INTERNATIONAL ENERGY AGENCY

Worldwide Trends in Energy Use and Efficiency

Key Insights from IEA Indicator Analysis

In support of the G8 Plan of Action

ENERGY INDICATORS

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Governments in many countries are increasingly aware of the urgent need to make better use of the world's energy resources. Improved energy efficiency is often the most economic and readily available means of improving energy security and reducing greenhouse gas emissions. What progress are we currently making in our efforts to improve energy efficiency? Why are countries' energy intensities so different? And how can the introduction of best available technologies help reduce energy use?

To answer these questions, the IEA has developed in-depth indicators – tools that provide state-of-the-art data and analysis on global energy use, efficiency developments and CO_2 emissions. These indicators form part of the IEA contribution to the G8 *Gleneagles Plan of Action for Climate Change, Clean Energy and Sustainable Development*.

Worldwide Trends in Energy Use and Efficiency summarises the main results and conclusions from this work. It brings together information on all end-use sectors plus power generation, for key developed and developing countries. Using new statistics and methodologies, the analysis clearly identifies the factors driving and restraining the demand for energy, and the opportunities for improved energy efficiency. It also highlights the gaps in currently available data and proposes a major new international effort to improve the availability and quality of information on this crucial topic.

OECD

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INTERNATIONAL ENERGY AGENCY

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-seven of the OECD 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 promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies.

The IEA member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. Poland is expected to become a member in 2008. The European Commission also participates in the work of the IEA.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.
The European Commission takes part in the work of the OECD.

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FOREWORD

Improved energy efficiency is a shared policy goal of many governments around the world. The benefits of more efficient use of energy are well known and include reduced investments in energy infrastructure, lower fossil fuel dependency, increased competitiveness and improved consumer welfare. Efficiency gains can also deliver environmental benefits by reducing greenhouse gas emissions and local air pollution.

However, tracking trends in energy efficiency and comparing the performance of countries is not straightforward. Energy efficiency is only one of a number of factors that impact energy use, so it is perfectly possible to have improving energy efficiency, while still seeing rises in energy consumption. Disentangling the various factors that drive and restrain energy use is the key purpose of the IEA energy indicator work.

This summary report is the latest in a series of publications on energy indicators from the IEA in support of the Gleneagles Plan of Action. This follows a request from the leaders of the G8 at their July 2005 summit for advice on how to achieve a clean, clever and competitive energy future.

The overall message from the indicators work is clear; the current rate of energy efficiency improvement is not nearly enough to overcome the other factors driving up energy consumption. As a result we are heading for an unsustainable energy future. We must find new ways to accelerate the decoupling of energy use and CO_2 emissions from economic growth. The good news is that this analysis also shows there is still substantial scope for improving energy efficiency based on existing technology. However, realising this potential will require strong and innovative action on the part of governments. Governments also need to put greater efforts into improving the availability, timeliness, quality and comparability of the detailed data needed to target and evaluate the new policies that will be required.

The analysis contained in this book would not have been possible without the substantial help we received from governments, organisations, companies and industry associations with collecting and validating the underlying data. We are very grateful for the close collaboration of the statisticians and analysts in IEA member countries, including experts from the European Union sponsored ODYSSEE network.

This publication was prepared by the Office of Energy Technology and R&D (ETO) in co-operation with the Energy Statistics Division (ESD). Peter Taylor is the co-ordinator of the IEA indicators work and had overall responsibility for the report. The other authors were Michel Francoeur, Olivier Lavagne d'Ortigue, Cecilia Tam and Nathalie Trudeau. Many other IEA colleagues contributed to the analysis. Particular thanks go to the IEA Communication and Information Office (CIO) for their work in designing the layout and producing this publication.

Nobuo Tanaka
Executive Director

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Introduction

Governments in many countries are increasingly aware of the urgent need to make better use of the world's energy resources. Improved energy efficiency is often the most economic and readily available means of improving energy security and reducing greenhouse gas emissions. To support better energy efficiency policy-making and evaluation, the International Energy Agency (IEA) is developing in-depth indicators of energy use, efficiency trends and CO_2 emissions.

The work has been undertaken in response to a request from G8 leaders to support the Gleneagles Plan of Action, launched in July 2005. In this Plan, the leaders addressed the global challenges of tackling climate change, promoting clean energy and achieving sustainable development. They identified the need to transform the way we use energy as a top priority.

This publication provides a summary of the key results of the indicators work so far. It shows how indicators can be used to identify the factors driving and restraining the demand for energy, explains why there are differences in energy intensities amongst countries, and quantifies how the introduction of best available technology can help reduce energy use. It builds on two earlier indicator reports, published in 2007, *Tracking Industrial Energy Efficiency and CO_2 Emissions* and *Energy Use in the New Millennium: Trends in IEA Countries*.

Key Findings

Recent Trends in Energy Use and Efficiency

Detailed analysis for IEA countries shows that improved energy efficiency continues to play a key role in shaping energy use and CO_2 emissions patterns, but that the rate of improvement has slowed substantially. Results for a group of 16 IEA countries show that since 1990 about half of the increased demand for energy services has been met through higher energy consumption, and the other half through gains in energy efficiency. All sectors achieved efficiency improvements, which averaged 0.9% per year between 1990 and 2005. These improvements led to energy and CO_2 savings of 15% and 14% respectively in 2005 (16 EJ and 1.3 Gt CO_2). This translates into fuel and electricity cost savings of at least USD 180 billion in 2005. However, the efficiency gains are about half those seen in previous decades; energy efficiency improvements averaged 2% per year between 1973 and 1990. Therefore, over the longer term, the savings from improved energy efficiency have been even more significant. Without any energy efficiency gains since 1973, energy use in a group of 11 IEA countries would have been 58% higher in 2005 than it actually was. This is the equivalent of 59 EJ of energy not consumed.

Data for countries outside the IEA are much less detailed and comprehensive, limiting the indicators that can be developed. However, initial analysis reveals that final energy consumption in developing and transition countries is growing less quickly than gross domestic product, due to a combination of structural changes and energy efficiency improvements. Since 1990, these reductions in energy intensity have generally been greater than for IEA countries. Nevertheless, the energy intensities of developing and transition countries remain higher on average than for the IEA. At a sectoral level, some interesting results are also emerging on the different patterns of energy use and efficiency in various parts of the world.

Potential for Further Energy Savings

Despite the recent improvements in energy efficiency, there still remains a large potential for further energy savings across all sectors. For instance, analysis of industry shows that the application of proven technologies and best practices on a global scale could save between 25 EJ and 37 EJ per year, which represents between 18% and 26% of current primary energy use in industry. The associated CO_2 emissions savings are 1.9 Gt CO_2 to 3.2 Gt CO_2 per year. The largest savings potentials can be found in the iron and steel, cement and chemical and petrochemical sectors.

In the electricity generation sector, if all countries produced electricity at current best practice levels of efficiency then fossil fuel consumption for public electricity generation could be reduced by between 23% and 32%. This is equivalent to energy savings of between 21 EJ and 29 EJ per year and CO_2 reductions of 1.8 Gt CO_2 to 2.5 Gt CO_2. The largest savings of both energy and CO_2 emissions are from improving the efficiency of coal-fired plants. On a regional basis, just under half the global savings would be from OECD countries, with the remainder from developing and transition countries.

Conclusions and Further Work

Accelerating energy efficiency improvements is a crucial challenge for energy and climate policies. The rate of energy efficiency improvement needs to be increased substantially to achieve a more secure and sustainable energy future. The good news is that this is indeed possible. There are some signs that the rate of improvement in energy efficiency has been increasing slightly in the last few years, as a result of the many policies recently initiated. Furthermore, this report shows examples across all sectors of particular countries achieving higher than average rates of energy efficiency improvement. It also highlights that a large potential remains for further energy efficiency gains. All governments must learn from the best practices of others and act now to develop and implement the necessary mix of market and regulatory policies, including stringent norms and standards. This should be complemented by efforts to drive down the CO_2 intensity of electricity production by moving towards a cleaner technology mix. The IEA has presented a list of high-priority energy efficiency policy recommendations to help governments increase rates of energy efficiency improvement.

Energy indicators can play an important role in supporting energy efficiency policy development and evaluation. Many IEA member countries already use energy indicators and their use is attracting increasing interest from other countries. The IEA role is to assist and internationalise these efforts by developing transparent and consistent international databases and methodologies and by collaborating with governments, industry and other international and regional organisations.

In taking forward the indicators work, the most urgent need is to improve the availability, timeliness, quality and comparability of the underlying data. The situation is most challenging for non-IEA countries, with little or no detailed data available for most countries. Data quality and comparability also still need to be improved in IEA countries, particularly for the industry sector. Improvements to the data could best be achieved through an agreed system of reporting for major developed and developing countries, working with both governments and industry. The IEA, together with other regional organisations, is currently developing a common indicator template. This template could be used to define a joint questionnaire on energy efficiency, similar to the existing five annual IEA energy statistics questionnaires. This improved reporting would then provide a means for developing indicators that can be tailored to the needs of both IEA and other countries. Finally, the IEA encourages countries to use the indicators framework to support the implementation and evaluation of its energy efficiency policy recommendations.

INTRODUCTION

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This publication provides an overview of recent work by the International Energy Agency (IEA) to develop in-depth indicators of energy use, efficiency developments and CO_2 emissions. The indicators are used to identify the factors driving and restraining the demand for energy, explain why there are differences in energy intensities amongst countries, and quantify how the introduction of best available technology can help reduce energy use.

This work has been undertaken in response to a request from G8 leaders to support the Gleneagles Plan of Action (GPOA), launched in July 2005. The GPOA addresses the global challenges of tackling climate change, promoting clean energy and achieving sustainable development. In particular, it identifies improvements to energy efficiency as having benefits for energy security, economic growth and the environment.

The following chapters update and expand on the key results for the industry, household, service and transport sectors presented in two recent IEA indicator books: *Tracking Industrial Energy Efficiency and CO_2 Emissions* and *Energy Use in the New Millennium: Trends in IEA Countries*.[1] New features of the analysis include:

- ▷ expanded coverage to include aggregate indicators for key developing and transition countries, based on IEA statistics;
- ▷ extended time series for most indicators with data for the year 2005;
- ▷ detailed indicators for a further two IEA countries (Republic of Korea and Switzerland), bringing the total included to 22;
- ▷ updated results for industry, including regional potentials for some key sub-sectors; and
- ▷ new indicators examining the efficiency of electricity generation from fossil fuels.

A key focus of the IEA indicators work is to provide an integrated analysis of how energy efficiency in all end-use sectors and electricity generation has affected recent developments in energy use and CO_2 emissions. The potentials for further efficiency improvements are also quantified for industry and electricity generation.

The remainder of this report is structured as follows. Chapter 2 highlights the overall trends, examining energy use and CO_2 emissions across all end-use sectors. Each of the following four chapters explores one end-use sector in more detail: industry, households, services and transport. Chapter 7 then presents indicators for electricity generation. Finally, Chapter 8 summarises key conclusions and discusses ideas for further work.

1. The reader is referred to these publications for more detailed analysis and for further information on the data sources and methodologies used.

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OVERALL TRENDS

Summary

- Between 1990 and 2005 global final energy use increased by 23% while the associated CO_2 emissions rose by 25%. Most of the growth in energy use and CO_2 emissions occurred in non-OECD countries.
- Globally, energy consumption grew most quickly in the transport and service sectors, driven by rising passenger travel and freight transport, and a rapid expansion in the service economy.
- Oil products remained the most important final energy commodity with a global share of 37% in 2005, driven by their use in transport. Electricity consumption is growing rapidly in many countries; its global use increased by 54% between 1990 and 2005. Traditional biomass and coal both remain important in non-OECD countries although their shares of total final energy use are declining.
- Energy use has been increasing more slowly than economic activity in most countries. As a result, global energy intensity, calculated in terms of final energy use per unit of gross domestic product (GDP), fell by 26% between 1990 and 2005. The reductions in energy intensity were largest in non-OECD countries, due to a combination of structural changes and efficiency improvements.
- In contrast, final energy use per capita increased in most countries between 1990 and 2005. This increase was linked to growing wealth which leads to increased per capita demand for energy-using goods and services. On average, final energy use per capita in non-OECD countries is only 23% of the level in the OECD.
- Better understanding of the factors affecting energy consumption, including the role of energy efficiency, requires indicators based on more detailed data than are available in the IEA statistical balances. However, this more detailed information is currently only available on a comparable basis for some IEA countries.
- Analysis with these disaggregate indicators for 16 IEA countries (IEA16) shows that improved energy efficiency has been the main reason why final energy use has been decoupled from economic growth. Without the energy efficiency improvements that occurred between 1973 and 2005 in 11 of those countries, energy use would have been 58%, or 59 EJ, higher in 2005 than it actually was. However, since 1990 the rate of energy efficiency improvement has been much lower than in previous decades.
- These findings provide an important policy conclusion – 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.

Introduction

This chapter examines energy use by final consumers in the main end-use sectors: industry, households, services and transport (excluding international aviation and marine transport). CO_2 emissions that result from this final energy consumption are also covered, including indirect emissions from the use of electricity and heat. However, the analysis does not include either the fuels used in the energy sector for the production of electricity and heat or for the transformation of crude oil into refined petroleum products.[2]

Trends in the development of final energy and CO_2 emissions by sector and energy commodity are presented, together with aggregate indicators showing final energy intensity (final energy use per unit of gross domestic product (GDP)) and energy use per capita in different countries and regions. These aggregate indicators have the advantage that they can be compiled on a reasonably consistent basis for all countries and regions and so allow comparisons of trends and levels across different countries.

However, such indicators are not sufficiently detailed to explain fully the factors affecting energy consumption and CO_2 emissions. More detailed energy indicators are required to make the link between drivers of demand and their impact on overall energy consumption. Such disaggregated information is much less readily available. Comprehensive and detailed data for all end-use sectors are available for a group of 16 IEA countries (see Annex A for country coverage). This has allowed more detailed indicators to be constructed for these countries, including a decomposition analysis to quantify the impact of the different factors affecting final energy use.

