure 9-11

Service Sector CO_2 Emissions per Value-added



The country variations in CO_2 emissions per value-added are even more dramatic in the service sector than seen for manufacturing. In 1998 the difference between the two extreme countries included in Figure 9-11 was more than a factor of 10. In Norway, at the low end, there are close to no emissions from power generation and with a very high share of electricity in the service sector fuel mix, the total emissions are very low. The United States, at the high end, also has a high share of electricity, but since the power sector is relatively CO_2 intensive this increases emissions relative to many other countries.

If only CO_2 emissions from direct end use of fuels are considered, levels differ a lot less. The differences reflect variations in: the shares of coal, gas and oil in the sector's fuel mix; building area per value-added; energy use per building area; and in climate since much of the fuel use in this sector is for space heating.

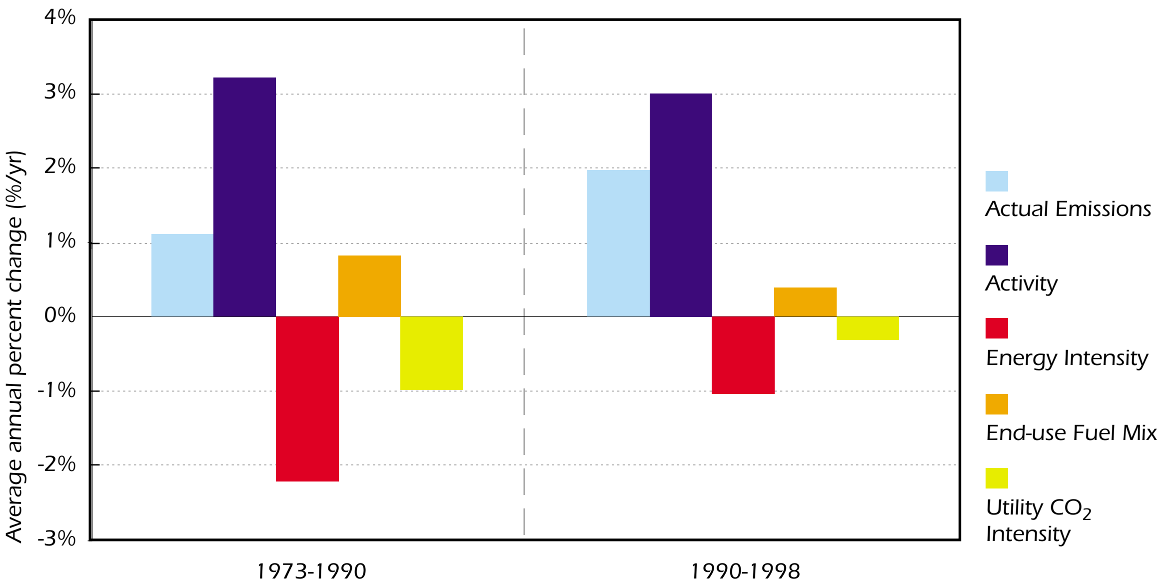
CO_2 emissions from direct fuel use per value-added went down considerably between 1973 and 1998 in all countries, both due to fuel switching and reduced energy intensities. However, the development of emissions from electricity use per value-added is more mixed. These variations can be explained by different developments of utility sector emissions and electricity end-use intensities.

Factors behind Changes in Service CO_2 Emissions

Emissions are on the rise as energy intensities slow

Figure 9-12

Decomposition of Changes in Service Sector CO_2 Emissions, IEA-11



CO_2 emissions from the service sector increased both before and after 1990, although at a lower rate than value-added grew. But while the average growth rate in value-added was more or less the same during the periods shown in Figure 9-12, the rate of increase in emissions almost doubled from the 1973-1990 to the 1990-1998 period.

The main reason is that the rate at which energy intensity fell was much lower after 1990 then before.[9] Reduced utility CO_2 intensity helped to slow the emissions increase in both periods, but less so after 1990. On the other hand, the increasing share of electricity in the end-use fuel mix inserted an upward pressure on IEA-11 emissions more or less offsetting the downward utility intensity effect in both periods.

CO_2 intensity (the combined effect of changes in energy intensities, end-use fuel mix and utility intensity) fell in all countries between 1973 and 1990, except Australia where it rose primarily because of the increased share of high carbon electricity in the fuel mix. In fact, electricity steadily gained share in the end-use fuel mix of all countries, and while this helped countries with low-carbon electricity to reduce emissions, it drove up emissions in countries like Australia.

9. Note that the service sector is not further disaggregated into end uses or sub-sectors and thus the aggregate energy per value-added ratio represents the energy intensity effect. For the same reason, structural changes are not defined for the decomposition analysis of this sector.

Since 1990 CO_2 emission declines relative to value-added have slowed in most countries, primarly due to slower falls in energy intensities (Table 9-5). As in the period before 1990, increasing electricity demand pushed up emissions in some countries and reduced them in others, depending on the carbon intensity of the electricity production. Utility CO_2 intensity, however, did continue to decrease in most countries, easing what otherwise would have been an even stronger increase in the services sector CO_2 emissions.

Table 9-5

Decomposition of Changes in Service Sector CO_2 Emissions

Annual Average Percent Change (%/yr)

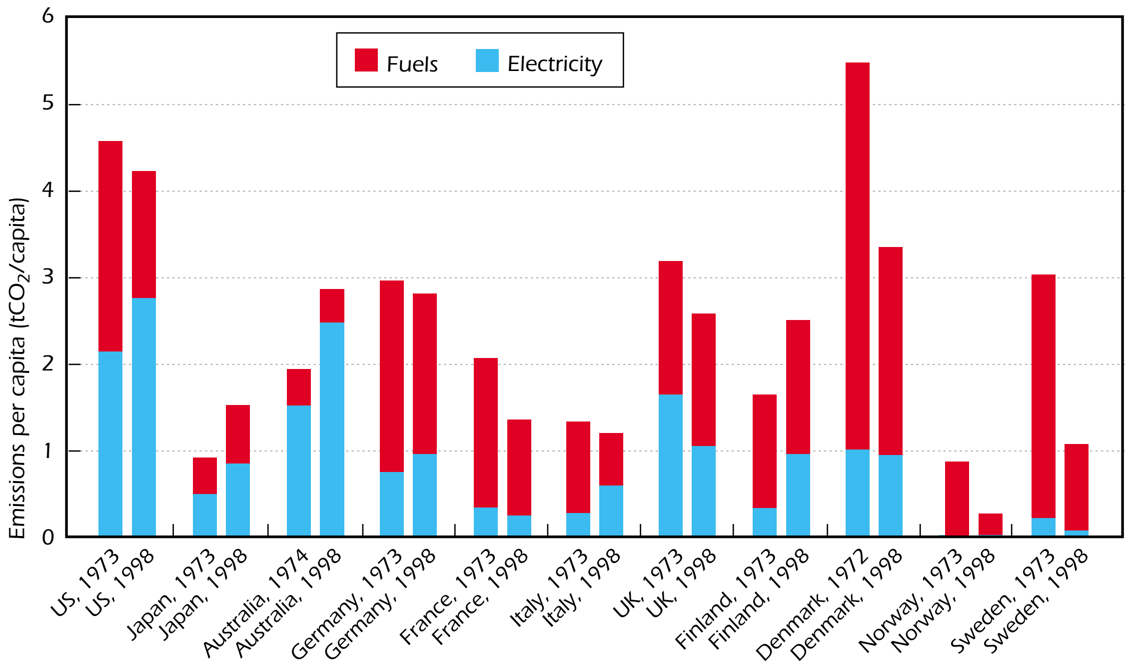
	Actual Emissions	Activity	Energy Intensity	End-use Fuel Mix	Utility Fuel Mix
			1973-1990		
Australia	4.7	3.6	0.3	1.4	-0.7
Denmark	-0.5	2.2	-2.8	1.3	-1.6
Finland	0.5	3.6	-3.2	0.5	-0.2
France	-0.6	3.6	-1.4	-1.1	-3.6
Germany	-1.5	3.3	-4.0	0.5	-2.2
Italy	1.8	3.3	-2.7	1.1	0.4
Japan	2.4	4.4	-1.8	0.7	-1.4
Norway	-4.8	3.2	0.0	-7.3	-0.2
Sweden	-3.4	2.5	-2.5	-2.8	-2.0
UK	0.5	2.4	-1.7	0.5	-0.9
US	1.6	3.1	-2.1	1.1	-0.6
EU-7	-0.5	3.0	-2.8	0.2	-1.8
IEA-11	1.1	3.2	-2.2	0.8	-1.0
			1990-1998		
Australia	4.9	4.0	-0.1	0.4	0.5
Denmark	-0.9	1.9	-1.1	0.7	-2.2
Finland	-5.4	1.1	-4.5	-0.8	-0.8
France	-0.7	1.4	-0.8	-0.9	-0.3
Germany	0.1	3.1	-1.9	0.0	-1.2
Italy	2.5	1.6	1.8	0.1	-0.9
Japan	2.4	2.8	0.2	0.3	-0.8
Norway	0.6	3.9	-2.1	-1.9	0.3
Sweden	-6.6	1.3	-1.6	-0.9	-3.6
UK	-1.3	2.9	-1.5	0.3	-2.7
US	2.6	3.2	-1.3	0.6	0.2
EU-7	-0.4	2.5	-1.1	-0.1	-1.5
IEA-11	2.0	3.0	-1.0	0.4	-0.3

Household CO_2 Emissions per Capita

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

Figure 9-13

Residential CO_2 Emissions per Capita*



* District heat is included with fuels in this figure.

CO_2 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 CO_2 emissions from residential electricity use within the IEA-11.

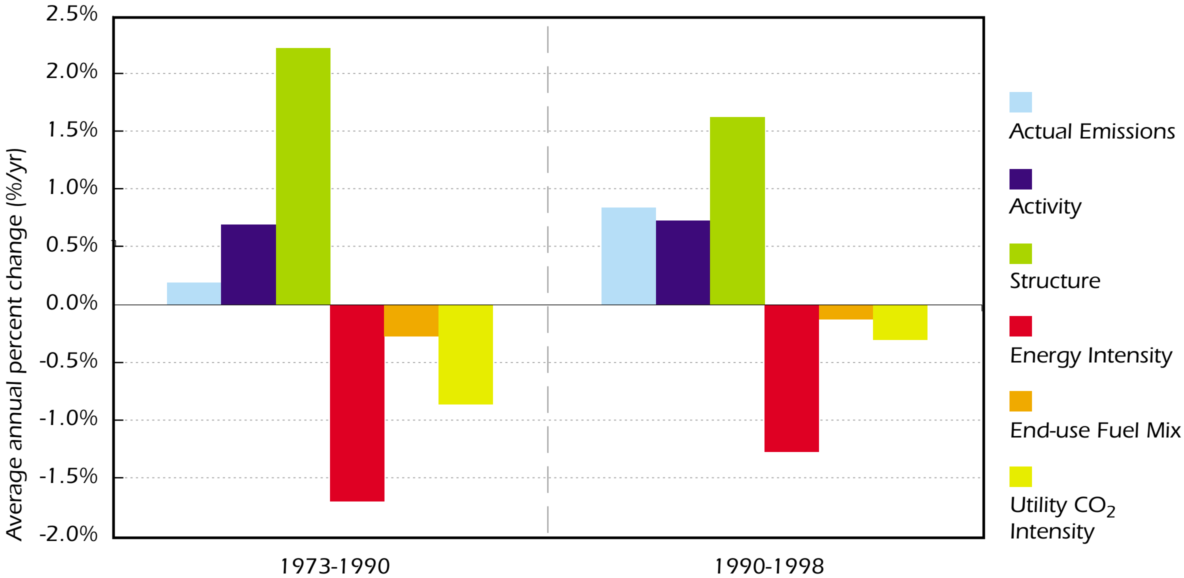
Most of the fuel use in households is for space heating. So countries with relatively cold climates and a low share of electricity in the space heating mix can be expected to have high CO_2 emission levels from fuels. Countries such as Germany, the United Kingdom and Denmark fall into this category. 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 CO_2 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.

Factors behind Changes in Household CO_2 Emissions

Moderate acceleration of IEA-11 *emissions, but large variations in trends across countries*

Figure 9-14

Decomposition of Changes in Residential CO_2 Emissions, IEA-11



For IEA-11 as a whole, household emissions grew at an average rate of 0.2% per year between 1973 and 1990, which was about half a percentage point lower than population growth ("Activity" in Figure 9-14). Consequently IEA-11 per capita CO_2 emissions in the household sector did decline somewhat.