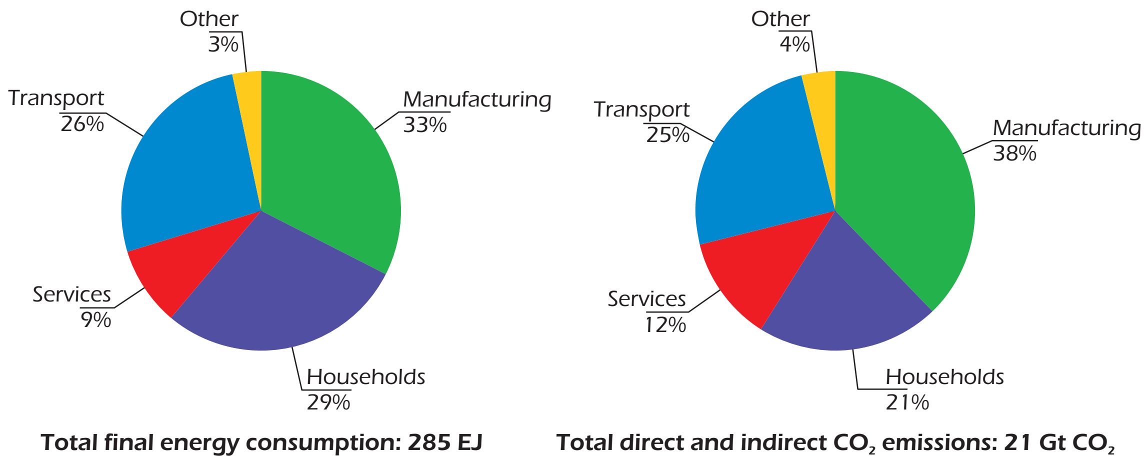
Global Trends

Between 1990 and 2005, global final energy consumption increased by 23%. Energy consumption grew most quickly in the service and transport sectors, both sectors showing an increase of 37%. These increases were driven by strong growth in activity in these sectors for many countries (see Chapters 5 and 6). Figure 2.1 shows that in 2005, manufacturing industry was the end-use sector that globally consumed the most energy, with a 33% share. It was followed by households (29%) and transport (26%).

Trends in CO_2 emissions are driven by the amount and type of energy used and the indirect emissions associated with the production of electricity. Between 1990 and 2005, global CO_2 emissions from final energy use increased to 21.2 Gt CO_2, a rise of 25%. Manufacturing was again the most important sector in 2005, with a share of 38%, but for CO_2 emissions the share from transport (25%) was higher than for households (21%). The sectors rank differently depending on whether energy or CO_2 emissions are being considered, as they do not all use the same mix of energy commodities and so have different average levels of CO_2 emissions per unit of energy consumption.

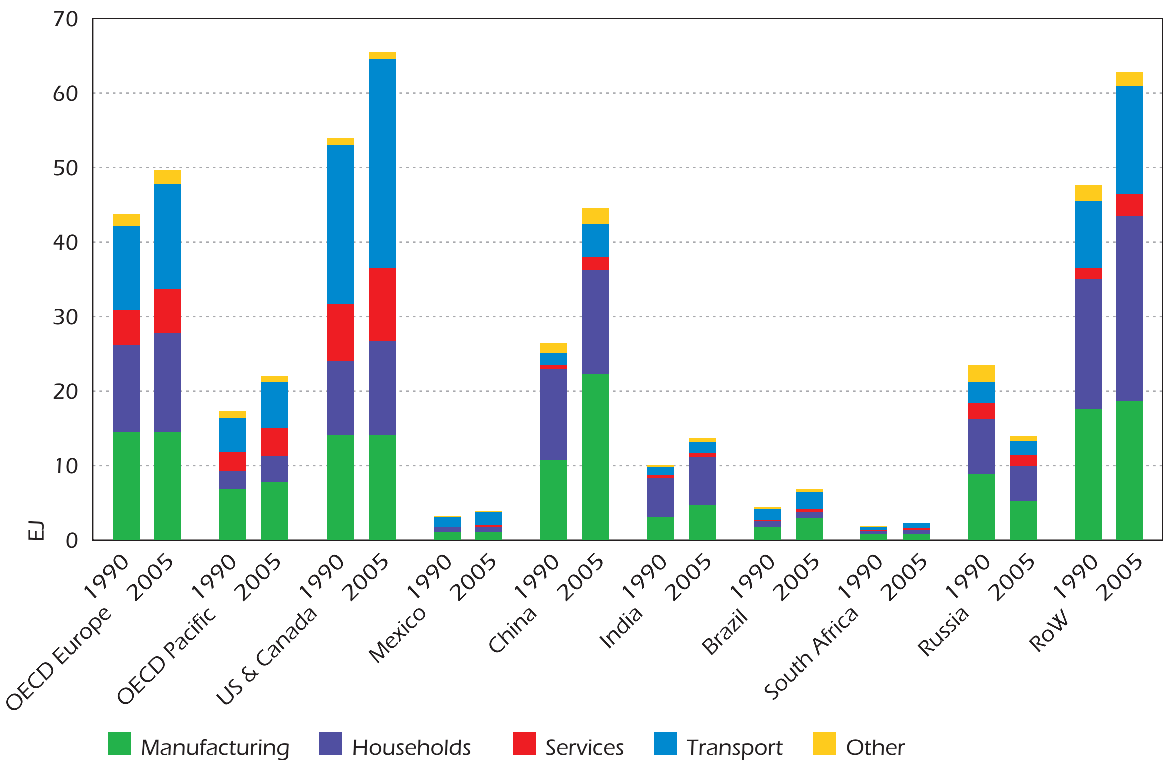
2. The definition of final energy consumption used in this chapter differs from that in the IEA energy balances. Full details of the coverage used here can be found in Annex A of IEA, 2007b. The coverage of industry also differs from that in Chapter 3. In this chapter only manufacturing industry is included, whereas Chapter 3 covers all industry: manufacturing, mining and quarrying and construction.

Figure 2.1 ▶ ***Shares of Global Final Energy Consumption and CO_2 Emissions by Sector, 2005***



Sources: IEA, 2007c; IEA, 2007d; IEA, 2007e.
Note: Other includes construction and agriculture/fishing.

Figure 2.2 ▶ ***Total Final Energy Consumption by Sector***



Sources: IEA, 2007c; IEA, 2007d; IEA estimates.
Note: Other includes construction and agriculture/fishing.

Trends in energy use varied significantly amongst countries and regions (Figure 2.2). Between 1990 and 2005, final energy use grew less quickly in OECD countries (+19%) than in non-OECD countries (+27%). In OECD countries, the growth was mostly due to increasing transport energy consumption. In 2005, the transport sector accounted for

35% of total final energy use. The service sector was the second fastest growing sector, but since it only accounts for about 14% of final energy use the impact of its increase on overall energy use was less important. Despite showing only a small increase in energy consumption, the manufacturing sector retains a substantial share of total final energy use in OECD countries at 27%.

Non-OECD countries show a very different picture. In these countries manufacturing and household energy use dominates, with shares in 2005 of 38% and 36% respectively. In contrast, despite growing most rapidly between 1990 and 2005, the transport sector only accounts for 17% of total energy use.

Energy use in China is increasing most quickly amongst the major economies, due to rapid economic growth. Between 1990 and 2005, China's manufacturing energy demand more than doubled, transport energy use almost tripled and the service sector increased its consumption by three and a half times. Overall, China's final energy use increased by 69% over this period. In contrast, Russia currently has significantly lower energy consumption in all sectors of the economy when compared to 1990. Total final energy consumption decreased by 41% between 1990 and 2005, as a result of the major economic restructuring that took place in the early and mid-1990s. Most of the decreases in energy use occurred before 1998 and since then final energy use has been more stable.

Not only does the pattern of sectoral energy use vary significantly between OECD and non-OECD countries, but the final energy mix is also quite different (Figure 2.3). Due to the relative importance of the transport sector in the OECD countries, oil products accounted for 47% of total final energy use in 2005. Natural gas and electricity were the other major energy commodities with shares of 20% and 22% respectively. In contrast, the use of coal is declining and in 2005 it accounted for just 6% of total final energy use.

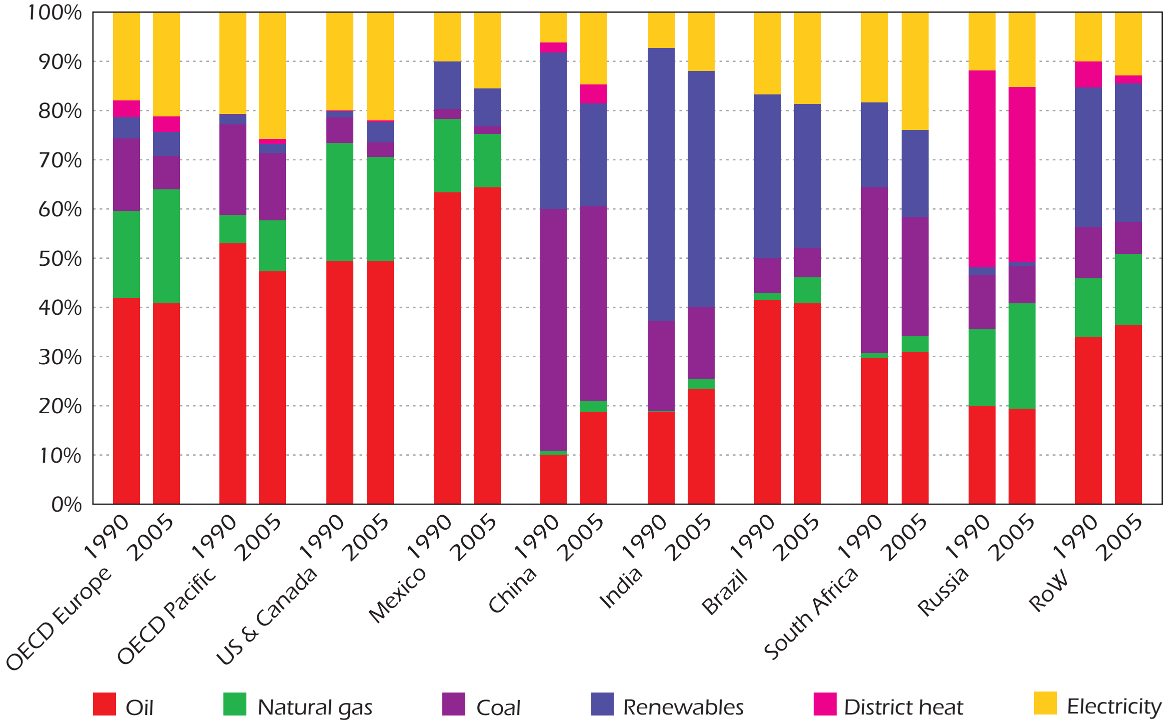
Oil products also have the largest share of consumption in non-OECD countries, accounting on average for 28% of total final energy use in 2005. In many of these countries, oil products are used not only for transport, but are important fuels in industry and households. With a share in 2005 of 25%, use of combustible renewable energy (mostly biomass) is also significant, particularly in India. However, the share of renewables is slowly declining due to the increased use of other energy commodities, such as electricity. Electricity now represents 14% of final energy use in non-OECD countries. Direct coal use remains important in some countries (such as China) and has an overall share of final consumption in non-OECD countries of 18%. The share of district heat is in decline, but its use is still significant in some transition economies, such as Russia.

Non-OECD countries experienced a faster growth in CO_2 emissions (+39%) than OECD countries (+15%). In the OECD the increase in CO_2 emissions was slightly less than the increase in final energy use, meaning that the CO_2 intensity of final energy use has fallen. However, the reverse was true in non-OECD countries, which consequently experienced an increase in the carbon intensity of energy use (Figure 2.4).

Countries with a high share of renewable energy (*e.g.* India and Brazil) have a lower carbon energy mix than the global average. On the other hand, countries with a high share of coal use (*e.g.* South Africa and China) have much higher carbon intensity. The fuels used to produce electricity and the conversion efficiency of this production play a key role in the overall carbon intensity of the final energy mix (see Chapter 7 on electricity generation).

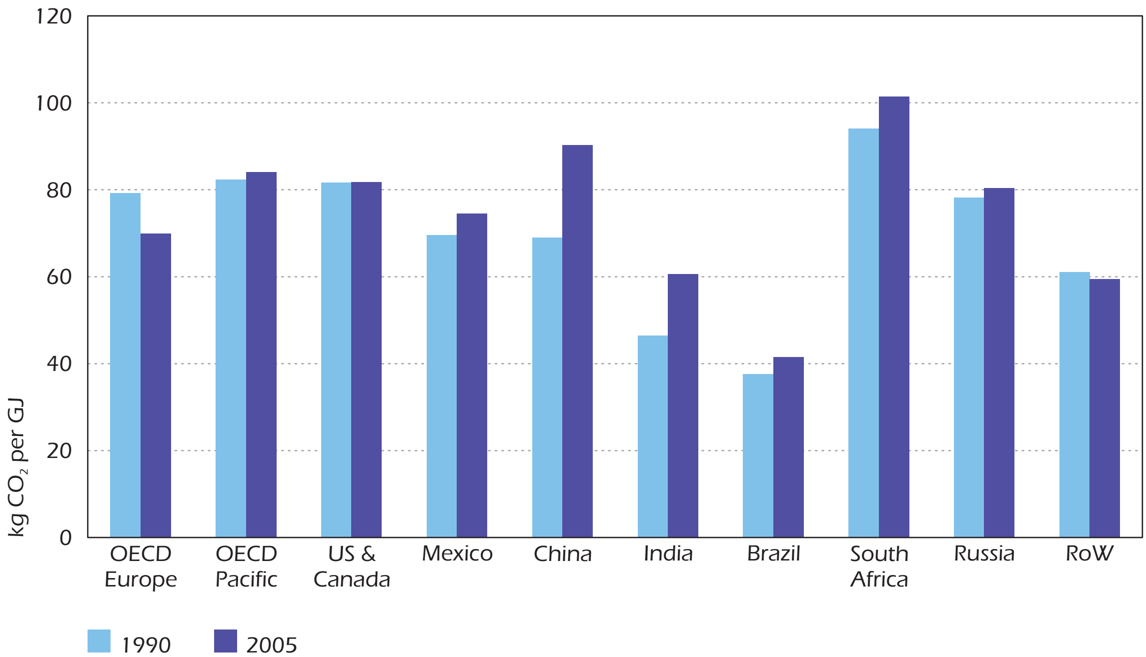
2

Figure 2.3 ▶ ***Total Final Energy Consumption by Energy Commodity***



Sources: IEA, 2007c; IEA, 2007d; IEA estimates.
Note: Excludes fuel use in electricity and heat production.