The most important driving factor behind the growth in emissions is the structural component of residential energy use. This represents growing demand for energy services due to larger dwelling area, fewer persons per dwelling, and increased ownership of electric appliances. This factor drove up emissions at an average rate of 2.2 % per year between 1973 and 1990. Together with population growth, this led to an upward force on emissions of 3% per year. Conversely, significant declines in energy intensities and utility CO_2 intensity, augmented by a somewhat less carbon intensive end-use fuel mix, lowered overall CO_2 intensity by about 2.8% per year. However, this was insufficient to restrain emissions from growing.

After 1990 emissions from IEA-11 households grew at an average rate of 0.8% per year, just above the population growth. The higher growth rate in emissions compared to the 1973-1990 period came despite lower growth in the structure component, indicating that the decline in CO_2 intensity slowed compared to the previous period. In fact, each of the three factors affecting this intensity reduced emissions less after 1990 than before.

Looking at trends in individual IEA-11 countries shows that household CO_2 emissions increased in five countries before 1990 and in six after 1990. The wide variations are to some extent a result of differences in utility CO_2 intensity. While countries that had carbon-intensive electricity production in 1973 also had the greatest potential for reducing utility sector emissions, the increasing share of electricity in the end-use fuel mix would often increase emissions as long as the CO_2 co-efficient for electricity remained higher than for fuels combusted at the end-use level. On the other hand, Norway, which had the strongest relative reduction in household emissions in both periods, saw emissions decline mostly as a result of the increasing share of near zero-carbon electricity. It should be noted, though, that measured in absolute values the reductions are very small since Norway in 1973 already had very low emissions from residential energy use. In many countries the gradual substitution of oil, and in some cases coal, by natural gas in the end-use fuel mix more than offset the effect of increased use of high-carbon electricity, which is why the end-use fuel mix component did not raise emissions much in any country.

Table 9-6

Decomposition of Changes in Residential CO_2 Emissions

Annual Average Percent Change (%/yr)

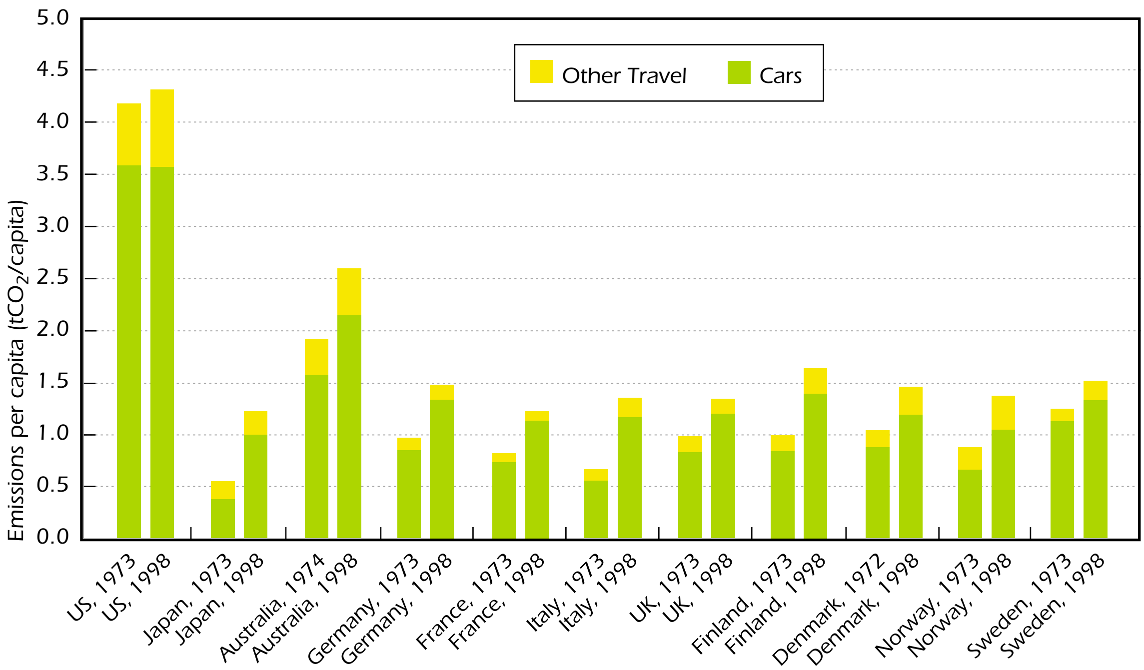
	Actual Emissions	Activity	Structure	Energy Intensity	End-Use Fuel Mix	Utility Fuel Mix
			1973-1990			
Australia	3.1	1.4	2.2	0.4	-0.1	-0.7
Denmark	-2.1	0.2	1.7	-3.2	0.2	-1.4
Finland	2.5	0.4	2.5	-2.2	1.4	-0.9
France	-1.8	0.5	2.0	-1.1	-2.0	-3.1
Germany	-0.8	0.0	2.8	-2.2	-0.4	-1.6
Italy	0.8	0.2	2.7	-1.5	-0.2	0.3
Japan	3.1	0.8	2.8	1.6	0.2	-1.4
Norway	-3.8	0.4	2.1	-0.3	-5.8	-0.1
Sweden	-3.8	0.3	1.4	-2.3	-2.8	-1.5
UK	-0.6	0.1	1.9	-0.9	-1.1	-0.7
US	0.3	1.0	2.1	-2.2	0.0	-0.5
EU-7	-0.8	0.2	2.3	-1.7	-0.8	-1.3
IEA-11	0.2	0.7	2.2	-1.7	-0.3	-0.9
			1990-1998			
Australia	2.7	1.2	1.5	-0.8	-0.2	0.5
Denmark	-0.7	0.4	0.8	-0.5	0.2	-1.4
Finland	1.2	0.4	1.2	0.9	-0.3	-0.9
France	0.1	0.4	1.4	-1.2	-0.1	-0.3
Germany	0.2	0.4	1.6	0.0	-1.3	-0.8
Italy	-2.2	0.2	1.6	-2.6	-0.4	-0.6
Japan	1.7	0.3	2.9	-0.1	0.1	-0.8
Norway	-5.2	0.6	1.6	-2.4	-5.2	0.2
Sweden	-3.8	0.4	-0.2	0.0	0.1	-3.0
UK	-0.9	0.2	1.2	-0.3	0.0	-2.0
US	1.4	1.0	1.5	-1.9	0.1	0.2
EU-7	-0.6	0.3	1.4	-0.6	-0.5	-1.1
IEA-11	0.8	0.7	1.6	-1.3	-0.1	-0.3

Passenger Transport CO_2 Emissions per Capita

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

Figure 9-15

Passenger Transport CO_2 Emissions per Capita



The United States has by far the highest per capita CO_2 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 CO_2 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.

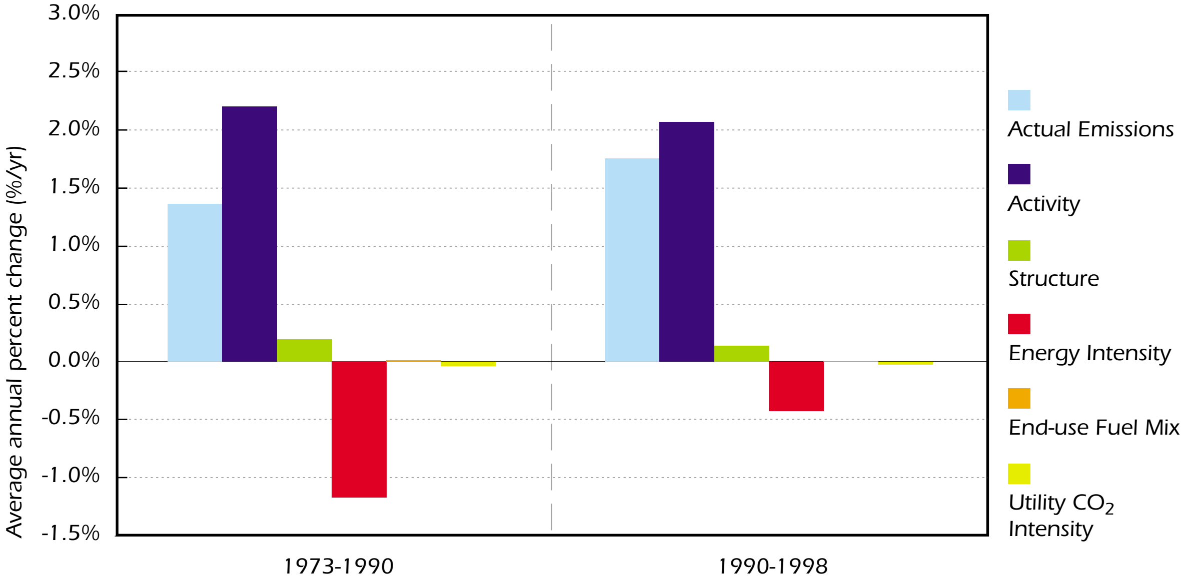
Per capita fuel use, and thus CO_2 emissions, varied much less in 1998 than in 1973. In fact, among the European countries and Japan, per capita emissions levels from both total travel and from cars are surprisingly similar. Compared to the United States levels, big differences remain, although much less than in 1973. Comparing 1973 car CO_2 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.

Factors behind Changes in Passenger Transport CO_2 Emissions

Emissions are increasing as fuel intensity reductions are lagging growth in travel activity

Figure 9-16

Decomposition of Changes in Passenger Transport CO_2 Emissions, IEA-11



The average growth rate in CO_2 emissions from IEA-11 passenger travel has accelerated slightly over the 1990-1998 period compared to the growth rate between 1973 and 1990, even though travel activity growth was more or less the same in the two periods. The stronger growth in CO_2 emissions is clearly a result of less reduction in fuel intensities in the IEA-11 travel modes. While the impact from intensity declines averaged a 1.2% per year reduction before 1990, the intensity impact only reduced emissions by 0.4% per year after 1990. The shifts in the modal structure towards more air and car travel raised CO_2 emissions somewhat in both periods. Given that petroleum products have dominated the fuel share in all countries, the effect on emissions from fuel switching and changes in the utility component were close to zero.

Among the IEA-11 countries, only the United States showed a major reduction in energy intensity before 1990. By 1990, falling energy intensities alone had reduced United States travel CO_2 emissions by 25%. The other countries saw either a modest decrease or increase in intensities over this period. After 1990, the United States travel intensity decline slowed as the fall in car intensity came to an end, while in most European countries the energy intensity declines accelerated somewhat. Note that after 1990 the intensity in Japan showed a significant increase as Japanese cars grew larger and more powerful, which led to a strong increase in emissions from passenger travel in Japan.

In almost all countries, modal shifts toward cars and air travel raised CO_2 emissions in both periods, boosting the impact on emissions from growth in travel activity. It is not surprising that changes in end-use fuel mix had almost no effect since fuel switching in passenger transport is almost entirely among petroleum products with little variation in carbon content. In countries where electric rail travel is significant, there has been a modest impact from reduced utility CO_2 intensity.