Figure 2.4 ▶ ***Carbon Intensity of the Final Energy Mix***



Sources: IEA, 2007c; IEA, 2007d; IEA, 2007e; IEA estimates.

A starting point for understanding the differences in the evolution and absolute levels of final energy use amongst countries is to examine some aggregate energy indicators that show energy use divided by a measure of activity that drives energy demand. For the overall economy, total final energy consumption (TFC) per unit of gross domestic product (GDP) and energy use per capita are the most commonly used aggregate indicators.

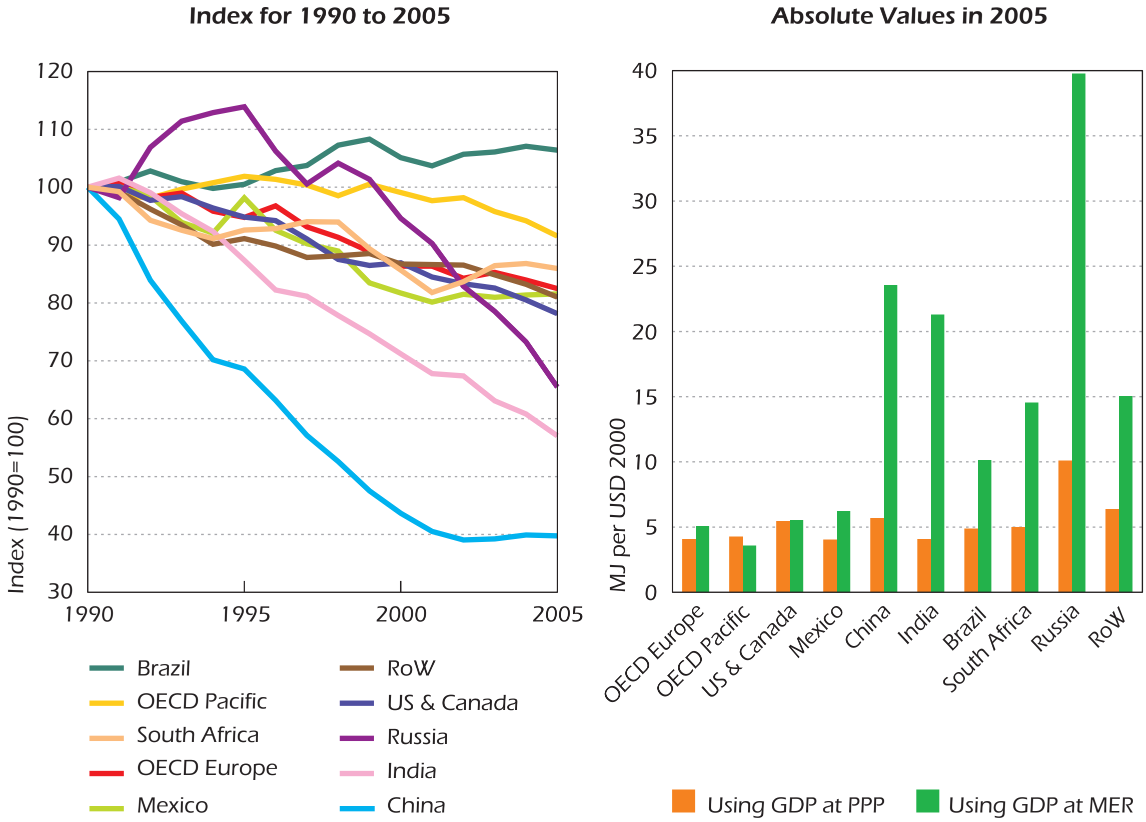
The ratio of TFC to GDP measures how much energy is needed to produce one unit of economic output. In order to perform cross-country comparisons, a common measure of GDP must be used. Two main approaches are used to convert GDP in national currency to a common unit of measure: conversion at market exchange rates (MER) and at purchasing power parity (PPP). The MER approach simply uses actual exchange rates to convert GDP or value-added in national currencies to a common currency, such as the United States dollar (USD). In contrast, the PPP approach defines a "basket of goods" (or services) and then equalises the purchasing power of various currencies to "buy" these goods in their home countries. These special exchange rates are then used to convert GDP or value-added to USD. In both cases the analysis presented here uses exchange rates for the year 2000 to translate national currencies to USD.

The two approaches produce different results for the level of TFC per GDP (or aggregate final energy intensity), which can affect how countries compare with one another (Figure 2.5). Using GDP at PPP, aggregate final energy intensity in 2005 varies from 4.0 MJ per USD in Mexico to 10.1 MJ per USD in Russia. When using GDP at MER, TFC per GDP varies from 3.6 MJ per USD in OECD Pacific to 39.8 MJ per USD in Russia. Using MER, all the non-OECD countries presented in the analysis use more energy per unit of GDP than those in the OECD. However, these differences narrow considerably and sometimes completely disappear when calculating aggregate final energy intensity based on GDP at PPP.

Several factors explain why these variations in energy consumption levels per unit of economic output are so different amongst countries. Part of the difference reflects variations in energy efficiency. However, it would be misleading to rank energy efficiency performance according to a country's energy consumption per GDP measured using either PPP or MER. The ratio is affected by many non-energy factors such as climate, geography, travel distance, home size and manufacturing structure. This highlights the need for more detailed indicators to take account of these factors and to separate out the role of energy efficiency.

Trends in aggregate final energy intensity reveal that all countries and regions analysed have shown a decline since 1990, with the exception of Brazil. In general, non-OECD countries have shown a faster rate of reduction than OECD countries. In many cases these reductions can be attributed to strong efficiency improvements due to the introduction of modern, efficient technologies and processes. For instance, an analysis for China (LBNL, 2006) has shown that improved energy efficiency, particularly in industry, was one of the main factors driving down energy use per unit of GDP during the 1990s. On the other hand, changes in the structure of the economy can act either to increase or decrease the level of aggregate final energy intensity. In the case of Brazil, strong increases in energy use, particularly in the manufacturing and transport sectors between 1990 and 2005, coupled with modest economic growth, led to a slight rise in aggregate final energy intensity.

Figure 2.5 ▶ ***Total Final Energy Consumption per Unit of GDP***

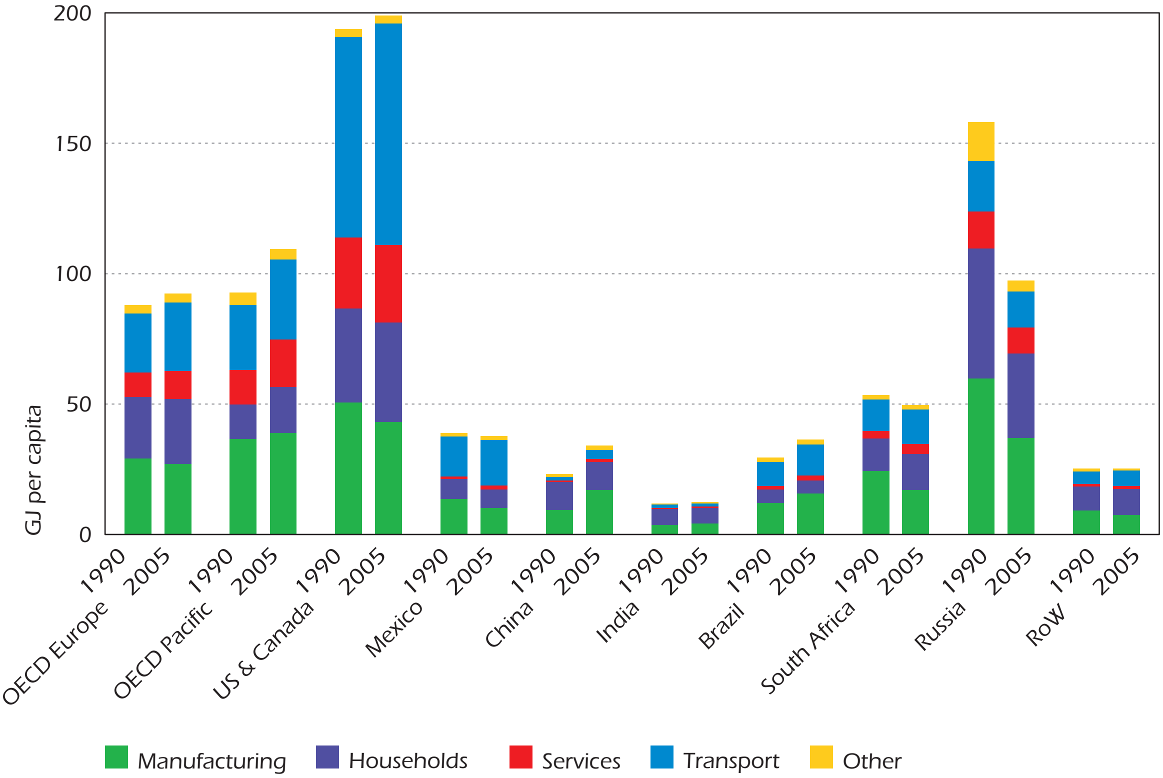


Sources: IEA, 2007c; IEA, 2007d; IEA estimates.

An alternative aggregate indicator to TFC per GDP is final energy use per capita (Figure 2.6). This indicator measures the amount of final energy "used" per person in a country. In contrast to aggregate final energy intensity, this indicator shows an increase for most countries and regions. For the OECD, energy use per capita increased by 6% between 1990 and 2005, while the increase in non-OECD countries was 1%. However, Russia is a significant exception, with energy use per capita having fallen by 39% over this period. This is linked with falling wealth, as measured by GDP per capita. Indeed, if Russia is excluded from the calculation for non-OECD countries, then per capita energy use in the remaining countries increased by 14% between 1990 and 2005. South Africa has also experienced a small decrease in energy use per capita over this timeframe. China, which showed the most significant decrease in TFC per GDP between 1990 and 2005, had the biggest increase in energy use per capita over this period (+47%), reflecting growing personal wealth (GDP per capita).

In terms of absolute levels, the United States and Canada are by far the largest consumers of energy on a per person basis, at almost 200 GJ per capita. This level is around twice that seen in other parts of the OECD. In contrast, energy use per capita in India is only 13 GJ in 2005. On average, energy use per capita in non-OECD countries is only 23% of the level seen in the OECD.

Figure 2.6 ▶ ***Total Final Energy Consumption per Capita***



Sources: IEA, 2007c; IEA, 2007d; IEA estimates.
Note: Other includes construction and agriculture/fishing.

The aggregate indicators, final energy use per GDP and final energy use per capita, are two very different ways of looking at the link between developments in final energy consumption and some of the most important underlying drivers. Both these indicators can be constructed for a wide range of countries and are useful for simple cross-country comparisons. However, neither indicator includes sufficient information about the factors impacting energy consumption to understand fully what is happening. More detailed end-use data are needed for each sector concerning activity levels, structural effects and efficiency trends to develop disaggregate indicators that can provide a more complete explanation of changes in final energy use and the associated CO_2 emissions. The development of these detailed indicators has been the main focus of the IEA energy indicators work.

Disaggregate Indicators

Comparable and disaggregated end-use information about the patterns of energy consumption in all end-use sectors (manufacturing, households, services and transport) is available for 16 IEA countries for the period from 1990 to 2005. This information, coupled with economic and demographic data, can then be used to construct indicators that identify the factors behind increasing energy use and those that restrain it.

One of the most important issues to understand from an energy policy perspective is to what extent improvements in energy efficiency have been responsible for the declines in final energy intensity seen in the different IEA countries. To understand the role of energy efficiency, it is necessary to separate the impact of changes in sub-sectoral energy intensities (which are used as a proxy for energy efficiency) from the effects of changes in economic structure and other factors that influence the demand for energy. This is done using a decomposition approach that separates and quantifies the impacts of changes in activity, structure and energy intensities on final energy use in each sector and country (see Box 2.1). The results of the sector decompositions are then aggregated to analyse country-wide trends.

Box 2.1

Decomposing Changes in Energy Use

The IEA methodology for analysing energy end-use trends distinguishes between three main components affecting energy use: activity levels, structure (the mix of activities within a sector) and energy intensities (energy use per unit of sub-sectoral activity). Depending on the sector, activity is measured as value-added, passenger-kilometres, tonne-kilometres or population. Structure further divides activity into industry sub-sectors, transportation modes, or measures of residential end-use activity. Using an appropriate measure of end-use activity, energy intensities are then calculated for each of these sub-sectors, modes or end-use activities.

The energy intensity effect, which is used as a proxy for changes in energy efficiency, separates out how changing energy intensities influence energy consumption for a particular sector. This is done by calculating the relative impact on energy use that would have occurred between a base year (usually 1990 in this publication) and a future year (usually 2005) if the aggregate activity levels and structure for a sector remained fixed at base year values while energy intensity followed its actual development. A similar approach is used to calculate the activity and structure effects, which together represent the energy service effect. See IEA, 2007b for further details.

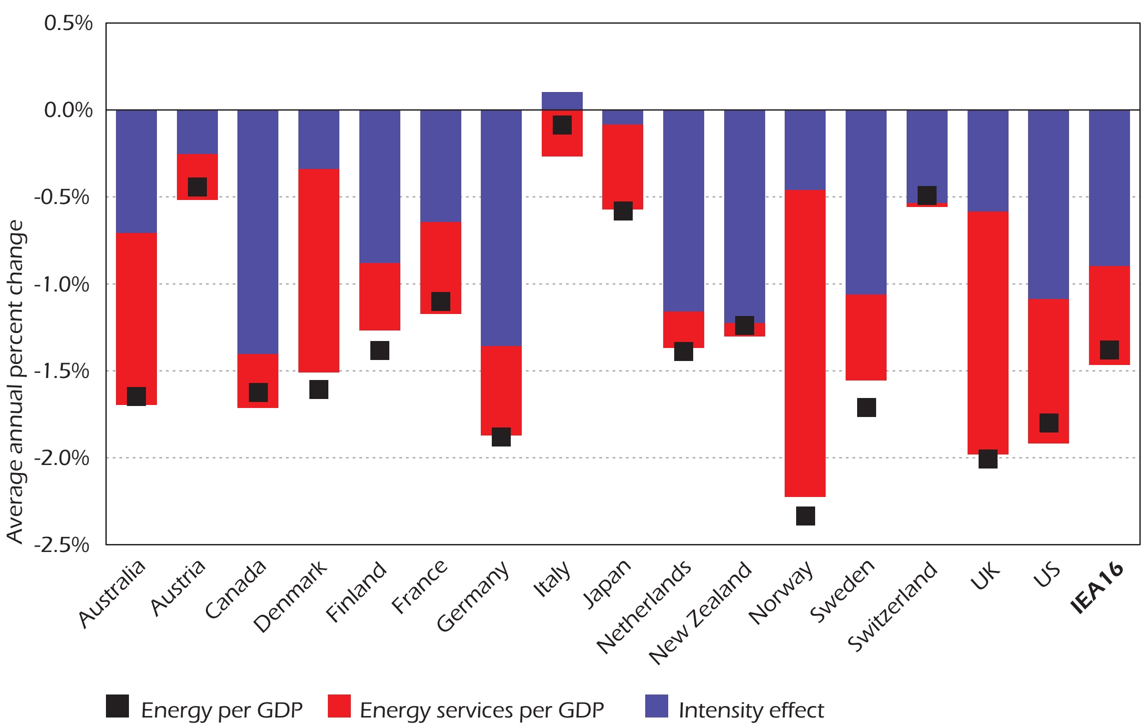
The separation of impacts on energy use from changes in activity, structure and intensity is critical for policy analysis. Most energy-related policies target energy intensities and efficiencies, often by promoting new technologies. Accurately tracking changes in intensities helps measure the effects of these new technologies.