Table 9-7

Decomposition of Changes in Passenger Transport CO_2 Emissions

Annual Average Percent Change (%/yr)

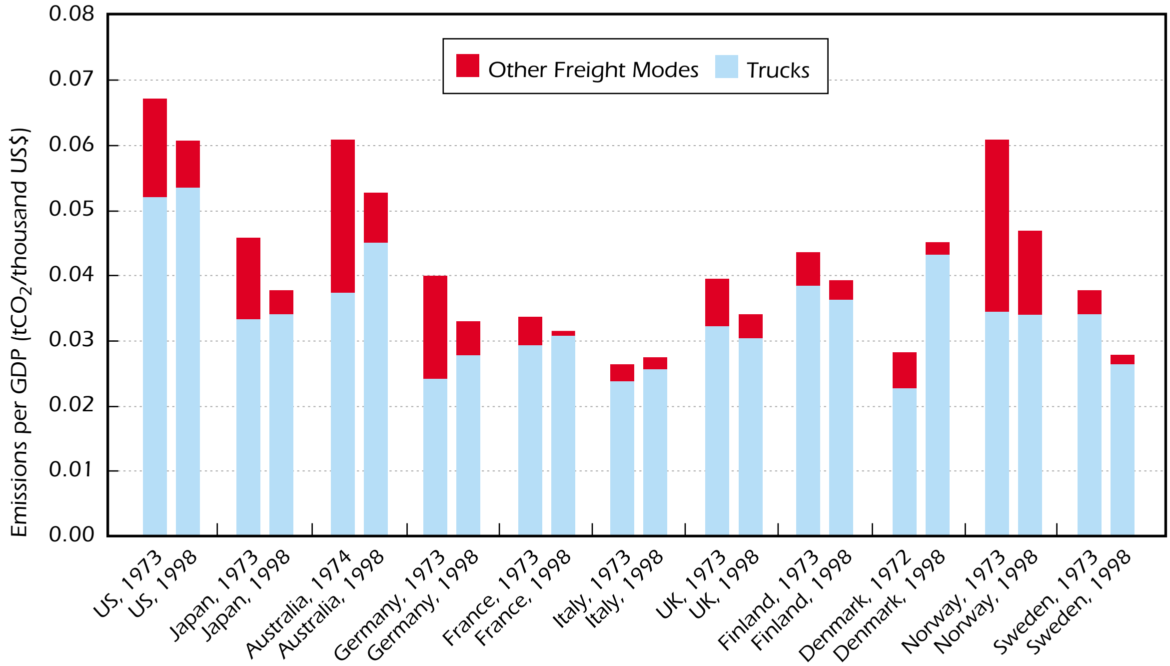
	Actual Emissions	Activity	Structure	Energy Intensity	End-use Fuel Mix	Utility CO_2 Intensity
			1973-1990			
Australia	2.9	3.3	-0.1	-0.2	0.0	0.0
Denmark	1.5	1.5	-0.1	0.1	0.1	0.0
Finland	3.9	2.8	0.2	0.7	0.0	0.0
France	2.5	2.5	0.1	-0.1	0.1	-0.2
Germany	2.9	2.1	0.3	0.5	0.0	-0.1
Italy	3.3	3.4	0.1	-0.5	0.0	0.0
Japan	3.8	2.8	1.3	-0.5	0.0	-0.2
Norway	3.2	2.9	0.3	-0.2	0.0	0.0
Sweden	1.6	1.3	0.0	0.2	0.0	-0.1
UK	2.2	2.5	0.2	-0.7	0.0	-0.1
US	0.7	2.0	0.1	-1.6	0.0	0.0
EU-7	2.7	2.5	0.2	-0.1	0.0	-0.1
IEA-11	1.4	2.2	0.2	-1.2	0.0	0.0
			1990-1998			
Australia	1.9	2.1	0.8	-0.5	0.0	0.0
Denmark	2.0	1.9	0.0	0.1	0.1	-0.1
Finland	-0.8	0.3	0.2	-1.2	0.0	0.0
France	1.3	1.6	0.2	-0.6	0.2	0.0
Germany	-0.5	0.4	0.1	-0.8	0.0	-0.1
Italy	2.8	2.5	0.3	0.1	-0.1	0.0
Japan	4.4	1.7	1.0	1.7	-0.1	-0.1
Norway	0.4	1.4	0.3	-1.2	0.0	0.0
Sweden	0.1	-0.4	-0.1	0.6	0.0	0.0
UK	-0.1	0.5	0.0	-0.8	0.1	-0.1
US	1.9	2.5	0.0	-0.6	0.0	0.0
EU-7	0.6	1.0	0.1	-0.6	0.0	-0.1
IEA-11	1.8	2.1	0.1	-0.4	0.0	0.0

Freight CO_2 Emissions per GDP

Freight CO_2 emission levels have more or less followed GDP growth

Figure 9-17

Freight CO_2 Emissions per GDP



CO_2 emissions from trucks dominate freight emissions per GDP in all countries. Emissions from other modes (domestic water and rail) have declined everywhere since 1973 and are in some countries almost negligible compared to truck emissions. This reflects both the increasing share of trucks in total freight transport and the much lower energy and CO_2 emission intensities for water and rail haulage.

Freight emissions per GDP vary considerably across countries, but they are not as dramatic as seen for passenger transport emissions per capita. In both 1973 and 1998, freight CO_2 emissions were the highest in the United States, closely followed by Australia and Norway, in each case primarily a result of long haulage distances. In Norway much of the domestic haulage is with ships, which explains the high emissions from non-trucking modes.

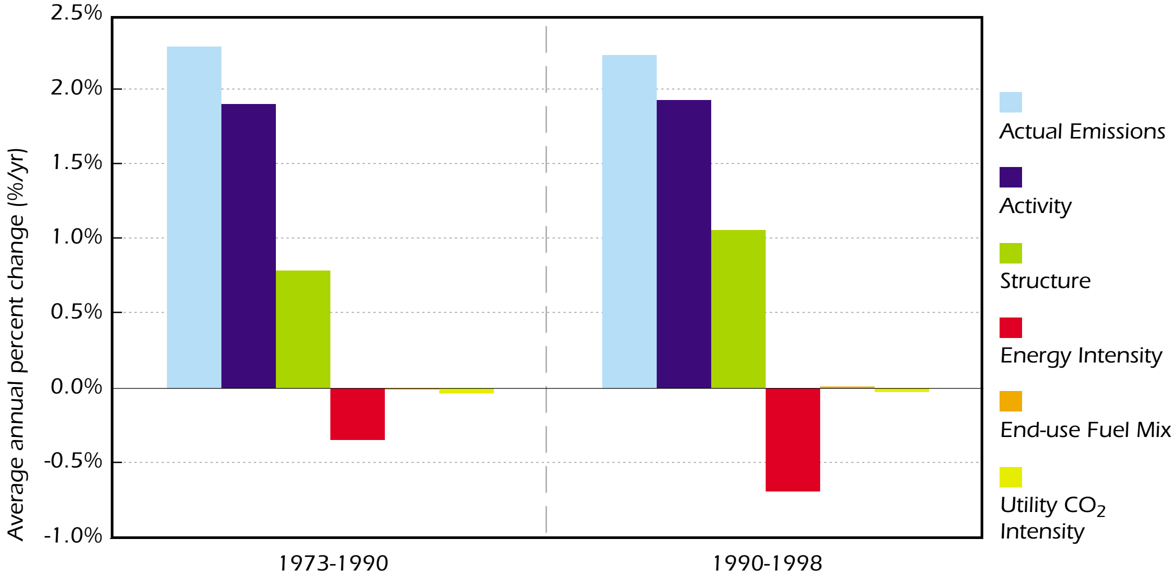
In almost all countries, CO_2 emissions from trucks per unit of GDP were about the same in 1998 as in 1973, i.e., no significant decoupling of trucking fuel use from GDP growth. This happened as trucking activity more or less has followed GDP developments, while trucking intensities declined little over the 1973 to 1998 period.

Factors behind Changes in Freight Transport CO_2 Emissions

Strong and steady growth in emissions, although the fuel intensity decline has slowly started to accelerate since 1990

Figure 9-18

Decomposition of Changes in Freight CO_2 Emissions, IEA-11



Freight showed the highest relative growth in emissions of all sectors in the IEA-11. Between 1973 and 1990, freight CO_2 emissions increased at an average annual rate of 2.3%. This is more than the 1.9% annual growth in activity (tonne-km), which means that CO_2 emissions per unit of activity increased in this period. This development is affected by the modal structure becoming more fuel and CO_2 intensive as the share of trucking increased. This effect alone pushed up emissions by 0.8% per year. Corrected for this structural change, the decline in modal intensities only reduced emissions by a modest 0.3% per year over the period.

After 1990 both emissions and freight activity kept growing at the previous rate. Trucking gained even more share of total haulage than between 1973 and 1990, but the impact this had on CO_2 emissions was balanced out by a somewhat stronger decline in fuel intensity. Still the intensity reduction is very modest compared to the levels that would be needed to significantly reduce growth in freight CO_2 emissions.

Table 9-8 shows that freight CO_2 emissions increased in all countries before 1990, and in almost all countries after. In many cases CO_2 emissions increased more than increases in freight activity. This happened as modest declines in fuel intensities were not enough to offset the upward pressure on emissions from the increasing share of trucking in the haulage mix.

Table 9-8

Decomposition of Changes in Freight CO_2 Emissions

Annual Average Percent Change (%/yr)

	Actual Emissions	Activity	Structure	Energy Intensity	End-use Fuel Mix	Utility Fuel Mix
			1973-1990			
Australia	2.8	2.3	2.9	-2.2	0.0	0.0
Denmark	5.0	0.5	0.4	4.1	0.0	0.0
Finland	1.9	1.7	0.5	-0.3	0.0	0.0
France	2.0	0.5	1.3	0.5	0.1	-0.2
Germany	0.2	1.9	0.6	-1.9	-0.1	-0.3
Italy	3.9	3.6	0.7	-0.6	0.0	0.0
Japan	2.6	1.7	1.8	-0.6	0.0	0.0
Norway	1.9	0.6	1.2	-0.1	0.0	0.0
Sweden	2.0	1.0	0.4	0.7	0.1	-0.1
UK	1.6	2.4	0.1	-1.0	0.0	0.0
US	2.4	1.9	0.5	0.0	0.0	0.0
EU-7	1.8	1.9	0.6	-0.7	0.0	-0.1
IEA-11	2.3	1.9	0.8	-0.3	0.0	0.0
			1990-1998			
Australia	2.2	4.0	-0.1	-1.6	0.0	0.0
Denmark	0.6	0.8	-0.1	-0.1	0.0	0.0
Finland	2.3	-0.1	-0.3	2.8	0.0	0.0
France	1.8	2.0	0.5	-0.7	0.1	0.0
Germany	3.2	2.4	0.6	0.4	-0.1	-0.3
Italy	-0.6	1.3	-0.3	-1.5	0.0	0.0
Japan	1.3	0.1	0.9	0.3	0.0	0.0
Norway	3.6	4.0	0.7	-1.2	0.1	0.0
Sweden	-2.5	1.4	1.2	-4.6	-0.2	0.0
UK	1.2	1.5	0.3	-0.7	0.1	0.0
US	2.8	2.3	1.5	-0.9	0.0	0.0
EU-7	1.4	1.8	0.3	-0.6	0.0	-0.1
IEA-11	2.2	1.9	1.1	-0.7	0.0	0.0

Reduced Emissions from CO_2 Intensity Declines

Absent the reductions in CO_2 intensities since 1973, emissions in 1998 would have been 60% higher

Figure 9-19

Actual CO_2 Emissions versus Emissions without CO_2 Intensity Reductions, IEA-11

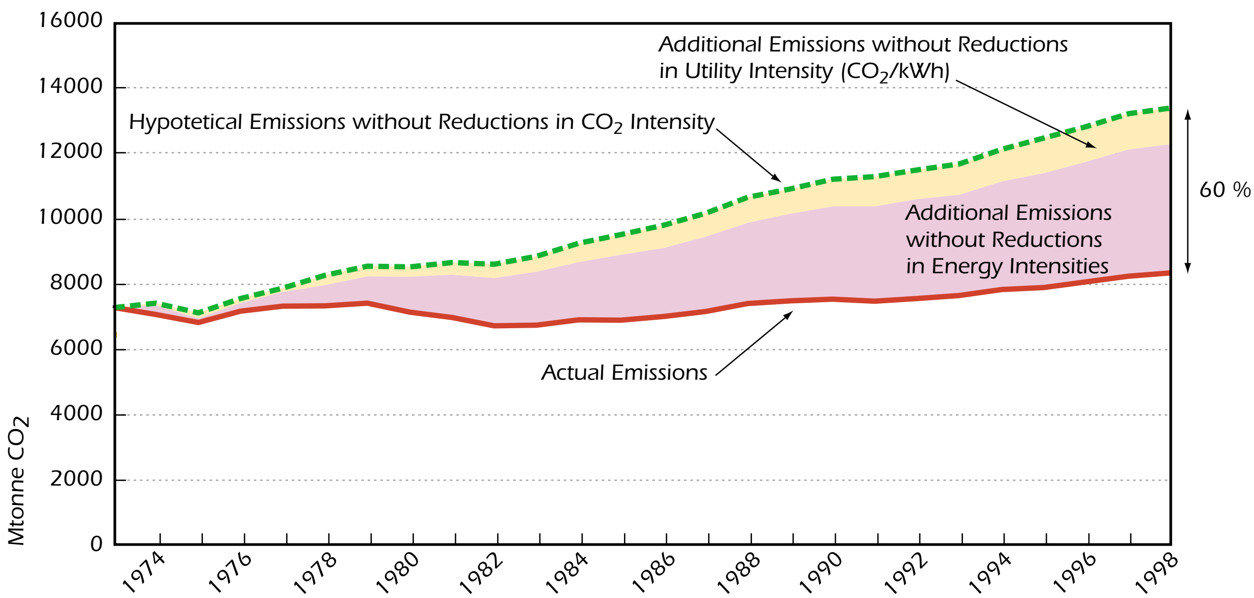


Figure 9-19 compares the development of actual CO_2 emissions for the IEA-11 with a hypothetical case where CO_2 intensities remained at 1973 levels until 1998. The difference between the upper line (hypothetical emissions) and the lower line (actual emissions) represents the avoided emissions due to decline in CO_2 intensity. The calculation is analogous to the way energy savings are calculated (see equation 5 in Chapter 2 and Chapter 3, Figure 3-16). The contributions to the avoided emissions are shown separately for the utility CO_2 intensity effect and the energy intensity effect. The third component affecting CO_2 intensity, end-use fuel mix, changed very little for the IEA-11 group between 1973 and 1998 (see Figure 9-7) and is thus not included in Figure 9-19.