Changes in energy consumption per GDP in each country are attributed to changes in the ratio of energy services to GDP and to changes in energy efficiency (actually sub-sector energy intensities) for more than 20 end-uses. The intensity effect for the whole economy is calculated as the aggregate impact of the sectoral intensity effects. The results of aggregate impact calculations show that the energy intensity effect and the decoupling of energy services demand and GDP since 1990 have both contributed to reduced energy consumption per unit of GDP in the IEA16 (Figure 2.7). However, declining end-use intensities (the energy intensity effect) have been the most important factor. Some 65% of the total decline in energy use per GDP for the IEA16 can be attributed to reductions from the energy intensity effect.

The relative contribution of changes in energy services per GDP and the intensity effect to the overall trend varies among countries. With the exception of Italy, all countries show that the intensity effect contributed to reducing the ratio of energy use to GDP: for most countries, it was the dominant factor. This is particularly true in the case of Canada, the Netherlands, Germany, New Zealand, Sweden and the United States. In contrast, for Norway and the United Kingdom, changes in energy services per unit of GDP were most important.

The reasons for the different trends in the intensity effect amongst countries are complex. Canada and the United States show large intensity reductions, but had high levels of energy use per GDP in 1990 and are now slowly converging to the IEA average. The sharp intensity declines seen in Germany were helped by the widespread closure of inefficient industrial plants following reunification. In the Netherlands, the intensity improvements were driven by the household and freight transport sectors. Countries that initially had lower energy use per GDP have generally seen smaller declines in intensity. This is the case for Denmark and Japan. In Austria, intensity improvements in households and passenger transport were partially offset by increased intensity in services. A similar picture is seen for Italy, where increased energy intensity in the service sector more than offset reductions in other sectors, leading to a small overall increase in the energy intensity effect.

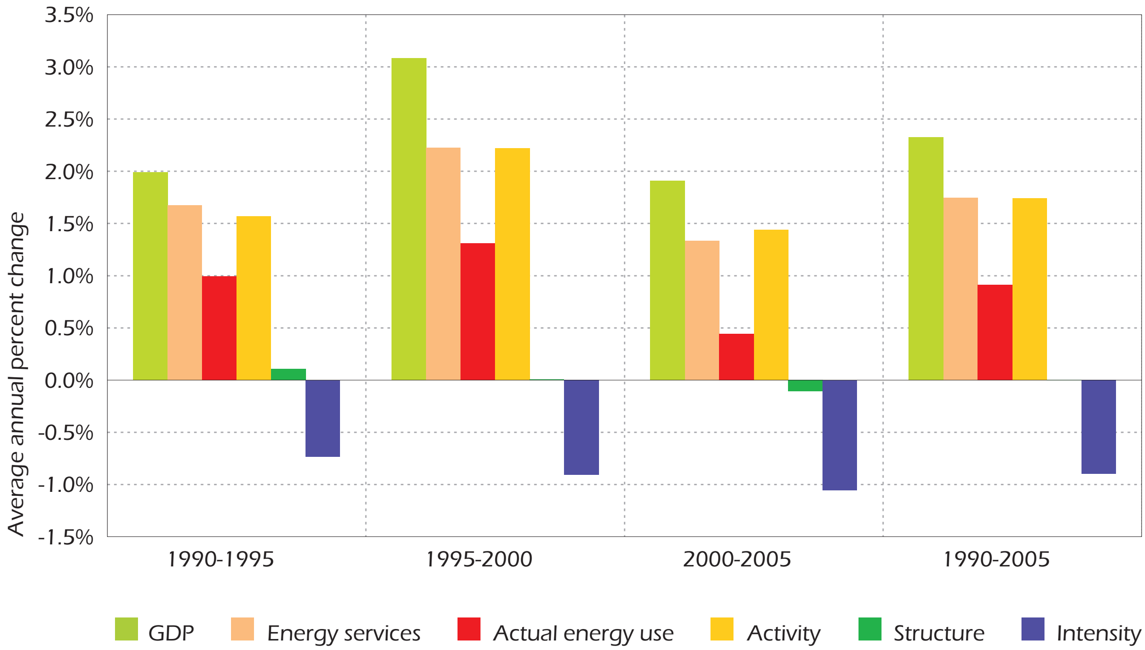
Figure 2.7 ▶ ***Changes in TFC/GDP Decomposed into Changes in Energy Services/GDP and Intensity Effect, 1990 - 2005***



Source: IEA indicators database.
Note: The figure only shows the relative changes since 1990 and so does not reflect absolute advances in energy efficiency. Some countries had achieved higher levels of energy efficiency than others prior to 1990.

Examining the three effects discussed in Box 2.1 – activity, structure and intensity – makes it possible to analyse in more detail how the factors affecting total final energy consumption in the IEA16 have evolved over time (Figure 2.8). In the early 1990s, GDP growth was relatively low (2% per year) and, with the decline in the intensity effect partly offsetting the combined impacts of activity and structure, final energy use increased by an average of 1% per year. In the mid- to late 1990s, economic growth accelerated. The demand for energy services also increased more rapidly. There was some increase in the rate of energy intensity reduction during this period, but it was not sufficient to prevent the rate of final energy demand growth rising to an average of 1.3% per year. After 2000, economic growth and the demand for energy services again slowed; the structure effect became negative. This slowing of underlying service demand, coupled with a further increase in the rate of energy intensity reduction, was sufficient to keep the growth in final energy use to below 0.5% per year.

Figure 2.8 ▶ ***Factors Affecting Total Final Energy Consumption, IEA16***



Source: IEA indicators database.

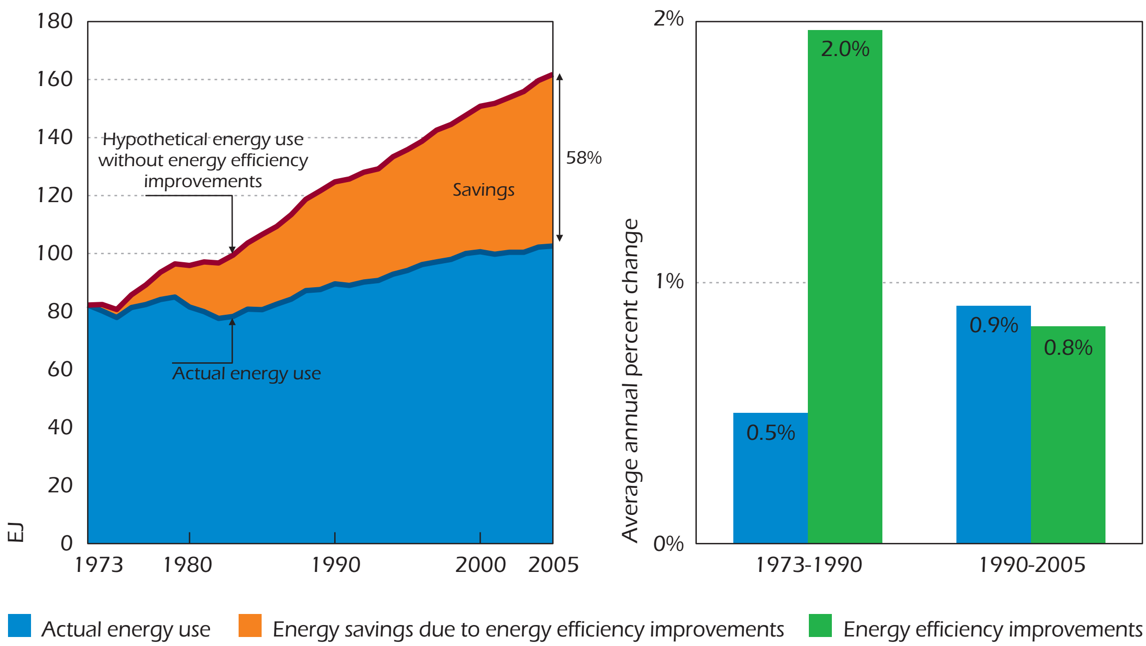
Further analysis of the developments in the intensity effect at a sector level show that, between 1990 and 2005, improvements in the manufacturing sector were most important in restraining growth in total final energy consumption. Energy intensity reductions in households and services were also important at different times. In the household sector, significant improvements in space heating intensity resulted in strong energy savings in the early 1990s. In contrast, the savings from the service sector made an impact only in the late 1990s, during a period of high economic growth in this sector. Intensity improvements in the transport sector played a smaller role.

It is possible to use this decomposition approach to track the historical role of energy efficiency in shaping final energy use patterns in IEA countries. Between 1990 and 2005, the overall improvement in energy efficiency in all end-use sectors of the economy for the IEA16 was 0.9% per year. These improvements led to energy and CO_2 savings of 15% and 14% respectively in 2005. This represents an annual energy saving of 16 EJ in 2005 and 1.3 Gt of avoided CO_2 emissions. It also translates into fuel and electricity cost savings of at least USD 180 billion in 2005. However, the efficiency gains were much lower than in previous decades; energy efficiency improvements for a group of 11 IEA countries (IEA11) averaged 2% per year between 1973 and 1990. Had the earlier rate of energy efficiency improvement been sustained then there would have been no increase in energy use in the IEA since 1990. However, there are some signs that the rate of improvement may be increasing slightly in the last few years.

Figure 2.9 shows that over the longer term, the savings from improved energy efficiency are even more significant. Without the energy efficiency improvements that occurred between 1973 and 2005, energy use in the IEA11 would have been 58%, or 59 EJ, higher in 2005 than it actually was. This makes energy savings the most important "fuel" in the IEA11 for this time period – *i.e.* the amount of energy saved in 2005 was slightly higher than the actual consumption of oil, or of electricity and natural gas combined.

These findings provide an important policy conclusion: 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 since the 1990s.

Figure 2.9 ▶ ***Long-Term Energy Savings from Improvements in Energy Efficiency, All Sectors, IEA11***



Source: IEA indicators database.

INDUSTRY

Summary

- Final energy use in industry, including feedstocks in the chemical and petrochemical sector, was 116 EJ in 2005. The associated CO_2 emissions, including indirect emissions from the use of electricity, were 9.9 Gt CO_2. Much of the growth in industrial energy demand since 1990 has been in non-OECD countries, notably China.
- Most energy-intensive industrial sectors are complex involving multiple process steps and producing a wide variety of products. It is not possible to capture such complexity through a single energy or CO_2 indicator. A number of different indicators are necessary to give the full picture of energy efficiency and CO_2 trends and levels in a country.
- Physically based indicators are often preferable to those based on economic measures of output. Such indicators have the advantage that they are not affected by price fluctuations, can be directly related to individual processes and allow a well-founded analysis of improvement potentials.
- Analysis using an indicator approach shows that there have been substantial improvements in energy efficiency in all major energy-intensive industries and in all world regions. This is often as a result of the introduction of new, more efficient technology.
- On average, Japan and the Republic of Korea have the highest levels of industrial energy efficiency, followed by Europe and North America. Energy efficiency levels in developing and transition countries show a mixed picture. Generally, the efficiency levels are lower than in OECD countries but, where there has been a recent, rapid expansion using the latest plant design, efficiencies can be high.
- A significant potential for further energy and CO_2 savings remains. The application of proven technologies and best practices on a global scale could save between 25 EJ and 37 EJ of energy per year (1.9 Gt CO_2 to 3.2 Gt CO_2 emissions per year), which represents 18% to 26% of current primary energy use in industry. The largest savings potentials can be found in the iron and steel, cement, and chemical and petrochemical sectors.
- Much more work is needed to improve the quality of the underpinning data and to refine the methodologies. Data are particularly poor for the iron and steel, chemical and petrochemical and pulp and paper sectors. Governments should work together with industry and the IEA to address these issues.

Introduction

The industry sector covers the manufacture of finished goods and products, mining and quarrying of raw materials and construction.[3] Power generation, refineries and the distribution of electricity, gas and water are excluded.

3. The coverage of industry in this chapter is consistent with the IEA recent publication *Tracking Industrial Energy Efficiency and CO_2 Emissions* (IEA, 2007a). It covers manufacturing industry (including energy used as feedstocks in the chemical and petrochemical industry), as well as mining, quarrying and construction. In contrast, Chapter 2 follows the definition used in *Energy Use in the New Millennium: Trends in IEA Countries* (IEA, 2007b). This covers manufacturing energy use (excluding feedstocks) and has construction as part of the sector "other".

Traditionally, due to a lack of data, the IEA has used indicators for industry based on energy use or CO_2 emissions per unit of value-added output. While such indicators are good at capturing aggregate trends in energy use and efficiency, they are less suited to detailed cross-country comparisons of industrial energy efficiency developments by sub-sector or process, or for an examination of improvement potentials. This is because they do not take full account of differences in product quality and composition or the processing and feedstock mix, which can vary widely between countries. Furthermore, indicators based on economic ratios cannot be validated by technological data.

The IEA therefore undertook a major study, *Tracking Industrial Energy Efficiency and CO_2 Emissions* (IEA, 2007a), which presents detailed indicators based of physical production. The advantages of this approach are that the indicators:

- are not influenced by price fluctuations, which facilitates trends analysis;
- can be directly related to process operations and technology choice, so allowing a closer measure of technical energy efficiency; and
- enable a well-founded analysis of efficiency improvement potentials.[4]

This chapter briefly presents the main findings from an aggregate decomposition analysis using the value-added approach, before describing in more detail key results from a set of indicators based on physical output.

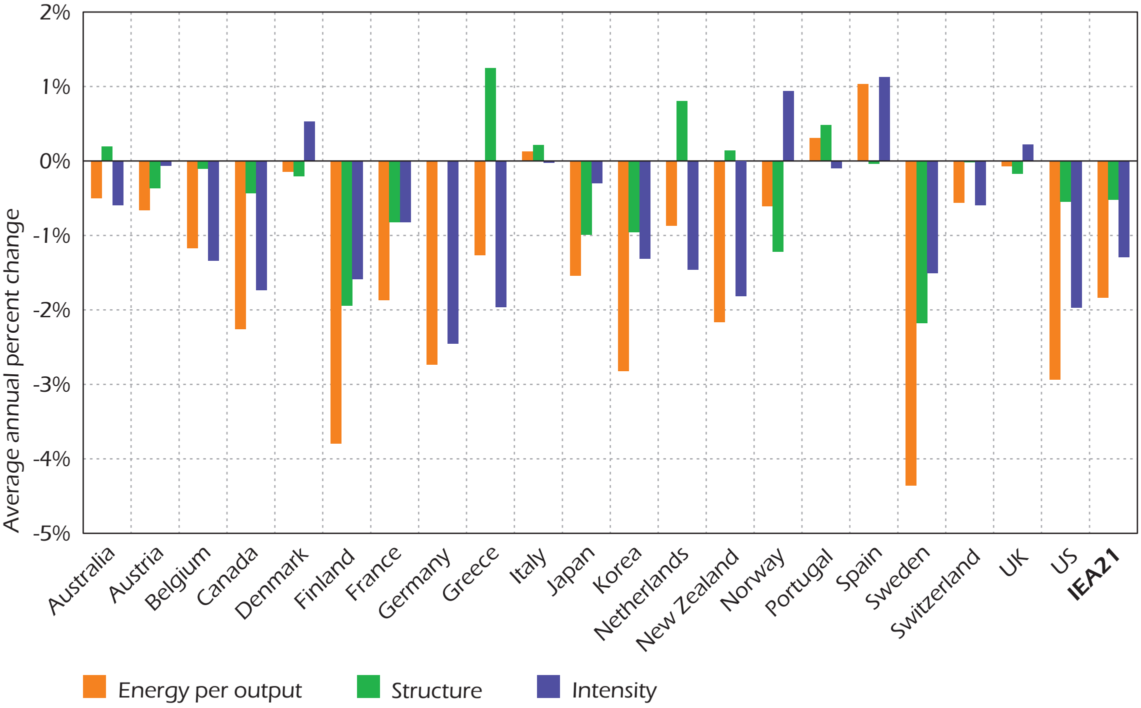
Global Trends

Global final energy use in industry totalled 116 EJ in 2005. This includes energy consumed in coke ovens, blast furnaces and steam crackers and feedstocks for the production of synthetic organic products. The associated CO_2 emissions, including indirect emissions from the use of electricity, were 9.9 Gt CO_2. Global industrial energy consumption has increased by 21% since 1990, with most of the growth being in non-OECD countries, notably China.

For a group of 21 IEA countries (IEA21), for which consistent data are available, there has been a strong decoupling of energy use from output (as measured by value-added). Despite a 39% increase in output, final energy use in the industry sector of the IEA21 increased by only 5%, between 1990 and 2005. Furthermore the analysis shows that energy efficiency improvements (as measured by changes in the structure-adjusted intensities) were the main factor restraining energy consumption growth in most countries (Figure 3.1). Without the energy savings resulting from these improvements, energy consumption in the IEA21 would have been 21% higher in 2005. This represents an energy saving of 7.3 EJ in 2005, which is equivalent to 520 Mt of avoided CO_2 emissions in that year.

4. The potentials calculated using the indicators are "instantaneous" technical potentials that do not consider practical constraints, such as capital stock turnover. They are therefore not suitable as a basis for short-term target setting. However, the potentials are useful for showing the extent to which energy efficiency can be improved by using existing best practice technology and where in the world this potential lies.

Figure 3.1 ▶ ***Decomposition of Changes in Industrial Energy Intensity, 1990 - 2005***



Source: IEA indicators database.
Note: Covers only manufacturing industries.

A few countries showed different results to the overall trends. For instance, in Finland, Norway and Sweden structural changes were the main factor restraining the growth in energy consumption. In the case of Finland and Sweden, this effect was augmented by a sharp decline in the structure-adjusted intensity. In contrast, structure-adjusted intensity increased in Norway, but because industry moved towards a less energy-intensive structure, there was a decrease in aggregate energy intensities. Denmark and Spain also showed increases in structure-adjusted intensities. In the case of Denmark this was largely due to increased energy intensities in the food and drink and non-metallic minerals sub-sectors, whereas in Spain the increased energy intensity of the chemicals sub-sector was an important factor.

The rest of this chapter explores in more detail the energy efficiency trends of five key energy intensive industrial sub-sectors. In each case, results are presented for the countries with the highest shares of global production. The analysis makes use of indicators that are based on physical production, *e.g.* energy use per tonne of product.

Disaggregate Indicators

Disaggregate indicators have been developed for iron and steel, cement, pulp and paper, chemicals and petrochemicals and aluminium. These indicators are used to track energy efficiency progress over time and also to calculate the technical potential for energy reductions in each sector that could be achieved by moving to best available technology (BAT) or best practice technology (BPT).[5] The conclusion is that the application of these technologies on a global basis could save between 25 EJ and 37 EJ of energy per year (on a primary energy equivalent basis), which represents 18% to 26% of current energy use in industry. The associated CO_2 savings would be between 1.9 Gt CO_2 and 3.2 Gt CO_2 per year.

Iron and Steel

The iron and steel sector is the second largest industrial user of energy, consuming 23 EJ in 2005. It is also the largest industrial source of CO_2 emissions. The four most important producers (China, Japan, the United States and Russia) account for 57% of total world steel production (Table 3.1).

Steel is produced via a dozen or so processing steps, laid out in various configurations depending on product mixes, available raw materials, energy supply and investment capital. There are three principal modern processing routes:[6]

- blast furnace (BF)/basic oxygen furnace (BOF), based on 70% to 100% iron ore and the remainder scrap for the iron input;
- scrap/electric arc furnace (EAF) method, based on scrap for the iron input; and
- direct reduced iron (DRI)/EAF method, based on iron ore and often scrap for the iron input.[7]

The scrap/EAF route is much less energy intensive (4 GJ to 6 GJ per tonne)[8] than the BF/BOF route (13 GJ to 14 GJ per tonne), because there is no need to reduce iron ore to iron, and it removes the need for the ore preparation, coke-making and iron-making steps. Significant energy savings can be made by switching from BF/BOF processes to scrap/EAF in some countries. However, as scrap supply is determined by the amount of steel reaching the end of its useful life, there is a limit to the proportion of total steel output that can be produced by the scrap/EAF route.

5. BAT is taken to mean the latest stage of development (state-of-the-art) of processes, facilities or of methods of operation which include considerations regarding the practical suitability of a particular measure for enhancing energy efficiency. In contrast to BAT, BPT is a term that applies to technologies and processes that are currently deployed. BAT could, in many cases, be identical to BPT. In other cases, a new technology may have just emerged, but is not yet deployed. If this is the case, the BAT energy efficiency may be better than BPT. The terms best practice and BAT are often mixed.

6. A fourth route, the open hearth furnace (OHF) route has an iron input profile similar to the BOF route, but is an outdated technology and its use is less than 3% of current global production.

7. Direct reduced iron (DRI) can be economically substituted for scrap in places where scrap is in short supply and there are cheap sources of fossil fuels (*e.g.* stranded gas supplies).

8. An electric arc furnace uses about 1.6 GJ of electricity per tonne of steel for 100% scrap feedstock and somewhat more with increasing DRI inputs. In actual operation, however, EAF energy use is somewhat higher. To be truly comparable, the electricity should be expressed in primary energy terms. With electricity generation efficiency ranging from 35% to more than 50%, EAF primary energy use is in the range of 4 GJ to 6 GJ per tonne of steel.

Table 3.1 ▶ ***Global Steel Production, 2006***

	Production Mt/yr	Production Share %	Cumulative Production Share (%)	BOF Steel (%)	EAF Steel* (%)	OHF Steel (%)
China	422.7	34.0	34.0	87.0	13.0	0.0
Japan	116.2	9.3	43.3	74.0	26.0	0.0
United States	98.6	7.9	51.2	43.1	56.9	0.0
Russia	70.8	5.7	56.9	61.6	18.4	20.0
Republic of Korea	48.5	3.9	60.8	54.3	45.7	0.0
Germany	47.2	3.8	64.6	68.9	31.1	0.0
India	44	3.5	68.2	47.3	50.5	2.3
Ukraine	40.9	3.3	71.4	56.4	9.8	33.8
Italy	31.6	2.5	74.0	37.4	62.6	0.0
Brazil	30.9	2.5	76.5	73.9	24.4	0.0
Other	292.8	23.5	100.0	–	–	–
Total	**1 244.2**	**100.0**	**100.0**	**65.5**	**32.0**	**2.4**

Source: International Iron and Steel Institute (IISI), 2007.

* Includes both the scrap/EAF and DRI/EAF routes.

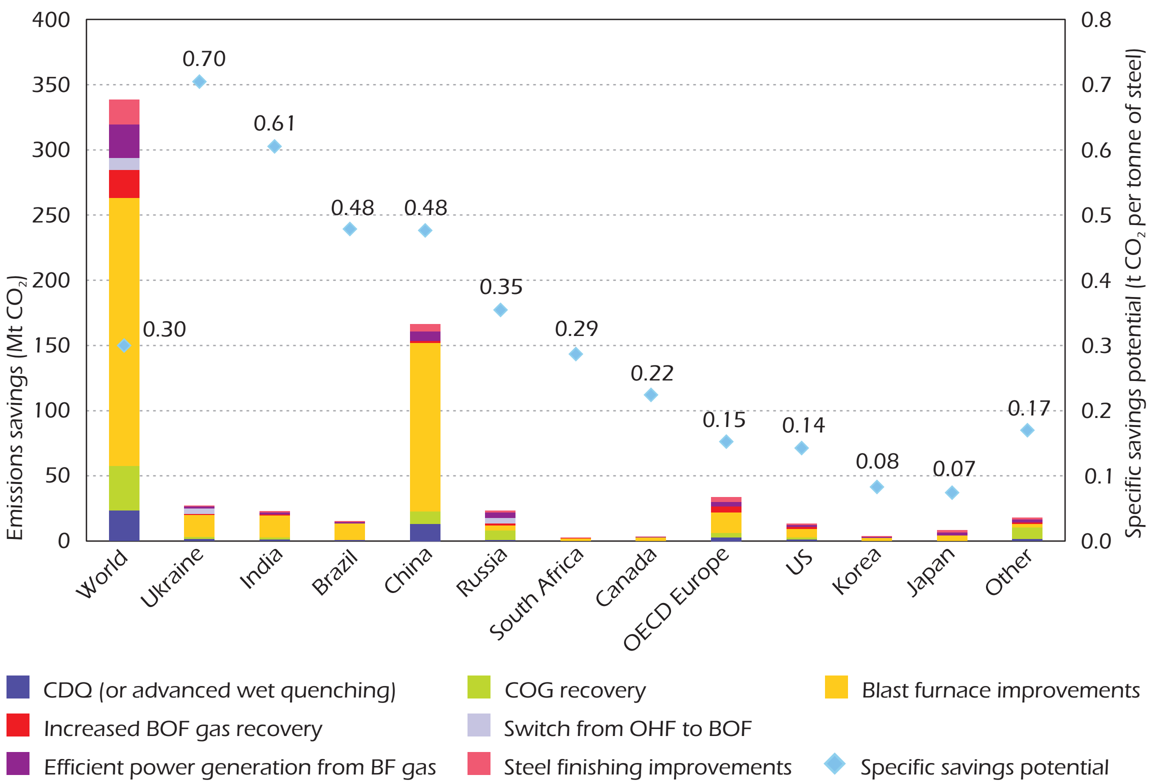
A broad-based comparison of total sub-sector energy use per tonne of crude steel is of limited use because the production processes are very different. At the very least, the BF/BOF, scrap/EAF and DRI processes need to be treated separately. Even then, there are considerable differences in the energy efficiency of primary steel production between countries and even between individual plants. These differences can be explained by factors such as economies of scale, the level of waste-energy recovery, the quality of iron ore, operations know-how and quality control. Useful indicators for this sector would include:

- ▷ total primary and final energy use per tonne of crude steel (including finishing);
- ▷ total primary and final energy use per tonne of BF/BOF steel production;
- ▷ total final energy use per tonne of DRI (split between gas- and coal-based processes);
- ▷ total primary and final energy use per tonne of EAF steel (excluding finishing); and
- ▷ total direct CO_2 emissions per tonne of crude steel.

These detailed indicators would need to be based on consistent boundary definitions across countries and take account of a number of common industry practices. These practices include the widespread trading of iron ore pellets, coke and scrap steel, the sale of blast furnace gas and coke oven gas for power generation and the use of slag by-products as a substitute for cement clinker. However, the necessary disaggregated energy data are not currently available to construct these detailed indicators. Neither are there comparable data to develop indicators for steel rolling and finishing on an aggregate level. More work is needed to collect the necessary data.

However, bottom-up estimates can be made of the energy and CO_2 reductions that could be achieved if BAT was applied worldwide. Figure 3.2 provides a breakdown of such technological potentials by country. The total potential is almost 4.5 EJ, with a CO_2 savings potential of 340 Mt CO_2. China accounts for 45% of this potential. However this is partly due to the high share of China in total world production. In terms of energy reduction potentials per unit of steel produced, OECD countries tend to have lower values than other world regions. The average global energy savings potential is 3.9 GJ per tonne of steel produced, which is equivalent to 0.3 t CO_2 per tonne of steel. Blast furnace improvements constitute the single most important efficiency category in most countries.

Figure 3.2 ▶ ***CO_2 Reduction Potentials in Iron and Steel in 2005, Based on Best Available Technology***



Source: IEA analysis.