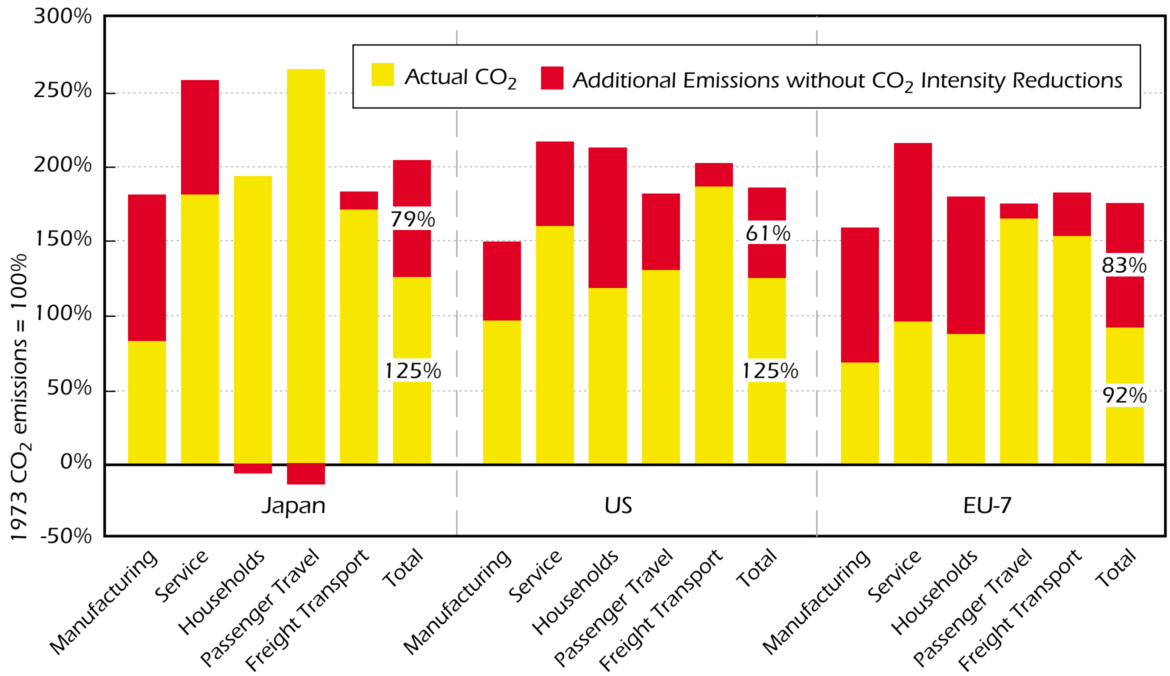
By 1998 the total avoided emissions amounted to about 5000 Mtonnes of CO_2, which corresponds to 60% of IEA-11 actual emissions in 1998. Thus emissions in 1998 would have been 60% higher if CO_2 intensities had remained as in 1973. Roughly a quarter of the reductions by 1998 were due to the decline in the utility CO_2 intensity, since emissions per kWh of electricity and district heat generated fell due to both a lower-carbon fuel mix and higher generation efficiency.

Actual and Reduced Emissions from CO_2 Intensity Declines

Total impact from reduced CO_2 intensities is similar across the three regions, but important differences at sector levels

Figure 9-20

Actual CO_2 Emissions versus Emissions without CO_2 Intensity Reductions, 1998



The decline in CO_2 intensities led to considerable emissions reductions in all countries. In Figure 9-20, the top of the stacked bars illustrates the 1998 emissions levels that would have been seen in Japan, the United States and the in EU-7 if CO_2 intensities had remained at 1973-levels. The lower part of the bars shows the actual level of emissions in 1998. The upper part indicates reductions from the decline in CO_2 intensities from 1973 to 1998. As a percentage of 1973 emissions the total reductions by 1998 amounted to 79% in Japan, 61% in the United States and 83% in EU-7.

In 1998 CO_2 emissions in Japan were up 25% from the 1973 level, but would have been more than a factor-two higher if CO_2 intensities had not declined. Actual emissions in the United States also grew by 25% from 1973 levels, which compares to a 186% increase if CO_2 intensities had not declined since 1973. The EU-7 emissions fell between 1973 and 1998, but emissions would have grown 75% if CO_2 intensities had not declined.

Without the decline in CO_2 intensities, emissions in 1998 would have been 63% higher in Japan, 49% higher in the United States and 90% higher for the EU-7 countries. This compares to the 60% higher emissions would have been for the whole IEA-11 group without declines in CO_2 intensities (Figure 9-19).

There are significant differences among the three regions in terms of how much emissions fell in each sector. In Japan, the manufacturing sector, followed by the service sector led the reductions, with only by modest reduction in the freight sector. CO_2 intensity actually increased in passenger transport and households, reflecting that in 1973 Japanese cars were very small and indoor heating comfort low. In the EU-7 the service sector had the strongest CO_2 intensity decline, followed by households and manufacturing. There were also modest reductions from transport, particularly from freight transport. The United States saw the strongest relative reductions from the household sector. Compared to the EU-7 and Japan, the relative reductions from manufacturing and service sectors in the United States were more modest. On the other hand, the United States had more significant CO_2 emission reductions from passenger travel, in this case a result of very heavy and fuel intensive cars in the early 1970s compared to Europe and Japan.

Chapter 10. CONCLUSIONS AND IMPLICATIONS FOR THE FUTURE

One of the most important findings from this study is that the rate of energy savings in IEA Member country economies has slowed since 1990, as has the decline in CO_2 emissions relative to GDP. This shows that the changes caused by the oil price shocks in the 1970s and the resulting energy policies did considerably more to control growth in energy demand and reduce CO_2 emissions than the energy efficiency and climate policies implemented in the 1990s.

The slowing rates of energy savings pose a concern from both an environment and an energy security perspective. The two most significant energy carriers in the IEA countries' end-use fuel mix, oil and electricity, are also the two fastest growing. Oil consumption is driven by rapid growth in transport demand, while the increasing ownership and use of various electric appliances and equipment in household and service sector buildings is propelling demand for electricity. In the short to medium term, transport is likely to remain almost entirely dependent on oil. Although renewables have started to make in-roads for electricity generation, increased electricity demand over the next few years in many IEA countries will be met to a large extent by new coal or gas-based power plants. With the considerable conversion losses in electricity generation and the low probability that CO_2 capture and storage from these plants will be widespread in the near term, the increased electricity demand will significantly add to the burden of controlling CO_2 emissions in IEA countries.

The question is then, what growth in energy service demand can be expected in the various sectors and what prospects are there to again accelerate energy savings?

Manufacturing

Manufacturing sub-sectoral energy intensities declined significantly until the last half of the 1980s. This development was augmented in most IEA countries by a shift to a less energy-intensive manufacturing structure. Thus, a considerable decoupling of energy use from overall manufacturing output took place. However, since then, the fall in sub-sectoral energy intensities has almost come to a halt. Although continued structural changes helped restrain energy demand, it was not enough to hinder solid growth in manufacturing energy use. Whether such structural changes are going to continue to moderate growth in manufacturing energy use is difficult to say. However, if manufacturing is to return to the situation of the 1970s and 1980s when energy per output fell enough to avoid growth in manufacturing energy use, improvements of energy efficiency need to be resumed.

Households

Space heating is the most significant residential energy end use in almost all IEA countries. Bigger houses and fewer people per dwelling have put upward pressure on space heating demand in all countries. Until 1990, the effect of this pressure was more than offset by significant reductions in the amount of heat used per floor area. After 1990, intensity reductions have been modest, with the result that space heating demand has grown in most countries. This trend is likely to continue unless growth in house area per capita starts to saturate and/or reductions in space heating intensities are picked up again.

Growth in the ownership and use of electric appliances has driven much of the increase in residential electricity remand. Traditional "big appliances", such as dishwashers and refrigerators, dominated the growth up to the early 1980s. Since then, their role in stimulating demand has been less important due to both saturation effects and improved appliance efficiencies. On the other hand, the use of "miscellaneous" appliances - from home electronics and office equipment to small kitchen appliances - is growing strongly. To what extent this growth will continue and to what extent energy efficiency measures such as regulations for stand-by consumption are implemented will be important for future growth in electricity demand. The recent IEA publication *Cool Appliances; Policy Strategies for Energy-Efficient Homes* shows how stronger policy measures could save significant amounts of electricity from the use of appliances. One of the largest potential for savings is in the area of stand-by power consumption. The IEA's 2001 publication *Things That go Blip in the Night; Standby Power and How to Limit It* provides guidance on policy strategies that may be used in this area.

Service Sector

Commercial and public service buildings today constitute an important share of electricity use in IEA countries. There are few signs that electricity demand growth will level off as long as the increased proliferation of electric devices for cooling, ventilation, lighting, and office and network equipment continues. Thus, improving the efficiency of this type of equipment will be crucial for controlling growth in future electricity demand.

Passenger Transport

Growth in passenger travel has been strong over the last three decades and has been the primary driver for increased oil demand in IEA countries. Trends through 1998 do not indicate any slowing of car travel growth rates, but in a few countries, where more recent data are available, growth in car travel per capita appears to have levelled off somewhat. However, it is too early to conclude to what extent this may indicate saturation effects in countries where car ownership and utilisation rates are high.

In many countries reductions in the average fuel intensity for the car stock have slowed since 1990. However, recent trends show that the fuel intensity of new cars sold in many European countries and Japan has again started to decline. This is helped by Europe's auto-industry voluntary commitment to improve fuel economy and Japan's "Top Runner" programme, which encourages manufacturers to improve all vehicles to the level of the best performer in each market segment. The improvements in new car fuel economy will impact the average fleet intensity as new cars replace old ones. It is unclear to what extent these improvements, combined with a potential gradual saturation effect in per capita car-use, will offset population increase and, thus, growth in transport oil demand in the near future. These improvements also will have to work against the consumer preference for larger, heavier and more powerful cars, which has been most prominent in North America but is beginning to occur in other regions as well. (See *Saving Oil and Reducing CO_2 Emissions in Transport*, IEA, 2001).

Freight Transport

Growth in freight haulage, particularly by trucks, also has been an important contributor to the increase in oil demand since 1973. Total tonne-km transported has followed GDP growth to a large extent. However, growth in haulage relative to GDP did slow a little in some of the IEA-11 countries during the late 1990s. This may indicate that growth in the movement of goods could be starting to slow.

Reducing the energy intensity of trucks (energy per tonne-km) can be achieved both by improving energy efficiency and increasing load factors. In many IEA-11 countries, energy per truck-km has declined, but not enough to offset the impact of trucks carrying lighter products and, in some cases, by reduced average truck size. This tendency may continue if an increasing share of the goods transported are lighter items moved shorter distances. On the other hand, significant reductions in energy use for freight can be achieved if long-distance haulage is shifted from trucks to the much less energy-intensive rail and shipping modes.

APPENDIX

List of Tables

Table A1 Final Energy Use by Fuel

	Energy Demand (PJ)			Shares (%)			Avg. Annual % Change		
	1973	1990	1998	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Australia	**1600**	**2245**	**2595**	**100**	**100**	**100**	**2.0**	**1.8**	**1.7**
Electricity	182	419	528	11	19	20	4.9	2.9	3.2
Oil	827	993	1135	52	44	44	1.1	1.7	1.2
Natural Gas	117	379	465	7	17	18	6.9	2.6	3.6
Coal	326	271	245	20	12	9	-1.1	-1.3	-4.7
Biomass	147	184	221	9	8	9	1.3	2.3	0.7
District Heat	0	0	1	0	0	0	0.0	0.0	0.0
Canada	**n.a**	**5478**	**6065**	**n.a**	**100**	**100**	**n.a**	**1.3**	**1.1**
Electricity	n.a	1047	1191	n.a	19	20	n.a	1.6	1.8
Oil	n.a	2260	2465	n.a	41	41	n.a	1.1	1.6
Natural Gas	n.a	1483	1614	n.a	27	27	n.a	1.1	-0.3
Coal	n.a	209	218	n.a	4	4	n.a	0.5	0.3
Biomass	n.a	478	577	n.a	9	10	n.a	2.3	0.7
District Heat	n.a	0	0	n.a	0	0	n.a	0.0	6.3
Denmark	**582**	**523**	**566**	**100**	**100**	**100**	**-0.6**	**1.0**	**-0.8**
Electricity	47	95	107	8	18	19	4.1	1.5	0.9
Oil	444	270	257	76	52	45	-2.9	-0.6	-2.6
Natural Gas	18	47	68	3	9	12	5.7	4.7	0.5
Coal	1	13	13	0	3	2	14.3	-0.3	-13.5
Biomass	6	23	22	1	4	4	7.7	-0.3	6.1
District Heat	66	75	98	11	14	17	0.8	3.4	0.3
Finland	**584**	**817**	**890**	**100**	**100**	**100**	**2.0**	**1.1**	**0.3**
Electricity	92	218	282	16	27	32	5.1	3.2	2.0
Oil	373	299	257	64	37	29	-1.3	-1.9	-2.5
Natural Gas	0	40	39	0	5	4	27.0	-0.4	-7.1
Coal	28	81	74	5	10	8	6.3	-1.1	-5.8
Biomass	69	102	146	12	12	16	2.3	4.5	1.9
District Heat	22	77	92	4	9	10	7.5	2.2	7.9
France	**4952**	**5593**	**5980**	**100**	**100**	**100**	**0.7**	**0.8**	**1.8**
Electricity	526	1131	1368	11	20	23	4.5	2.4	2.3
Oil	3131	2548	2573	63	46	43	-1.2	0.1	1.8
Natural Gas	470	1068	1254	9	19	21	4.8	2.0	3.6
Coal	664	387	298	13	7	5	-3.2	-3.3	-13.0
Biomass	127	357	386	3	6	6	6.1	1.0	0.9
District Heat	34	102	101	1	2	2	6.5	-0.1	0.0
Germany	**8315**	**8391**	**8978**	**100**	**100**	**100**	**0.1**	**0.8**	**-0.2**
Electricity	1023	1533	1634	12	18	18	2.4	0.8	2.5
Oil	4874	4003	4049	59	48	45	-1.2	0.1	-1.6
Natural Gas	1192	1866	2312	14	22	26	2.6	2.7	1.7
Coal	1070	749	497	13	9	6	-2.1	-5.1	-5.9
Biomass	1	5	174	0	0	2	8.1	43.9	3.8
District Heat	155	236	313	2	3	3	2.5	3.5	-5.5
Italy	**3638**	**4155**	**4364**	**100**	**100**	**100**	**0.8**	**0.6**	**1.6**
Electricity	432	745	884	12	18	20	3.2	2.1	2.8
Oil	2492	2111	2085	69	51	48	-1.0	-0.2	0.5
Natural Gas	464	1052	1159	13	25	27	4.8	1.2	2.3
Coal	205	221	195	6	5	4	0.4	-1.6	-2.4
Biomass	44	26	41	1	1	1	-3.1	5.9	10.4
District Heat	0	0	0	0	0	0	0.0	0.0	0.0

**Growth rates for 1998 to 2001 are based on data from IEA* Energy Balances of OECD Countries*. Refer to Chapter 2 for discussion of differences between this data source and the data that are generally used in this study.*

	Energy Demand (PJ)			Shares (%)			Avg. Annual % Change		
	1973	1990	1998	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Japan	**8677**	**10721**	**12299**	**100**	**100**	**100**	**1.2**	**1.7**	**1.2**
Electricity	1460	2681	3316	17	25	27	3.6	2.7	0.1
Oil	5340	5613	6407	62	52	52	0.3	1.7	2.0
Natural Gas	290	606	876	3	6	7	4.3	4.6	-1.4
Coal	1485	1716	1602	17	16	13	0.8	-0.9	2.3
Biomass	101	97	79	1	1	1	-0.2	-2.6	-1.4
District Heat	1	9	20	0	0	0	15.8	10.7	-5.4
Netherlands	**n.a**	**1604**	**1867**	**n.a**	**100**	**100**	**n.a**	**1.9**	**1.6**
Electricity	n.a	251	308	n.a	16	17	n.a	2.6	2.2
Oil	n.a	441	537	n.a	28	29	n.a	2.5	1.7
Natural Gas	n.a	802	846	n.a	50	45	n.a	0.7	0.5
Coal	n.a	87	77	n.a	5	4	n.a	-1.5	-1.5
Biomass	n.a	2	2	n.a	0	0	n.a	-0.5	7.4
District Heat	n.a	21	96	n.a	1	5	n.a	19.2	8.5
Norway	**505**	**638**	**693**	**100**	**100**	**100**	**1.4**	**1.0**	**0.6**
Electricity	207	350	372	41	55	54	3.1	0.8	0.9
Oil	236	195	213	47	31	31	-1.1	1.1	-1.0
Natural Gas	0	0	1	0	0	0	0.0	0.0	0.0
Coal	46	50	54	9	8	8	0.5	0.9	-5.0
Biomass	16	41	47	3	6	7	5.6	1.8	4.6
District Heat	0	2	5	0	0	1	0.0	9.1	11.2
Sweden	**1337**	**1315**	**1363**	**100**	**100**	**100**	**-0.1**	**0.4**	**-0.8**
Electricity	228	419	439	17	32	32	3.6	0.6	1.7
Oil	840	485	445	63	37	33	-3.2	-1.1	-3.6
Natural Gas	4	15	17	0	1	1	7.9	1.4	7.0
Coal	55	62	62	4	5	5	0.7	-0.1	3.6
Biomass	151	207	234	11	16	17	1.8	1.6	-2.6
District Heat	59	128	166	4	10	12	4.6	3.3	0.9
UK	**5669**	**5589**	**5837**	**100**	**100**	**100**	**-0.1**	**0.5**	**0.5**
Electricity	775	975	1118	14	17	19	1.4	1.7	1.8
Oil	2748	2180	2142	48	39	37	-1.4	-0.2	-1.2
Natural Gas	915	1817	2192	16	33	38	4.0	2.3	0.8
Coal	1231	612	366	22	11	6	-4.1	-6.4	-6.1
Biomass	0	4	19	0	0	0	0.0	18.4	-13.0
District Heat	0	0	0	0	0	0	0.0	0.0	0.0
US	**46487**	**48661**	**55760**	**100**	**100**	**100**	**0.3**	**1.7**	**1.5**
Electricity	5808	8833	10832	12	18	19	2.5	2.6	0.7
Oil	22777	23061	26434	49	47	47	0.1	1.7	2.2
Natural Gas	12611	11865	13526	27	24	24	-0.4	1.6	-1.1
Coal	3872	2711	2497	8	6	4	-2.1	-1.0	1.9
Biomass	1419	2192	2471	3	5	4	2.6	1.5	16.3
District Heat	0	0	0	0	0	0	0.0	0.0	9.3
EUR-8	**25581**	**27022**	**28671**	**100**	**100**	**100**	**0.3**	**0.7**	**0.6**
Electricity	3328	5465	6205	13	20	22	2.9	1.6	2.2
Oil	15139	12090	12021	59	45	42	-1.3	-0.1	-0.5
Natural Gas	3064	5906	7042	12	22	25	3.9	2.2	1.9
Coal	3300	2176	1558	13	8	5	-2.4	-4.2	-6.6
Biomass	415	765	1070	2	3	4	3.6	4.2	1.3
District Heat	334	620	775	1	2	3	3.6	2.8	3.3
IEA-11	**82345**	**88650**	**99325**	**100**	**100**	**100**	**0.4**	**1.4**	**1.2**
Electricity	10778	17397	20880	13	20	21	2.8	2.3	1.1
Oil	44084	41757	45997	54	47	46	-0.3	1.2	1.4
Natural Gas	16082	18755	21909	20	21	22	0.9	1.9	0.0
Coal	8984	6874	5901	11	8	6	-1.6	-1.9	-0.9
Biomass	2082	3238	3841	3	4	4	2.6	2.1	8.9
District Heat	335	628	796	0	1	1	3.7	3.0	5.1

Table A2 Final Energy Use by End-use Sector

	Energy Demand (PJ)			Shares (%)			Avg. Annual % Change		
	1973	1990	1998	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Australia	**1600**	**2245**	**2595**	**100**	**100**	**100**	**2.0**	**1.8**	**1.7**
Manufacturing	772	921	1019	48	41	39	1.0	1.3	2.1
Household	203	316	367	13	14	14	2.6	1.9	1.7
Service	78	142	193	5	6	7	3.5	3.9	1.8
Passenger Transport	373	597	694	23	27	27	2.8	1.9	1.3
Freight Transport	173	270	322	11	12	12	2.6	2.2	1.3
Canada	**n.a**	**5478**	**6065**	**n.a**	**100**	**100**	**n.a**	**1.3**	**1.1**
Manufacturing	n.a	2002	2194	n.a	37	36	n.a	1.1	-0.7
Household	n.a	823	828	n.a	15	14	n.a	0.1	1.5
Service	n.a	858	937	n.a	16	15	n.a	1.1	4.4
Passenger Transport	n.a	1140	1281	n.a	21	21	n.a	1.5	0.7
Freight Transport	n.a	655	824	n.a	12	14	n.a	2.9	0.7
Denmark	**579**	**523**	**566**	**100**	**100**	**100**	**-0.6**	**1.0**	**-0.9**
Manufacturing	145	104	117	25	20	21	-1.9	1.4	-0.3
Household	250	180	186	43	34	33	-1.9	0.5	-0.7
Service	82	72	77	14	14	14	-0.7	0.7	0.9
Passenger Transport	71	91	107	12	17	19	1.5	2.0	-2.0
Freight Transport	32	76	80	5	15	14	5.1	0.6	-2.0
Finland	**584**	**817**	**890**	**100**	**100**	**100**	**2.0**	**1.1**	**0.3**
Manufacturing	221	353	409	38	43	46	2.7	1.8	0.4
Household	156	180	220	27	22	25	0.8	2.5	-2.0
Service	104	109	83	18	13	9	0.3	-3.5	4.0
Passenger Transport	66	125	117	11	15	13	3.8	-0.8	1.4
Freight Transport	36	50	60	6	6	7	1.9	2.3	1.4
France	**4952**	**5593**	**5980**	**100**	**100**	**100**	**0.7**	**0.8**	**1.8**
Manufacturing	1941	1516	1617	39	27	27	-1.5	0.8	0.6
Household	1457	1762	1840	29	32	31	1.1	0.5	2.1
Service	613	882	927	12	16	16	2.1	0.6	3.1
Passenger Transport	610	948	1038	12	17	17	2.6	1.1	1.7
Freight Transport	331	486	557	7	9	9	2.3	1.7	1.7
Germany	**8315**	**8391**	**8978**	**100**	**100**	**100**	**0.1**	**0.8**	**-0.2**
Manufacturing	3098	2498	2378	37	30	26	-1.3	-0.6	0.1
Household	2302	2416	2879	28	29	32	0.3	2.2	0.0
Service	1341	1160	1267	16	14	14	-0.9	1.1	-0.7
Passenger Transport	1064	1751	1694	13	21	19	2.9	-0.4	-0.5
Freight Transport	509	566	760	6	7	8	0.6	3.7	-0.5
Italy	**3638**	**4154**	**4364**	**100**	**100**	**100**	**0.8**	**0.6**	**1.6**
Manufacturing	1647	1517	1567	45	37	36	-0.5	0.4	2.1
Household	917	951	792	25	23	18	0.2	-2.3	2.1
Service	321	351	460	9	8	11	0.5	3.4	2.6
Passenger Transport	512	875	1103	14	21	25	3.2	2.9	0.6
Freight Transport	241	461	441	7	11	10	3.8	-0.5	0.6
Japan	**8677**	**10721**	**12299**	**100**	**100**	**100**	**1.2**	**1.7**	**1.1**
Manufacturing	5164	4658	4735	60	43	38	-0.6	0.2	-2.5
Household	916	1770	2116	11	17	17	3.9	2.2	-1.6
Service	941	1422	1807	11	13	15	2.4	3.0	9.4
Passenger Transport	755	1460	2084	9	14	17	3.9	4.5	1.4
Freight Transport	902	1411	1557	10	13	13	2.6	1.2	1.4