Cement

The cement industry uses about 8 EJ of energy per year and is the third largest industrial consumer of energy. China accounted for 47% of global cement production in 2006. Other major cement producers include India, the United States and Japan (Table 3.2).

There are two basic types of cement production processes and a number of different kiln types. Cement production is either "wet" or "dry", depending on the water content of the raw material feedstock. The dry process avoids the need for water evaporation and consequently has much lower energy intensity (around 4.6 GJ per tonne of clinker compared to between 5.9 GJ and 6.8 GJ per tonne of clinker). The other major difference is between vertical shaft kilns and their more efficient counterparts, rotary kilns. Today's state-of-the-art dry-rotary kilns are fairly fuel efficient, using around 2.9 GJ to 3.0 GJ per tonne of clinker.

Table 3.2 ▶ ***Global Cement Production, 2006***

	Production Mt/yr	Production Share (%)	Cumulative Production Share (%)	Process Type			
				Dry (%)	Semi-dry (%)	Wet (%)	Vertical (%)
China	1 200	47.1	47.1	50	0	3	47
India	155	6.1	53.1	50	9	25	16
United States	100	3.9	57.0	82	0	18	0
Japan	70	2.7	59.8	100	0	0	0
Republic of Korea	55	2.2	61.9	93	0	7	0
Russia	55	2.1	64.1	12	3	78	7
Spain	54	2.1	66.2	92	4.5	3.5	0
Turkey	48	1.9	68.1	-	-	-	-
Italy	43	1.7	69.8	-	-	-	-
Mexico	41	1.6	71.4	67	9	23	1
Other	730	28.6	100.0	-	-	-	-
Total	**2 550**	**100.0**	**100.0**	-	-	-	-

Sources: United States Geological Survey, 2008a; Batelle, 2002; PCA, 2005; Price, 2006; JCA, 2006; CEMBUREAU, 2006; Siam Cement Industry Company Ltd, 2005.

Note: For some countries information on process types were not available (shown by "-").

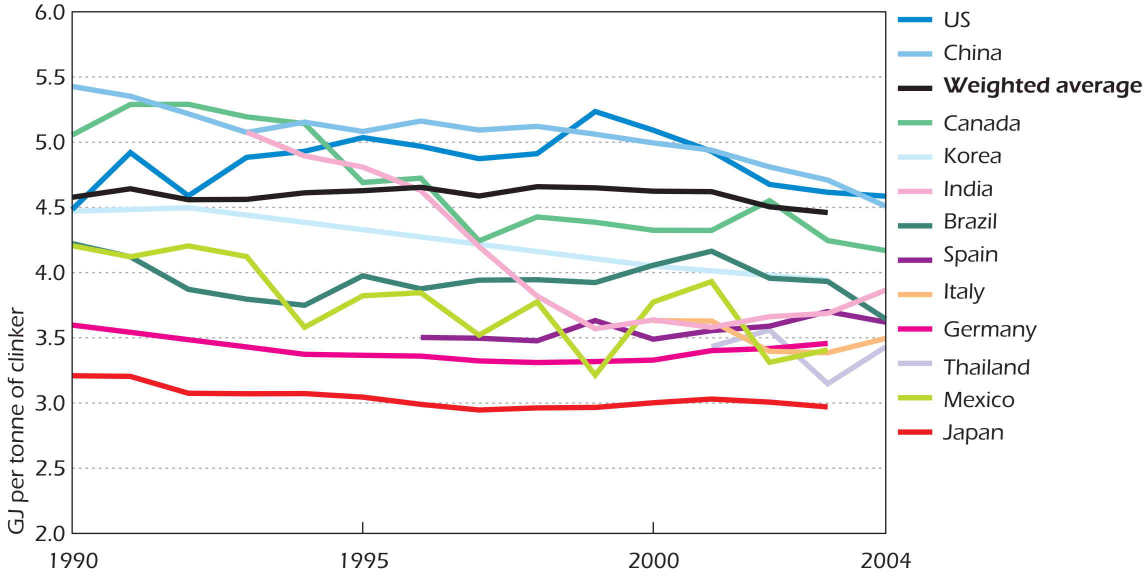
Since the production of cement is a relatively simple process, with well-defined system boundaries and a uniform product, it is well suited to indicator analysis. A number of indicators have been calculated for clinker (the partially fused product of a kiln, which is then ground for use in cement) and cement production to track developments over time. They include:

- ▷ energy consumption, including alternative fuels, per tonne of clinker;
- ▷ electricity consumption per tonne of cement;
- ▷ total primary energy equivalent per tonne of cement;
- ▷ total CO_2 emissions (process and energy-related) per tonne of cement;
- ▷ alternative fuel use in clinker production;
- ▷ clinker-to-cement ratio; and
- ▷ CO_2 emissions from energy consumption (including electricity) per tonne of cement.

Perhaps the most important indicator from an energy efficiency view point is the average energy consumption per tonne of clinker (Figure 3.3). The indicator shows that most countries experienced a downward trend in the energy intensity of clinker production between 1990 and 2004. This has largely been due to the shift from wet- to dry-process cement kilns, coupled with the replacement of older dry kilns by the latest technology using pre-heaters and pre-calciners.

3

Figure 3.3 ▶ ***Energy Consumption per Tonne of Clinker by Country, Including Alternative Fuels***



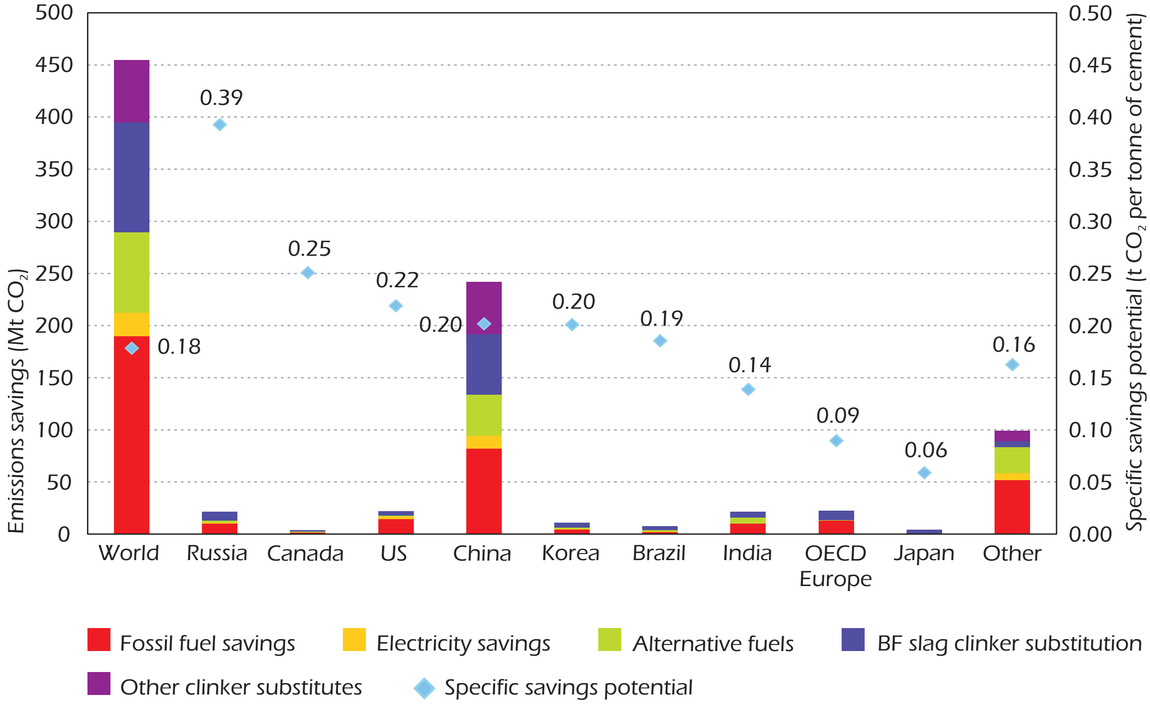
Source: IEA, 2007a.
Note: Care must be taken in interpreting the absolute values in this figure, due to the possibility that countries are using different boundaries and definitions.

Care is needed when interpreting the absolute levels of energy intensity shown. Further work is needed to refine this indicator to ensure that consistent definitions and boundaries are being used across all countries. However, it would appear that Japan has the most efficient clinker production and is at, or near, the practical lower limit of heat consumption for advanced dry kilns with pre-heaters and pre-calciners. In the European Union, the average energy consumption per tonne of clinker is currently about 3.6 GJ per tonne. China, Canada and the United States all use around 4.2 GJ to 4.6 GJ per tonne of clinker. For most of the other countries presented the range is between 3.2 GJ to 3.7 GJ per tonne of clinker.

The intensity indicators can also be used to examine the energy and CO_2 savings that would be possible from the introduction of BAT. The results show that the total technical energy efficiency potential in cement making today is about 2 EJ, leading to a CO_2 saving of 210 Mt CO_2. If clinker substitutes and fuel substitutes are included, the potential saving rises considerably to around 450 Mt CO_2 (Figure 3.4). This shows the importance of fuel and feedstock switching in this sector.

China accounts for more than half of this potential because of its large production volume and its relatively low energy efficiency. In terms of emission reduction potentials per tonne of cement, a number of countries have similar potentials to China, and Russia has a much higher specific potential. The world average potential is 0.18 t CO_2 per tonne of cement.

Figure 3.4 ▶ ***CO_2 Reduction Potentials in Cement in 2005, Based on Best Available Technology***



Source: IEA analysis.

Pulp and Paper

The pulp and paper industry is the fourth largest industrial user of energy, consuming 6.4 EJ in 2005. Approximately two-thirds of final energy consumption is fuel that is used to produce heat, while the remaining third is electricity, either from the grid or produced on site. Unlike other industrial sectors, the pulp and paper industry also produces energy as a by-product and currently generates about 50% of its own energy needs from biomass residues. The significant use of biomass means that the CO_2 intensity of energy use is not very high, and much lower than other energy-intensive industries.

Energy use in the paper and pulp industry is divided among a number of different pulp production and paper production processes. The main processes are:

- chemical pulping;
- mechanical pulping;
- paper recycling; and
- paper production.

The United States, China, Japan and Germany account for more than half of global paper and paperboard production (Table 3.3). The production of chemical and mechanical pulp is also concentrated in a few countries, with the United States, Canada, Brazil, Finland and Sweden being most important. Recycled paper also has a significant share of global fibre supply, representing half of the total, but this does not account for losses in waste paper processing. Almost half of the paper and board product mix is packaging and wrapping paper and board. About 30% is printing and writing paper. The remainder is newsprint, household and sanitary paper.

Table 3.3 ▶ ***Global Paper and Pulp Production, 2006***

	Paper and Paperboard Production Mt/yr	Production Share %	Cumulative Production Share (%)	Chemical Wood Pulp Mt/yr	Mechanical Wood Pulp Mt/yr
United States	84.3	23.1	23.1	47.0	4.2
China	58.0	15.9	39.0	1.8	0.6
Japan	29.5	8.1	47.0	9.6	1.2
Germany	22.7	6.2	53.2	1.5	1.5
Canada	18.2	5.0	58.2	11.6	11.4
Finland	14.2	3.9	62.1	8.0	4.6
Sweden	12.1	3.3	65.4	8.3	3.5
Republic of Korea	11.0	3.0	68.4	0.4	0.1
Italy	10.0	2.7	71.2	0.1	0.4
France	10.0	2.7	73.9	1.5	0.6
Brazil	8.5	2.3	76.2	10.7	0.5
Spain	6.4	1.7	78.0	1.9	0.1
United Kingdom	5.8	1.6	79.6	0.0	0.3
Other	74.6	20.4	100.0	27.5	6.9
Total	**365.1**	**100.0**	**100.0**	**129.8**	**35.8**

Source: United Nations Food and Agriculture Organisation Statistics, 2008.

Ideally, energy and CO_2 indicators for this sector should be developed for each main product category. Unfortunately, while some production data are available there are no publicly available sources of energy data at this level of detail. Instead, a number of aggregate product indicators have been proposed, with those for energy relating the actual fuel or electricity use for paper and pulp in each country (taken from IEA statistics)[9] to the fuel or electricity use that would occur given the use of BAT. These indicators are:

▷ heat consumption in pulp and paper production vs. BAT;

▷ electricity consumption in pulp and paper production vs. BAT; and

▷ CO_2 emissions per tonne of pulp exported and paper produced.

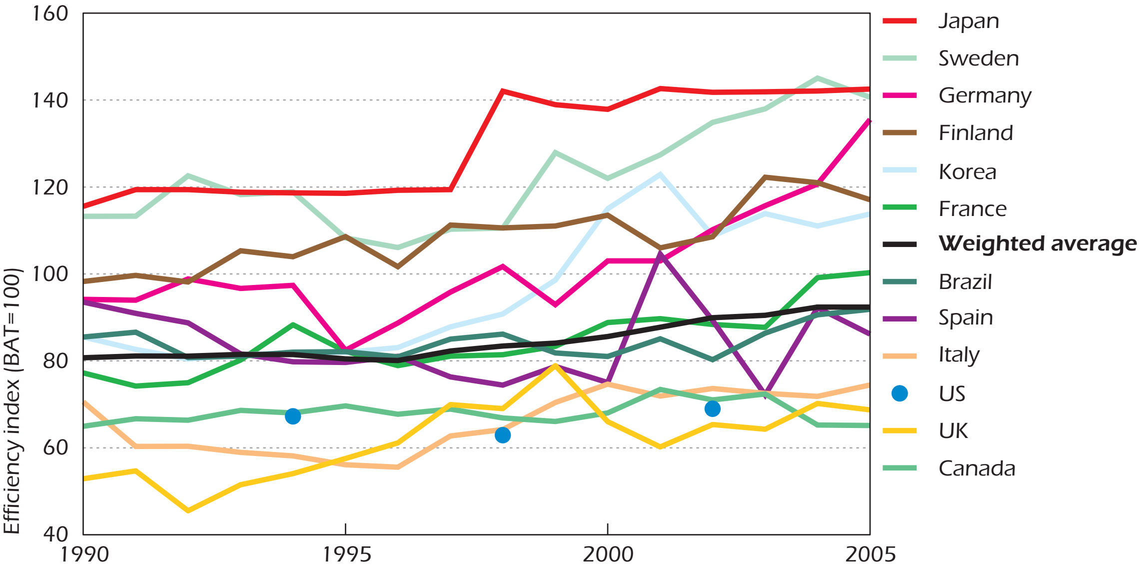
A country's energy efficiency index (EEI) would be equal to 100 if the energy used to produce its commodities was at the same level as BAT. Values below 100 indicate that energy consumption is higher than BAT levels and signify an opportunity for greater energy efficiency, if current BAT were applied. Figures above 100 could mean that the BAT figures are too conservative or indicate a high level of integrated mills (which overall are more energy efficient). Alternatively, they may result from accounting

9. For the United States, energy statistics are taken from the US Energy Information Administration.

inconsistencies across countries. Countries with more modern pulp and paper mills should normally have EEI ratios close to 100, while those with older facilities would be expected to have significantly lower ratios.