	Energy Demand (PJ)			Shares (%)			Avg. Annual % Change		
	1973	1990	1998	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Netherlands	**n.a**	**1604**	**1867**	**n.a**	**100**	**100**	**n.a**	**1.9**	**1.6**
Manufacturing	n.a	588	649	n.a	37	35	n.a	1.2	1.6
Household	n.a	452	510	n.a	28	27	n.a	1.5	1.0
Service	n.a	214	285	n.a	13	15	n.a	3.6	2.1
Passenger Transport	n.a	232	267	n.a	14	14	n.a	1.7	1.9
Freight Transport	n.a	117	155	n.a	7	8	n.a	3.5	1.9
Norway	**505**	**638**	**693**	**100**	**100**	**100**	**1.4**	**1.0**	**0.6**
Manufacturing	257	249	266	51	39	38	-0.2	0.8	0.9
Household	109	165	169	22	26	24	2.5	0.3	2.1
Service	48	83	95	10	13	14	3.2	1.7	0.4
Passenger Transport	50	85	88	10	13	13	3.2	0.4	-0.9
Freight Transport	41	56	74	8	9	11	1.9	3.4	-0.9
Sweden	**1337**	**1315**	**1363**	**100**	**100**	**100**	**-0.1**	**0.4**	**-0.8**
Manufacturing	584	504	555	44	38	41	-0.9	1.2	-0.1
Household	370	355	370	28	27	27	-0.3	0.5	-2.3
Service	168	167	163	13	13	12	0.0	-0.4	-1.6
Passenger Transport	147	194	197	11	15	14	1.6	0.2	0.2
Freight Transport	67	95	78	5	7	6	2.1	-2.4	0.2
UK	**5669**	**5589**	**5837**	**100**	**100**	**100**	**-0.1**	**0.5**	**0.5**
Manufacturing	2386	1524	1477	42	27	25	-2.6	-0.4	1.1
Household	1452	1691	1854	26	30	32	0.9	1.1	1.7
Service	676	755	844	12	14	14	0.7	1.4	1.2
Passenger Transport	764	1111	1107	13	20	19	2.2	0.0	-1.4
Freight Transport	391	508	555	7	9	10	1.5	1.1	-1.4
US	**46487**	**48661**	**55760**	**100**	**100**	**100**	**0.3**	**1.7**	**1.6**
Manufacturing	14077	12018	13853	30	25	25	-0.9	1.8	1.6
Household	10436	10293	10898	22	21	20	-0.1	0.7	1.5
Service	5648	6593	7650	12	14	14	0.9	1.9	1.4
Passenger Transport	12611	14171	16410	27	29	29	0.7	1.8	1.6
Freight Transport	3715	5586	6948	8	11	12	2.4	2.7	1.6
EUR-8	**25579**	**27021**	**28671**	**100**	**100**	**100**	**0.3**	**0.7**	**0.6**
Manufacturing	10280	8264	8386	40	31	29	-1.3	0.2	0.8
Household	7014	7699	8311	27	28	29	0.5	1.0	1.0
Service	3354	3579	3916	13	13	14	0.4	1.1	1.1
Passenger Transport	3283	5180	5452	13	19	19	2.7	0.6	0.0
Freight Transport	1648	2298	2605	6	9	9	2.0	1.6	0.0
IEA-11	**82342**	**88648**	**99324**	**100**	**100**	**100**	**0.4**	**1.4**	**1.2**
Manufacturing	30293	25862	27993	37	29	28	-0.9	1.0	0.7
Household	18569	20079	21692	23	23	22	0.5	1.0	1.0
Service	10020	11736	13567	12	13	14	0.9	1.8	2.6
Passenger Transport	17022	21407	24641	21	24	25	1.3	1.8	1.2
Freight Transport	6438	9565	11432	8	11	12	2.3	2.2	1.2

**Growth rates for 1998 to 2001 are based on data from IEA* Energy Balances of OECD Countries*. Since this source does not separate between energy use in passenger and freight transport, growth rates between 1998 and 2001 for total transport are used for both sectors in this table. Refer to Chapter 2 for discussion of differences between IEA* Energy Balances of OECD Countries *and the data that are generally used in this study*

Table A3 Electricity Use by End-use Sector

	Energy Demand (PJ)			Shares (%)			Avg. Annual % Change		
	1973	1990	1998	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Australia	**182**	**419**	**528**	**100**	**100**	**100**	**4.9**	**2.9**	**3.2**
Manufacturing	75	176	216	41	42	41	5.0	2.6	4.5
Household	71	144	171	39	34	32	4.2	2.1	2.5
Service	34	94	135	19	22	26	6.0	4.5	1.9
Passenger Transport	2	3	4	1	1	1	2.4	2.4	9.6
Freight Transport	0	2	2	0	0	0	12.7	2.4	9.6
Canada	**n.a**	**1047**	**1191**	**n.a**	**100**	**100**	**n.a**	**1.6**	**1.8**
Manufacturing	n.a	535	629	n.a	51	53	n.a	2.0	1.6
Household	n.a	128	136	n.a	12	11	n.a	0.7	2.7
Service	n.a	381	424	n.a	36	36	n.a	1.3	1.1
Passenger Transport	n.a	3	3	n.a	0	0	n.a	-0.8	0.0
Freight Transport	n.a	0	0	n.a	0	0	n.a	0.0	0.0
Denmark	**47**	**95**	**107**	**100**	**100**	**100**	**4.1**	**1.5**	**0.9**
Manufacturing	14	29	34	29	30	32	4.3	2.1	1.0
Household	19	35	37	41	37	34	3.5	0.6	0.0
Service	14	30	35	29	32	32	4.7	1.8	1.9
Passenger Transport	0	1	1	1	1	1	4.2	5.8	23.1
Freight Transport	0	0	0	0	0	0	0.0	0.0	23.1
Finland	**92**	**218**	**282**	**100**	**100**	**100**	**5.1**	**3.2**	**1.9**
Manufacturing	62	111	142	67	51	50	3.4	3.1	1.4
Household	17	76	94	18	35	33	8.9	2.6	2.5
Service	13	29	44	14	13	16	4.6	5.3	4.2
Passenger Transport	0	1	1	0	0	0	9.0	2.9	23.1
Freight Transport	0	1	1	0	0	0	20.9	1.7	23.1
France	**526**	**1131**	**1368**	**100**	**100**	**100**	**4.5**	**2.4**	**2.3**
Manufacturing	303	391	456	58	35	33	1.5	1.9	0.4
Household	103	402	502	20	36	37	8.0	2.8	2.8
Service	97	312	384	19	28	28	6.8	2.6	4.0
Passenger Transport	10	16	16	2	1	1	2.7	-0.3	4.0
Freight Transport	11	9	10	2	1	1	-1.3	1.7	4.0
Germany	**1023**	**1533**	**1634**	**100**	**100**	**100**	**2.4**	**0.8**	**2.6**
Manufacturing	550	692	710	54	45	43	1.4	0.3	3.4
Household	251	433	449	25	28	27	3.2	0.4	2.1
Service	176	354	418	17	23	26	4.1	2.1	1.6
Passenger Transport	13	24	23	1	2	1	3.6	-0.4	6.5
Freight Transport	33	30	35	3	2	2	-0.7	2.0	6.5
Italy	**432**	**745**	**884**	**100**	**100**	**100**	**3.2**	**2.1**	**2.8**
Manufacturing	271	391	450	63	53	51	2.2	1.7	4.0
Household	93	191	214	22	26	24	4.2	1.5	1.4
Service	54	144	202	12	19	23	5.8	4.2	1.8
Passenger Transport	9	12	10	2	2	1	1.8	-1.6	2.2
Freight Transport	5	7	8	1	1	1	2.0	1.2	2.2
Japan	**1460**	**2681**	**3316**	**100**	**100**	**100**	**3.6**	**2.7**	**0.2**
Manufacturing	961	1324	1449	66	49	44	1.9	1.1	-2.5
Household	278	696	932	19	26	28	5.4	3.7	0.7
Service	179	599	867	12	22	26	7.1	4.6	3.6
Passenger Transport	30	57	63	2	2	2	3.7	1.1	-5.5
Freight Transport	12	5	5	1	0	0	-4.9	-0.7	-5.5

	Energy Demand (PJ)			Shares (%)			Avg. Annual % Change		
	1973	1990	1998	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Netherlands	**n.a**	**251**	**308**	**n.a**	**0**	**100**	**n.a**	**2.6**	**2.3**
Manufacturing	n.a	117	139	n.a	0	45	n.a	2.1	0.7
Household	n.a	60	75	n.a	0	24	n.a	3.0	2.2
Service	n.a	71	89	n.a	0	29	n.a	2.9	4.4
Passenger Transport	n.a	4	5	n.a	1	1	n.a	3.4	6.1
Freight Transport	n.a	1	1	n.a	2	0	n.a	0.0	6.1
Norway	**207**	**350**	**372**	**100**	**100**	**100**	**3.1**	**0.8**	**0.9**
Manufacturing	128	160	159	62	46	43	1.3	-0.1	-0.2
Household	56	117	130	27	33	35	4.3	1.3	3.5
Service	20	70	81	10	20	22	7.3	1.9	-0.9
Passenger Transport	1	1	2	1	0	0	1.9	0.9	23.1
Freight Transport	1	1	1	0	0	0	0.7	-1.7	23.1
Sweden	**228**	**419**	**439**	**100**	**100**	**100**	**3.6**	**0.6**	**1.7**
Manufacturing	126	185	189	55	44	43	2.3	0.2	0.7
Household	54	137	150	24	33	34	5.5	1.1	1.9
Service	40	88	90	18	21	21	4.6	0.4	3.5
Passenger Transport	4	5	6	2	1	1	1.4	1.5	6.1
Freight Transport	4	4	4	2	1	1	0.6	1.5	6.1
UK	**775**	**975**	**1118**	**100**	**100**	**100**	**1.4**	**1.7**	**1.9**
Manufacturing	288	362	386	37	37	35	1.3	0.8	1.6
Household	326	345	400	42	35	36	0.3	1.8	1.7
Service	151	255	318	19	26	28	3.1	2.7	2.2
Passenger Transport	9	13	14	1	1	1	2.0	1.4	1.1
Freight Transport	0	0	0	0	0	0	-0.4	1.3	1.1
US	**5808**	**8833**	**10832**	**100**	**100**	**100**	**2.5**	**2.6**	**0.7**
Manufacturing	2099	2430	3077	36	28	28	0.9	3.0	-0.5
Household	2095	3367	3856	36	38	36	2.8	1.7	0.8
Service	1600	3017	3880	28	34	36	3.7	3.1	1.6
Passenger Transport	13	19	19	0	0	0	2.0	0.5	2.1
Freight Transport	0	0	0	0	0	0	0.0	0.0	2.1
EUR-8	**3328**	**5465**	**6205**	**100**	**100**	**100**	**2.9**	**1.6**	**2.2**
Manufacturing	1742	2322	2526	52	42	41	1.7	1.0	2.1
Household	920	1737	1974	28	32	32	3.7	1.6	2.1
Service	565	1281	1573	17	23	25	4.8	2.6	2.4
Passenger Transport	46	72	73	1	1	1	2.6	0.1	4.0
Freight Transport	54	52	59	2	1	1	-0.3	1.7	4.0
IEA-11	**10778**	**17397**	**20880**	**100**	**100**	**100**	**2.8**	**2.3**	**1.1**
Manufacturing	4878	6252	7268	45	36	35	1.5	1.9	0.2
Household	3364	5944	6933	31	34	33	3.3	1.9	1.2
Service	2378	4991	6455	22	29	31	4.4	3.2	2.1
Passenger Transport	92	152	159	1	1	1	2.9	0.6	1.9
Freight Transport	66	58	66	1	0	0	-0.7	1.6	1.9

**Growth rates for 1998 to 2001 are based on data from IEA* Energy Balances of OECD Countries. *Since this source does not separate between energy use in passenger and freight transport, growth rates between 1998 and 2001 for total transport are used for both sectors in this table. Refer to Chapter 2 for discussion of differences between IEA* Energy Balances of OECD Countries *and the data that are generally used in this study*

Table A4 Oil Use by End-use Sector

	Energy Demand (PJ)			Shares (%)			Avg. Annual % Change		
	1973	1990	1998	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Australia	**827**	**993**	**1135**	**100**	**100**	**100**	**1.1**	**1.7**	**1.2**
Manufacturing	239	109	104	29	11	9	-4.6	-0.6	0.6
Household	44	16	14	5	2	1	-5.9	-2.0	-2.3
Service	28	10	12	3	1	1	-6.1	2.1	2.7
Passenger transport	351	593	690	42	60	61	3.1	1.9	1.2
Freight transport	166	264	315	20	27	28	2.7	2.2	1.2
Canada	**n.a**	**2260**	**2465**	**n.a**	**100**	**100**	**n.a**	**1.1**	**1.6**
Manufacturing	n.a	182	128	n.a	8	5	n.a	-4.4	2.7
Household	n.a	193	137	n.a	9	6	n.a	-4.3	-1.5
Service	n.a	90	94	n.a	4	4	n.a	0.6	10.8
Passenger transport	n.a	1140	1281	n.a	50	52	n.a	1.5	0.7
Freight transport	n.a	655	824	n.a	29	33	n.a	2.9	0.7
Denmark	**444**	**270**	**257**	**100**	**100**	**100**	**-2.9**	**-0.6**	**-2.6**
Manufacturing	111	32	25	25	12	10	-7.3	-3.0	1.3
Household	178	57	40	40	21	15	-6.7	-4.6	-5.3
Service	50	14	6	11	5	2	-7.7	-10.1	-6.1
Passenger transport	73	90	106	16	34	41	1.3	2.0	-2.2
Freight transport	32	76	80	7	28	31	5.1	0.6	-2.2
Finland	**373**	**299**	**257**	**100**	**100**	**100**	**-1.3**	**-1.9**	**-2.5**
Manufacturing	136	43	42	36	14	17	-6.8	0.0	-10.6
Household	58	40	39	16	13	15	-2.3	-0.3	-11.1
Service	77	44	0	21	15	0	-3.3	0.0	-2.2
Passenger transport	65	124	116	18	41	45	3.8	-0.8	1.2
Freight transport	36	49	59	10	16	23	1.8	2.3	1.2
France	**3131**	**2548**	**2573**	**100**	**100**	**100**	**-1.2**	**0.1**	**1.8**
Manufacturing	947	310	293	30	12	11	-6.6	-0.7	8.3
Household	814	509	450	26	20	17	-2.8	-1.5	0.6
Service	450	320	262	14	13	10	-2.0	-2.5	-1.3
Passenger transport	600	931	1022	19	37	40	2.6	1.2	1.6
Freight transport	320	476	546	10	19	21	2.3	1.7	1.6
Germany	**4874**	**4003**	**4049**	**100**	**100**	**100**	**-1.2**	**0.1**	**-1.6**
Manufacturing	1084	383	297	22	10	7	-6.1	-3.2	-6.0
Household	1379	981	1034	28	24	26	-2.0	0.7	-1.8
Service	884	375	322	18	9	8	-5.0	-1.9	-3.7
Passenger transport	1051	1727	1671	22	43	41	2.9	-0.4	-0.7
Freight transport	476	537	725	10	13	18	0.7	3.8	-0.7
Italy	**2492**	**2111**	**2085**	**100**	**100**	**100**	**-1.0**	**-0.2**	**0.5**
Manufacturing	897	368	280	36	17	13	-5.2	-3.4	-2.1
Household	624	338	218	25	16	10	-3.6	-5.5	2.3
Service	231	88	61	9	4	3	-5.7	-4.7	23.1
Passenger transport	503	863	1093	20	41	52	3.2	3.0	0.5
Freight transport	236	454	434	9	22	21	3.9	-0.6	0.5
Japan	**5340**	**5613**	**6407**	**100**	**100**	**100**	**0.3**	**1.7**	**2.0**
Manufacturing	2599	1443	1375	49	26	21	-3.5	-0.6	-8.3
Household	430	715	787	8	13	12	3.0	1.2	-3.6
Service	697	646	672	13	12	10	-0.4	0.5	19.3
Passenger transport	724	1402	2022	14	25	32	3.9	4.6	1.5
Freight transport	890	1406	1552	17	25	24	2.7	1.2	1.5

	Energy Demand (PJ)			Shares (%)			Avg. Annual % Change		
	1973	1990	1998	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Netherlands	**n.a**	**441**	**537**	**n.a**	**100**	**100**	**n.a**	**2.5**	**1.7**
Manufacturing	n.a	75	100	n.a	17	19	n.a	3.7	10.1
Household	n.a	12	4	n.a	3	1	n.a	-12.7	0.0
Service	n.a	5	11	n.a	1	2	n.a	8.6	-34.1
Passenger transport	n.a	232	267	n.a	53	50	n.a	1.7	1.8
Freight transport	n.a	117	155	n.a	27	29	n.a	3.5	1.8
Norway	**236**	**195**	**213**	**100**	**100**	**100**	**-1.1**	**1.1**	**-1.0**
Manufacturing	81	23	29	34	12	14	-7.5	3.1	0.0
Household	40	22	13	17	11	6	-3.7	-6.0	-2.7
Service	26	12	11	11	6	5	-4.8	-0.6	2.5
Passenger transport	49	84	86	21	43	41	3.2	0.4	-1.1
Freight transport	40	56	73	17	29	34	1.9	3.5	-1.1
Sweden	**840**	**485**	**445**	**100**	**100**	**100**	**-3.2**	**-1.1**	**-3.6**
Manufacturing	267	78	91	32	16	21	-7.3	2.0	-6.0
Household	262	90	70	31	19	16	-6.3	-3.1	-12.9
Service	104	36	18	12	7	4	-6.3	-8.4	-14.2
Passenger transport	144	191	191	17	39	43	1.6	0.1	0.0
Freight transport	63	91	74	8	19	17	2.1	-2.6	0.0
UK	**2747**	**2179**	**2142**	**100**	**100**	**100**	**-1.4**	**-0.2**	**-1.2**
Manufacturing	1131	326	252	41	15	12	-7.3	-3.2	1.8
Household	163	107	148	6	5	7	-2.5	4.0	-0.5
Service	307	140	95	11	6	4	-4.6	-4.8	-5.2
Passenger transport	755	1099	1093	27	50	51	2.2	-0.1	-1.4
Freight transport	390	507	554	14	23	26	1.5	1.1	-1.4
US	**22777**	**23061**	**26434**	**100**	**100**	**100**	**0.1**	**1.7**	**2.2**
Manufacturing	2163	967	1019	9	4	4	-4.7	0.7	9.3
Household	2933	1546	1457	13	7	6	-3.8	-0.7	4.4
Service	1369	811	620	6	4	2	-3.1	-3.4	6.7
Passenger transport	12597	14152	16391	55	61	62	0.7	1.8	1.6
Freight transport	3715	5586	6948	16	24	26	2.4	2.7	1.6
EUR-8	**15138**	**12089**	**12021**	**100**	**100**	**100**	**-1.3**	**-0.1**	**-0.5**
Manufacturing	4655	1563	1310	31	13	11	-6.4	-2.2	-0.2
Household	3519	2143	2011	23	18	17	-2.9	-0.8	-1.2
Service	2129	1027	775	14	8	6	-4.3	-3.5	-3.3
Passenger transport	3241	5109	5379	21	42	45	2.7	0.6	-0.1
Freight transport	1593	2247	2546	11	19	21	2.0	1.6	-0.1
IEA-11	**44082**	**41756**	**45997**	**100**	**100**	**100**	**-0.3**	**1.2**	**1.4**
Manufacturing	9656	4082	3808	22	10	8	-5.1	-0.9	0.4
Household	6926	4420	4267	16	11	9	-2.6	-0.4	0.1
Service	4222	2494	2078	10	6	5	-3.1	-2.3	8.4
Passenger transport	16913	21257	24482	38	51	53	1.3	1.8	1.2
Freight transport	6365	9503	11362	14	23	25	2.4	2.2	1.2

**Growth rates for 1998 to 2001 are based on data from IEA* Energy Balances of OECD Countries*. Since this source does not separate between energy use in passenger and freight transport, growth rates between 1998 and 2001 for total transport are used for both sectors in this table. Refer to Chapter 2 for discussion of differences between IEA* Energy Balances of OECD Countries *and the data that are generally used in this study*

Table A5 Macro Indicators

	GDP						Population						GDP per Capita					
	Billion 1995 US$ (PPP)			Avg. Annual % Change			Millions			Avg. Annual % Change			Thousand US$ per Capita			Avg. Annual % Change		
	1973	1990	1998	1973-1990	1990-1998	1998-2001*	1973	1990	1998	1973-1990	1990-1998	1998-2001*	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Australia	205	333	445	2.9	3.6	3.2	13.6	17.2	18.8	1.4	1.2	1.2	15.1	19.4	23.6	1.5	2.5	2.0
Canada	370	620	744	3.0	2.3	3.8	22.5	27.7	30.3	1.2	1.1	1.0	16.5	22.4	24.6	1.8	1.2	2.9
Denmark	85	109	130	1.4	2.2	2.0	5.0	5.1	5.3	0.1	0.4	0.6	17.0	21.2	24.5	1.3	1.8	1.7
Finland	61	100	112	2.9	1.5	3.7	4.7	5.0	5.2	0.4	0.4	0.0	13.0	20.0	21.8	2.5	1.1	3.2
France	743	1138	1278	2.5	1.5	2.9	53.3	58.2	60.0	0.5	0.4	0.5	13.9	19.6	21.3	2.0	1.1	2.4
Germany	1119	1614	1821	2.2	1.5	1.8	79.0	79.4	82.0	0.0	0.4	0.1	14.2	20.3	22.2	2.1	1.1	1.6
Italy	680	1082	1211	2.7	1.4	2.1	54.8	56.7	57.6	0.2	0.2	0.2	12.4	19.1	21.0	2.5	1.2	1.9
Japan	1449	2732	3051	3.7	1.4	0.8	108.7	123.5	126.5	0.8	0.3	0.2	13.3	22.1	24.1	3.0	1.1	0.7
Netherlands	200	296	367	2.3	2.7	2.8	13.4	15.0	15.7	0.6	0.6	0.6	14.9	19.8	23.4	1.7	2.1	2.1
Norway	49	85	114	3.3	3.7	2.2	4.0	4.2	4.4	0.4	0.6	0.7	12.3	20.0	25.8	2.9	3.2	1.4
Sweden	122	171	188	2.0	1.2	3.2	8.1	8.6	8.9	0.3	0.4	0.0	15.0	20.0	21.3	1.7	0.8	3.0
United Kingdom	725	1008	1202	1.9	2.2	2.4	56.2	57.3	58.3	0.1	0.2	0.3	12.9	17.6	20.6	1.8	2.0	2.2
United States	4005	6521	8286	2.9	3.0	2.7	211.9	250.0	270.6	1.0	1.0	1.8	18.9	26.1	30.6	1.9	2.0	0.9
EUR-8	3584	5307	6057	2.3	1.7	2.3	265.0	274.5	282.0	0.2	0.3	0.2	13.5	19.3	21.5	2.1	1.3	2.1
IEA-11	9243	14893	17839	2.8	2.3	2.2	599.2	665.2	698.0	0.6	0.6	0.9	15.4	22.4	25.6	2.2	1.7	1.3