The analysis shows that the energy intensity of heat use in key countries varied widely from a remaining improvement potential of 35% for Canada to 43% better than BAT for Japan (Figure 3.5).[10] For electricity, this remaining improvement potential varied from 32% for the United Kingdom to 3% better than BAT for Germany. Two key countries are Canada and the United States, both rich in wood resources. The United States is the largest chemical pulp producer in the world and Canada is the largest producer of mechanical pulp. They are also among the countries with the most energy intensive pulp and paper industries, at least partly due to the old age of their pulp and paper mills.

Figure 3.5 ► ***Heat Consumption in Pulp and Paper Production versus Best Available Technology***

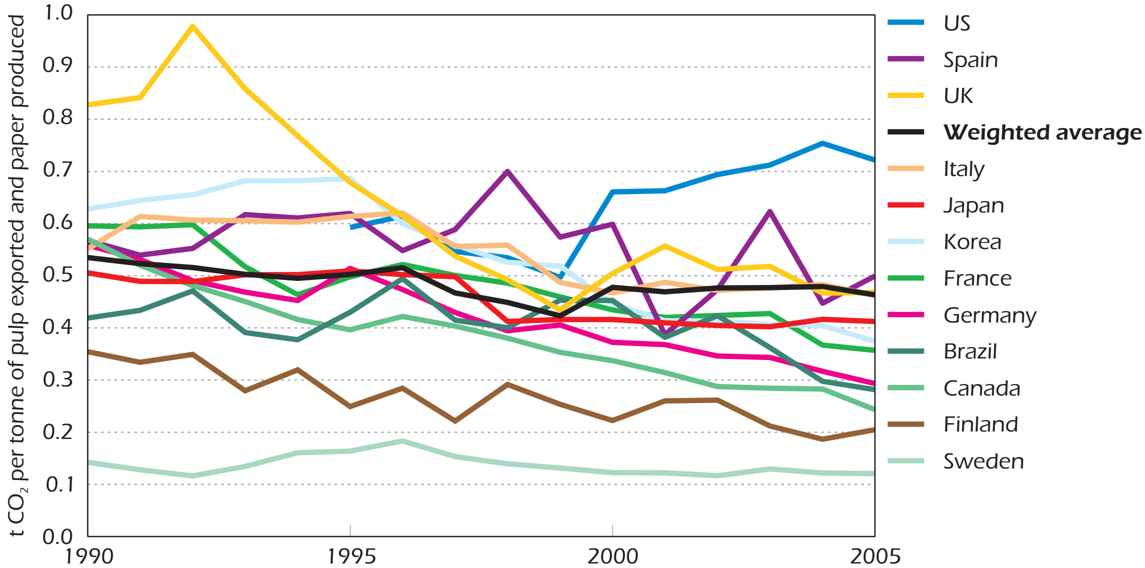


Sources: United States Energy Information Administration (EIA); IEA, 2007c; IEA, 2007d; IEA estimates.
Note: Data for the United States are only available every four years.

In addition to the EEI indicators, a CO_2 indicator has been developed to track differences in biomass use across countries. Figure 3.6 shows energy-related CO_2 emissions per tonne of production (paper and paperboard produced, plus pulp exports). Sweden, Finland and Canada have the lowest emissions per tonne of product due to high levels of hydroelectric power and high biomass use for energy. The United States, Spain and the United Kingdom have relatively high CO_2 intensity due to their reliance on fossil fuels.

10. The fact that the energy efficiency index for Japan, Sweden and Finland falls well above BAT indicates that there are issues of data consistency and comparability across countries. Different reporting methodologies, system boundaries, problems related to combined heat and power accounting, high recovered paper use rates and high level of integrated mills (in the case of Japan) could explain the unexpectedly high energy efficiency index of these countries. The IEA is continuing to work with both governments and the industry to resolve these issues.

Figure 3.6 ▶ ***CO_2 Emissions per Tonne of Pulp Exported and Paper Produced***



Sources: IEA, 2007c; IEA, 2007d; IEA, 2007e; United Nations Food and Agriculture Organisation Statistics, 2008.

The quality of the energy data has made it very difficult to develop reliable indicators for this sector. The indicators analysis has raised a number of questions regarding data comparability and consistency across countries. Reporting methodologies for biomass use seem to vary widely across countries. In the latest statistics submitted to the IEA, a number of countries have significantly revised down their biomass use in the sector compared with earlier submissions. Other countries report no biomass use despite producing chemical pulp, which has black liquor as a by-product.[11] The high level of combined heat and power (CHP) use in the sector combined with different CHP allocation rules for fuel input across countries also contribute to inconsistent energy statistics for the pulp and paper sector.

The indicators could be further improved by collecting additional information on the characteristics and extent of production in both integrated and non-integrated mills. The use of heat recovery systems plays an important role in the energy efficiency of the pulp and paper industry. The most efficient mills are integrated mills that can benefit from extensive heat recovery systems which take advantage of waste heat produced from different processes. Stand alone pulp mills have less scope for using waste heat and so are inherently more energy intensive.

Chemicals and Petrochemicals

Energy use in the chemical and petrochemical industry was 34 EJ in 2005, making it the largest industrial consumer of energy. The chemical industry includes facilities that produce bulk or speciality compounds by chemical reactions between organic and/or inorganic materials. The petrochemical industry includes facilities that create synthetic organic products from oil and natural gas feedstocks.

11. In a number of cases it appears that the biomass use is reported under non-specified industries instead of being reported under energy use in pulp, paper and print.

The chemical and petrochemical industry is highly diverse, with thousands of companies producing tens of thousands of products in quantities varying from a few kilogrammes to thousands of tonnes.

Feedstocks account for more than half of the total energy used in this sector. Most of the carbon from oil and natural gas feedstock is "locked" into final products such as plastics, solvents, urea and methanol. Energy used for feedstocks cannot be reduced through energy efficiency measures. However, some of the locked-in energy can be recovered when the waste product is incinerated.

Energy indicators for chemicals and petrochemicals are different from other sectors because of this locked-in feedstock energy and carbon. Ideally, indicators should be developed at the level of individual processes and products, but as with the pulp and paper sector, a lack of energy data at this level of detail makes this approach infeasible. Instead, aggregate product indicators for both energy and CO_2 have been developed, based on 42 of the most important products, representing more than 95% of all energy used in the chemical and petrochemical industry. These indicators are:

- ▷ total energy consumption excluding electricity use vs. BPT;
- ▷ total energy consumption including electricity use vs. BPT; and
- ▷ total CO_2 emissions vs. BPT.

BPT energy values are provided on a worldwide consolidated basis in Table 3.4. For electricity, BPT is assumed to be 25% lower than current electricity use (driven by more efficient motor systems). Only a small share of total electricity use in the chemical sector can be explained by direct process electricity demand and the bulk of the electricity in this sector is accounted for by pumping equipment for pipelines and storage tanks and auxiliary use for which no detailed data exist. Production volumes of BTX (benzene, toluene and xylene) have been split between steam cracking and naphtha extraction to account for the more energy-intensive nature of production from steam cracking compared to naphtha extraction.

Given the heterogeneous nature of the chemical and petrochemical sector, the present efficiency indicators are not appropriate for country comparisons. However, monitoring their evolution over time provides valuable information on trends in energy efficiency. The calculated BPT energy use for the 42[12] products ranges from 24 EJ (excluding electricity) to 26 EJ (including electricity) compared to actual energy use of 30 EJ (excluding electricity) to 33 EJ (including electricity). As the calculated BPT figure covers 95% of total energy use in the industry, an adjustment is required and hence the total BPT for the industry is estimated to be in the range of 25 EJ to 27 EJ. This implies a savings potential of 5 EJ to 6 EJ if energy use were based on BPT and represents an 18% to 22% reduction on current energy consumption.

The results of this analysis highlight a number of issues related to data quality. High value chemicals from naphtha extraction and fluid catalytic cracking are usually produced in refineries. This may lead to some accounting inconsistencies in IEA energy statistics, as energy use for petrochemicals produced at a refinery will most likely be accounted for in the transformation sector of the statistical balances rather

12. The separate categories of ethylene, propylene, BTX and butylene have been merged into a single high value chemicals (HVC) category with a split for production from steam cracking and naphtha extraction. The BPT energy use (excluding electricity) applied is 57 GJ per tonne for HVC (steam cracking) and 50 GJ per tonne for HVC (naphtha extraction).

than in the chemical and petrochemical category. Until recently, feedstock energy use was reported in IEA statistics under total energy use for the sub-sector, but it is now excluded. This may have led to some problems in country reporting between energy and feedstock use and hence, in this analysis, energy and feedstocks have been aggregated. Further work is needed to explore these issues.

Table 3.4 ▶ ***Indicator Use for Country Analysis of Global Chemical and Petrochemical Industry, 2005***

	Energy Use (Incl. Electricity)				Energy Use (Excl. Electricity)			
	Reported Energy Use EJ	BPT Energy Use EJ	EEI	Improvement Potential	Reported Energy Use EJ	BPT Energy Use EJ	EEI	Improvement Potential
United States	7.8	5.2	0.67	33%	6.9	4.6	0.67	33%
Saudi Arabia	1.2	0.9	0.75	25%	1.2	0.9	0.75	25%
Taiwan	0.9	0.7	0.75	25%	0.7	0.6	0.76	25%
Netherlands	0.7	0.5	0.78	22%	0.6	0.5	0.78	22%
Brazil	0.7	0.5	0.79	21%	0.6	0.5	0.8	20%
India	1.1	0.9	0.82	18%	1.1	0.9	0.82	18%
China	4.4	3.7	0.84	16%	3.6	3.1	0.86	14%
France	0.7	0.6	0.86	14%	0.6	0.6	0.87	14%
Japan	2.2	1.9	0.86	14%	2	1.7	0.87	13%
Germany	1.3	1.1	0.87	14%	1.1	1	0.88	12%
Italy	0.5	0.4	0.86	14%	0.4	0.3	0.88	12%
Republic of Korea	1.5	1.3	0.88	12%	1.4	1.2	0.89	11%
Canada	0.9	0.8	0.92	8%	0.8	0.7	0.94	6%
United Kingdom	0.5	0.5	0.93	7%	0.5	0.4	0.96	4%
Total	**33.4**	**26.1**	**0.78**	**22%**	**30.0**	**23.6**	**0.79**	**21%**

Sources: IEA, 2007c; IEA, 2007d; SRI consulting; Ministry of Energy, Trade and Industry Japan; IEA analysis.

Aluminium

More than half of the energy used in non-ferrous metals is for primary aluminium production. Electricity consumption is particularly significant, with aluminium smelters using 1.9 EJ of electricity in 2006, about 3.5% of global electricity consumption.

Aluminium production can be split into primary aluminium production and recycling. Primary production is about 20 times as energy intensive as recycling and represents the bulk of energy consumption. The main primary producers of aluminium are located in China, Russia, North America, Australia and Latin America (Table 3.5). Primary aluminium is produced in three distinct steps: bauxite (ore) mining, alumina refining and aluminium smelting. In principle, it would be possible to construct energy efficiency and CO_2 indicators relating to each of these steps.

Most of the energy consumed in alumina refineries is in the form of steam. The calcining (drying) of the alumina requires large amounts of high temperature heat. Due to a high demand for steam, modern plants use combined heat and power systems. The global average energy intensity was 12.0 GJ per tonne of alumina in 2006, with a range amongst different world regions between 11.2 GJ and 14.5 GJ per tonne (International Aluminium Institute, 2008).

Due to its high electricity intensity, specific electricity use is the most important energy indicator for aluminium smelting. World average electricity use for primary aluminium production in 2006 was 15 194 kWh per tonne. This average has declined about 0.4% per year over the last 25 years. On a regional basis, the averages range from 14 622 kWh per tonne of aluminium in Africa to 15 452 kWh per tonne in North America. Africa is the most efficient region due to new production facilities (Figure 3.7).

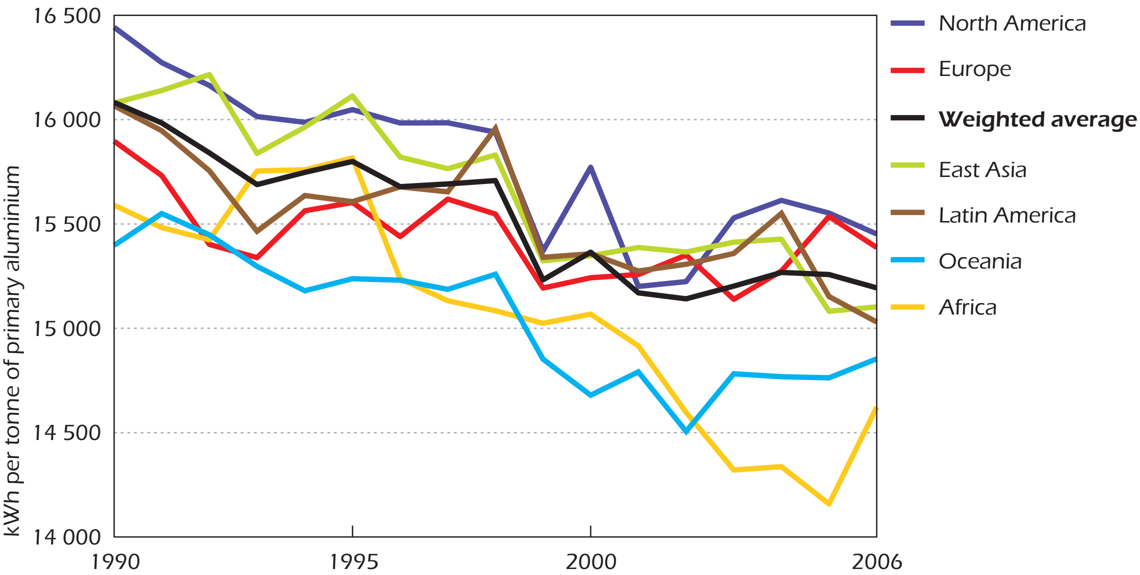
The potential for energy efficiency gains in aluminium production is limited. With existing technology, energy use in the key steps of aluminium production can be reduced by 6% to 8% compared with current best practice. This is equivalent to final energy savings of about 0.1 EJ to 0.6 EJ per year.