	Final Energy per GDP MJ/US$			Avg. Annual % Change			Oil Consumption per GDP MJ/US$			Avg. Annual % Change			Electricity Consumption per Capita GJ/Capita			Avg. Annual % Change		
	1973	1990	1998	1973-1990	1990-1998	1998-2001*	1973	1990	1998	1973-1990	1990-1998	1998-2001*	1973	1990	1998	1973-1990	1990-1998	1998-2001*
Australia	7.7	6.7	5.8	-0.8	-1.8	-1.5	4.0	3.0	2.5	-1.8	-2.0	-2.0	13.4	24.4	28.0	3.5	1.7	2.0
Canada	n.a	8.8	8.1	n.a	-1.0	-2.7	n.a	3.6	3.3	n.a	-1.2	-2.2	n.a	37.8	39.4	n.a	0.5	0.8
Denmark	6.8	4.8	4.4	-2.0	-1.3	-2.8	5.2	2.5	2.0	-4.3	-2.9	-4.6	9.4	18.5	20.2	4.0	1.1	0.3
Finland	9.6	8.2	8.0	-0.9	-0.4	-3.4	6.2	3.0	2.3	-4.2	-3.3	-6.2	19.7	43.6	54.7	4.7	2.8	2.0
France	6.7	4.9	4.7	-1.8	-0.6	-1.2	4.2	2.2	2.0	-3.7	-1.3	-1.1	9.9	19.4	22.8	4.0	2.0	1.8
Germany	7.4	5.2	4.9	-2.1	-0.7	-2.0	4.4	2.5	2.2	-3.3	-1.4	-3.4	13.0	19.3	19.9	2.3	0.4	2.4
Italy	5.4	3.8	3.6	-2.0	-0.8	-0.5	3.7	2.0	1.7	-3.7	-1.6	-1.5	7.9	13.1	15.4	3.0	2.0	2.6
Japan	6.0	4.0	4.1	-2.5	0.3	0.3	3.7	2.1	2.1	-3.4	0.3	1.2	13.4	21.7	26.2	2.8	2.4	-0.1
Netherlands	n.a	5.4	5.1	n.a	-0.8	-1.2	n.a	1.5	1.5	n.a	-0.2	-1.1	n.a	16.8	19.6	n.a	1.9	1.6
Norway	10.4	7.6	6.1	-1.9	-2.7	-1.6	4.9	2.3	1.9	-4.4	-2.7	-3.2	52.1	82.5	84.0	2.7	0.2	0.1
Sweden	11.0	7.7	7.2	-2.1	-0.8	-4.1	6.9	2.8	2.4	-5.2	-2.3	-6.8	28.0	49.0	49.6	3.3	0.2	1.7
United Kingdom	7.8	5.5	4.9	-2.0	-1.7	-1.9	3.8	2.2	1.8	-3.3	-2.4	-3.6	13.8	17.0	19.2	1.2	1.5	1.5
United States	11.7	7.6	6.8	-2.6	-1.3	-1.2	5.8	3.6	3.3	-2.7	-1.2	-0.5	27.4	35.3	40.0	1.5	1.6	-1.2
EUR-8	7.1	5.1	4.7	-2.0	-0.9	-1.7	4.2	2.3	2.0	-3.6	-1.7	-2.8	12.6	19.9	22.0	2.7	1.3	1.9
IEA-11	9.0	6.0	5.6	-2.4	-0.8	-1.0	4.8	2.9	2.6	-3.1	-1.0	-0.8	18.0	26.2	29.9	2.2	1.7	0.2

**The majority of the detailed data used in this study only go through 1998 (see Chapter 2). Growth rates for 1998-2001 are shown in this table to illustrate the most recent developments. Energy data used for the 1998-2001 growth rates are taken from IEA Energy Balances of OECD Countries (see footnotes to Tables A1 - A4.)*

Table A6 Decomposition of Changes in Energy Use; Economy-wide and by Sector

	Avg. Annual % Change							
	Energy Demand		Activity		Structure		Intensity	
	1973-1990	1990-1998	1973-1990	1990-1998	1973-1990	1990-1998	1973-1990	1990-1998
TOTAL								
Australia	2.0	1.8	2.0	2.3	0.8	0.1	-0.8	-0.4
Canada	n.a.	1.2	n.a.	2.2	n.a.	0.1	n.a.	-1.0
Denmark	-0.6	1.0	1.0	1.2	0.4	0.2	-2.3	-0.3
Finland	2.0	1.1	2.4	2.2	0.5	0.2	-1.2	-1.2
France	0.7	0.8	1.6	1.3	0.7	0.4	-1.7	-0.8
Germany	0.1	0.8	1.4	0.9	0.7	0.6	-2.1	-0.7
Italy	0.8	0.6	2.5	1.4	0.6	0.4	-3.4	-1.1
Japan	1.3	1.7	3.0	0.8	0.3	0.2	-2.5	0.9
Netherlands	n.a.	1.9	n.a.	1.7	n.a.	0.6	n.a.	-0.2
Norway	1.4	1.0	0.7	2.0	1.2	0.5	-0.6	-1.2
Sweden	-0.1	0.4	1.2	1.8	0.4	-0.3	-1.7	-0.7
United Kingdom	-0.1	0.5	1.1	0.9	0.5	0.3	-1.7	-0.6
United States	0.3	1.7	2.0	2.5	0.0	0.2	-1.9	-1.0
EUR-8	0.3	0.7	1.5	1.2	0.6	0.4	-2.1	-0.8
IEA-11	0.4	1.4	1.9	1.9	0.3	0.3	-2.0	-0.7
MANUFACTURING								
Australia	1.0	1.3	1.4	2.0	0.7	-0.8	-0.9	0.1
Canada	n.a.	1.1	n.a.	2.7	n.a.	-0.6	n.a.	-0.8
Denmark	-1.9	1.5	1.4	1.5	-0.6	0.4	-3.0	0.0
Finland	2.8	1.9	3.2	4.3	-0.1	-0.3	-0.4	-2.2
France	-1.4	0.8	2.0	1.8	-0.1	-0.6	-3.5	-0.3
Germany	-1.3	-0.6	1.4	0.3	-0.2	0.3	-2.4	-1.2
Italy	-0.5	0.4	3.4	1.3	0.0	0.2	-5.5	-1.0
Japan	-0.6	0.2	4.4	0.3	-0.8	-1.1	-4.4	1.3
Netherlands	n.a.	1.2	n.a.	1.8	n.a.	0.3	n.a.	-0.8
Norway	-0.2	0.8	-0.3	1.9	1.4	-0.2	-1.4	-0.6
Sweden	-0.9	1.2	1.4	3.7	-0.2	-1.2	-2.0	-0.7
United Kingdom	-2.6	-0.4	0.3	0.5	-0.3	-0.3	-2.8	-0.6
United States	-0.9	1.8	2.3	3.5	-1.3	-1.0	-2.1	-0.5
EUR-8	-1.3	0.2	1.6	1.3	-0.1	-0.1	-3.3	-0.9
IEA-11	-0.9	1.0	2.4	2.2	-0.8	-0.7	-2.9	-0.3
HOUSEHOLD								
Australia	2.6	1.9	1.3	1.2	1.8	1.4	-0.4	-1.0
Canada	n.a.	0.1	n.a.	1.1	n.a.	0.6	n.a.	-1.7
Denmark	-1.9	0.5	0.2	0.4	1.8	0.5	-3.8	-0.4
Finland	0.8	2.6	0.4	0.4	2.6	1.3	-2.3	0.9
France	1.1	0.5	0.5	0.4	2.2	1.5	-1.0	-1.4
Germany	0.3	2.2	0.0	0.4	2.6	1.6	-2.4	0.2
Italy	0.2	-2.3	0.2	0.2	2.5	1.5	-2.4	-3.6
Japan	3.9	2.3	0.8	0.3	2.4	2.4	1.6	0.0
Netherlands	n.a.	1.5	n.a.	0.6	n.a.	1.5	n.a.	-0.3
Norway	2.5	0.3	0.4	0.6	2.2	1.5	0.0	-1.7
Sweden	-0.3	0.5	0.3	0.4	1.8	0.2	-2.4	-0.1
United Kingdom	0.9	1.2	0.1	0.2	2.0	1.1	-1.3	-0.2
United States	-0.1	0.7	1.0	1.0	1.6	1.4	-2.6	-1.9
EUR-8	0.6	1.0	0.2	0.3	2.3	1.4	-1.9	-0.7
IEA-11	0.5	1.0	0.7	0.7	1.9	1.5	-2.0	-1.2

	Energy Demand 1973-1990	Energy Demand 1990-1998	Activity 1973-1990	Activity 1990-1998	Structure 1973-1990	Structure 1990-1998	Intensity 1973-1990	Intensity 1990-1998
	Average Annual Percent Change (%/yr)							
SERVICE								
Australia	3.6	3.9	3.3	4.0	0.0	0.0	0.3	-0.1
Canada	n.a.	1.1	n.a.	2.5	n.a.	0.0	n.a.	-1.4
Denmark	-0.7	0.7	2.3	1.9	0.0	0.0	-3.0	-1.1
Finland	0.3	-3.4	3.6	1.1	0.0	0.0	-3.2	-4.5
France	2.2	0.6	3.6	1.4	0.0	0.0	-1.4	-0.8
Germany	-0.8	1.1	3.3	3.1	0.0	0.0	-4.0	-1.9
Italy	0.5	3.4	3.3	1.6	0.0	0.0	-2.7	1.8
Japan	2.5	3.0	4.4	2.8	0.0	0.0	-1.8	0.2
Netherlands	n.a.	3.6	n.a.	3.1	n.a.	0.0	n.a.	0.5
Norway	3.2	1.8	3.2	3.9	0.0	0.0	0.0	-2.1
Sweden	0.0	-0.4	2.5	1.3	0.0	0.0	-2.5	-1.6
United Kingdom	0.7	1.4	2.4	2.9	0.0	0.0	-1.7	-1.5
United States	0.9	1.9	3.1	3.2	0.0	0.0	-2.1	-1.3
EUR-8	0.4	1.1	3.1	2.4	0.0	0.0	-2.6	-1.2
IEA-11	0.9	1.8	3.2	2.9	0.0	0.0	-2.2	-1.0
PASSENGER TRANSPORT								
Australia	2.8	1.9	3.1	2.1	0.0	0.8	-0.2	-0.5
Canada	n.a.	1.5	n.a.	1.7	n.a.	0.1	n.a.	-0.2
Denmark	1.5	2.0	1.6	1.9	-0.1	0.0	0.1	0.1
Finland	3.9	-0.8	2.8	0.3	0.2	0.2	0.7	-1.2
France	2.6	1.1	2.5	1.6	0.1	0.2	-0.1	-0.6
Germany	3.0	-0.4	2.1	0.4	0.3	0.1	0.5	-0.8
Italy	3.2	2.9	3.4	2.5	0.2	0.3	-0.5	0.1
Japan	4.0	4.6	2.8	1.7	1.4	1.1	-0.5	1.7
Netherlands	n.a.	1.7	n.a.	1.5	n.a.	0.0	n.a.	0.4
Norway	3.2	0.4	2.9	1.4	0.3	0.3	-0.2	-1.2
Sweden	1.7	0.2	1.3	-0.4	0.0	-0.1	0.2	0.6
United Kingdom	2.2	0.0	2.5	0.5	0.2	0.0	-0.7	-0.8
United States	0.7	1.9	2.0	2.5	0.1	0.0	-1.6	-0.6
EUR-8	2.7	0.6	2.5	1.0	0.2	0.1	-0.1	-0.6
IEA-11	1.4	1.8	2.2	2.1	0.2	0.1	-1.2	-0.4
FREIGHT TRANSPORT								
Australia	2.6	2.2	2.1	4.0	2.7	-0.1	-2.1	-1.6
Canada	n.a.	2.9	n.a.	2.9	n.a.	1.7	n.a.	-1.0
Denmark	5.3	0.6	0.5	0.8	0.4	-0.1	4.4	-0.1
Finland	1.9	2.3	1.7	-0.1	0.5	-0.3	-0.3	2.8
France	2.3	1.7	0.5	2.0	1.3	0.5	0.5	-0.7
Germany	0.6	3.7	1.9	2.4	0.9	0.8	-1.9	0.4
Italy	3.9	-0.5	3.6	1.3	0.8	-0.3	-0.6	-1.5
Japan	2.7	1.2	1.7	0.1	1.8	0.9	-0.6	0.3
Netherlands	n.a.	3.5	n.a.	2.3	n.a.	0.4	n.a.	0.8
Norway	1.9	3.5	0.6	4.0	1.2	0.7	-0.1	-1.2
Sweden	2.1	-2.4	1.0	1.4	0.4	1.1	0.7	-4.6
United Kingdom	1.5	1.1	2.4	1.5	0.1	0.3	-1.0	-0.7
United States	2.4	2.8	1.9	2.3	0.6	1.5	0.0	-0.9
EUR-8	2.0	1.6	1.8	1.8	0.7	0.4	-0.7	-0.6
IEA-11	2.4	2.3	1.9	1.9	0.8	1.1	-0.3	-0.7

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