Table 3.5 ▶ ***Global Primary Aluminium Production, 2006***

	Production Mt/yr	Production Share (%)	Cumulative Production Share (%)
China	9.35	27.7	27.7
Russia	3.72	11.0	38.8
Canada	3.05	9.1	47.8
United States	2.28	6.8	54.6
Australia	1.93	5.7	60.3
Brazil	1.50	4.4	64.8
Norway	1.33	3.9	68.7
India	1.10	3.3	72.0
South Africa	0.90	2.7	74.6
Bahrain	0.87	2.6	77.2
Dubai	0.73	2.2	79.4
Venezuela	0.61	1.8	81.2
Mozambique	0.56	1.7	82.9
Germany	0.54	1.6	84.5
Tajikistan	0.41	1.2	85.7
Iceland	0.32	0.9	86.7
Other	4.51	13.4	100.0
Total	**33.70**	**100.0**	**100.0**

Source: United States Geological Survey, 2008b.

Figure 3.7 ▶ ***Specific Power Consumption in Aluminium Smelting***



Source: International Aluminium Institute, 2008.

HOUSEHOLDS

Summary

- Energy consumption in households was 82 EJ in 2005. The associated CO_2 emissions (including indirect emissions from electricity use) were 4.5 Gt CO_2. Households are the only major end-use sector where the increase in energy consumption since 1990 has been greater in OECD countries (+22%) than in non-OECD countries (+18%).
- The energy mix in households varies significantly between OECD and non-OECD countries. While OECD countries rely mainly on electricity and natural gas (with a combined share of 72%), renewables, mainly biomass, dominate the energy mix in non-OECD countries (with a share of 59%). In Russia and some other transition economies, district heating is the most important energy commodity for households.
- A set of indicators has been developed to analyse trends in the energy use and CO_2 emissions of households. While aggregate indicators can be developed for all countries, more detailed indicators that focus on particular end-uses are only available for a group of 19 IEA countries (IEA19).
- In these 19 IEA countries, space heating energy use is growing slowly and remains the most important energy user, responsible for 53% of household final energy consumption. In contrast, appliance energy use (mostly electricity) is growing very rapidly and has overtaken water heating as the second most important household energy demand.
- Further analysis for space heating reveals that, for the IEA19, efficiency gains are being offset by increased demand as a result of larger homes and lower occupancy rates.
- The energy and CO_2 emissions increases from appliances are being driven by a wide range of mostly small appliances, as well as by air conditioning in some countries. Large appliances in a group of 15 European countries now represent only 51% of total appliance energy consumption, and this share is still falling.
- Countries should expand the range of end-use data they collect on a comparable basis to include a wider range of consumer appliances. This would allow better tracking of developments in some of the most rapidly changing areas of household energy use, which in turn would enable more effective development of labelling and standards policies.

Introduction

The household sector includes those activities related to private dwellings. It covers all energy-using activities in apartments and houses, including space and water heating, cooling, lighting and the use of appliances. It does not include personal transport, which is covered in the transport chapter.

In order to understand the evolution of household energy use and associated CO_2 emissions, a set of indicators has been developed. Data are available at an aggregate level for all countries, allowing for cross-country comparisons of total energy use and CO_2 emissions. However, more detailed information, including energy consumption by end-use and other household data (such as floor area and equipment characteristics) is only available on a comparable basis for the IEA19 (see Annex A for country coverage).

For the IEA19 more disaggregated analysis has been possible, including the development of indicators focusing on space heating and appliance energy use. In the case of space heating, a decomposition approach was used to separate various factors impacting energy use, such as dwelling size, occupancy levels and changes in energy efficiency. For appliances, only limited appliance-level information is available on a consistent basis across countries, so the analysis has focused on the example of televisions.

Global Trends

Global energy use in the household sector increased between 1990 and 2005 by 19% to reach 82 EJ. Households are the only major end-use sector where the increase in energy consumption since 1990 has been greater in OECD countries (+22%) than in non-OECD countries (+18%).

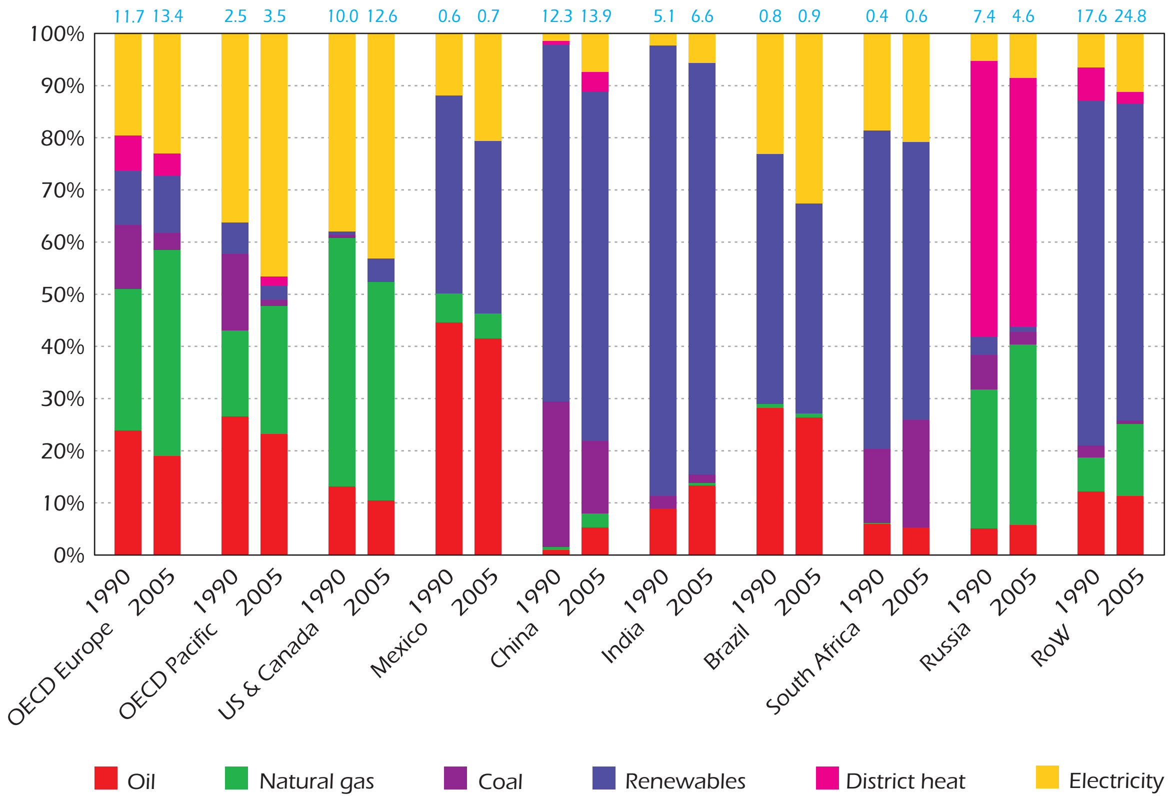
Electricity and natural gas are the main energy commodities used in OECD countries, providing 72% of total household energy requirements in 2005. Electricity use has been rising rapidly in these countries, largely due to the increased penetration of many different appliances. In non-OECD countries, renewable energy (mostly traditional biomass) remains the dominant energy commodity accounting for 59% of final energy use, but its share is decreasing. However, electricity use – although accounting for only a 10% share in 2005 – is by far the fastest growing energy commodity, its use increasing by 140% since 1990.[13] In Russia district heating remains important in the household sector with a share of 48%.

As a result of increases in final energy consumption and changes to the energy mix, global household CO_2 emissions increased between 1990 and 2005 by 21% to reach 4.5 Gt CO_2. This is slightly more than the increase in final energy use, implying an increased CO_2 intensity of the household energy mix.

Examining household emissions on a per capita basis reveals that in 2005 global average emissions were 0.7 tonne of CO_2 per person, broadly the same as in 1990. However, there are wide differences between countries. Per capita CO_2 emissions in OECD countries are on average more than five times higher than in non-OECD countries. This difference can be explained by a combination of lower per capita household energy use in non-OECD countries and a lower carbon intensity of the energy mix, due to a high share of renewable energy.

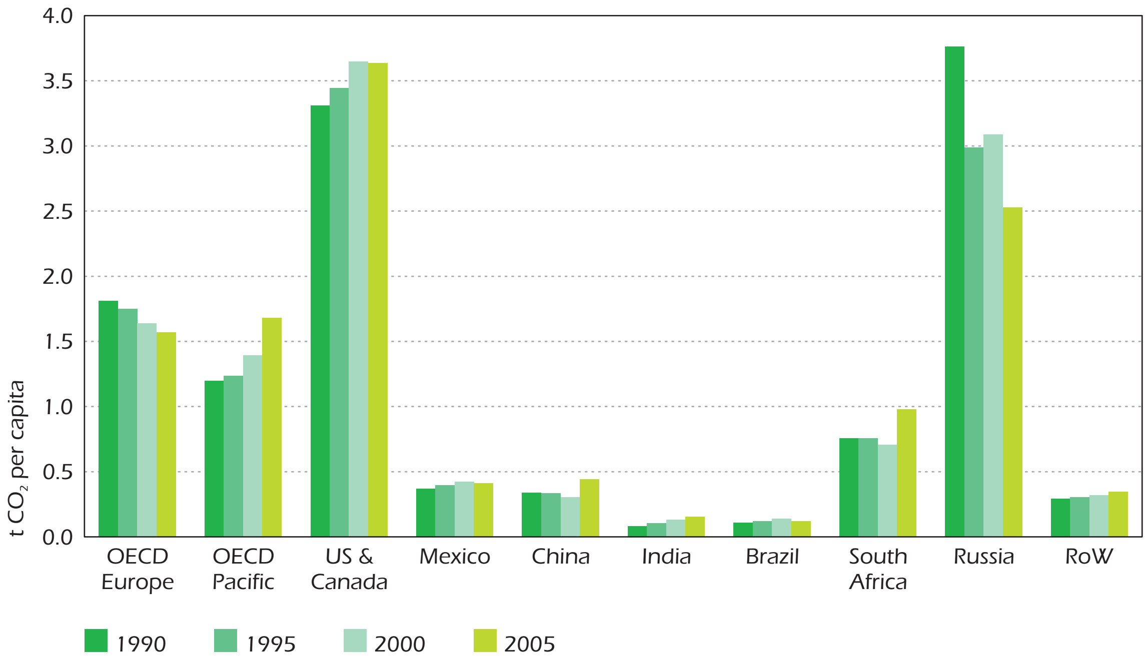
13. The falling share of inefficient traditional biomass use in favour of electricity and commercial fuels is one of the main reasons why increases in final energy use have been rather modest in non-OECD countries.

Figure 4.1 ▶ ***Household Energy Use by Energy Commodity***



Sources: IEA, 2007c; IEA, 2007d; IEA estimates.

Figure 4.2 ▶ ***Household CO_2 Emissions per Capita***



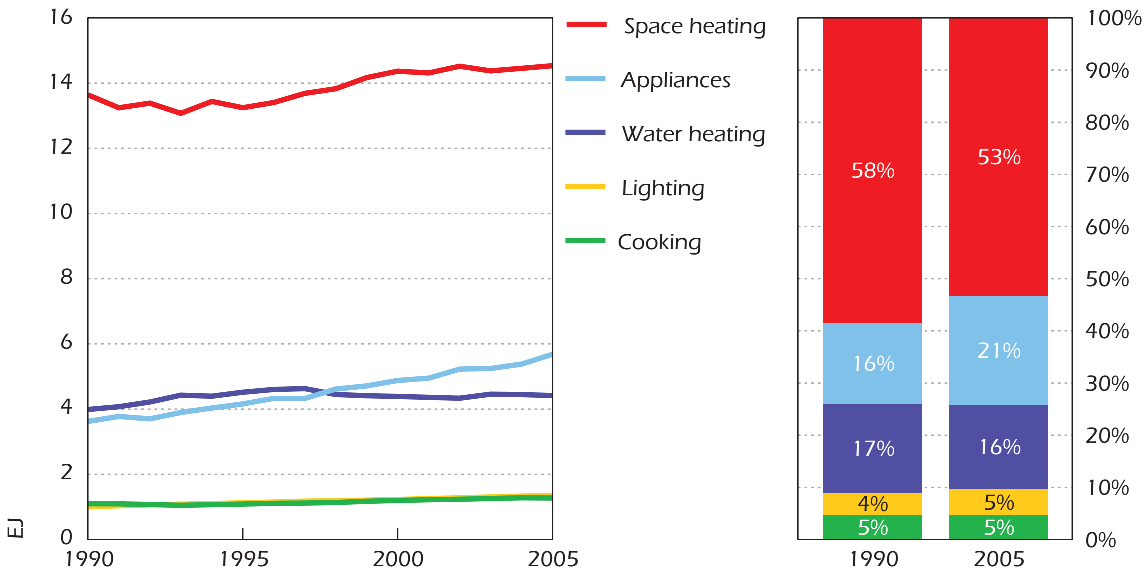
Sources: IEA, 2007c; IEA, 2007d; IEA, 2007e; IEA estimates.

Disaggregate Indicators

Space heating is by far the most important energy user in the residential sector of the IEA19, accounting for 15 EJ in 2005 (Figure 4.3). Space heating energy use, corrected for yearly climate variations, has only increased by 0.4% per year since 1990. This can be attributed to a significant reduction in space heating requirements per capita, driven by a combination of higher efficiencies of space heating equipment and improved thermal performance of new and existing dwellings. This low growth led to its share of total household energy consumption falling from 58% in 1990 to 53% in 2005.

Appliances are the most rapidly growing household demand for energy, with consumption increasing by 57% from 1990 to 2005. In the late 1990s, appliances overtook water heating as the second most energy-consuming category, accounting for 21% of total household energy consumption. In contrast, the share of water heating fell to 16% in 2005. The remaining end-uses, lighting and cooking, each account for around 5% of final energy use.

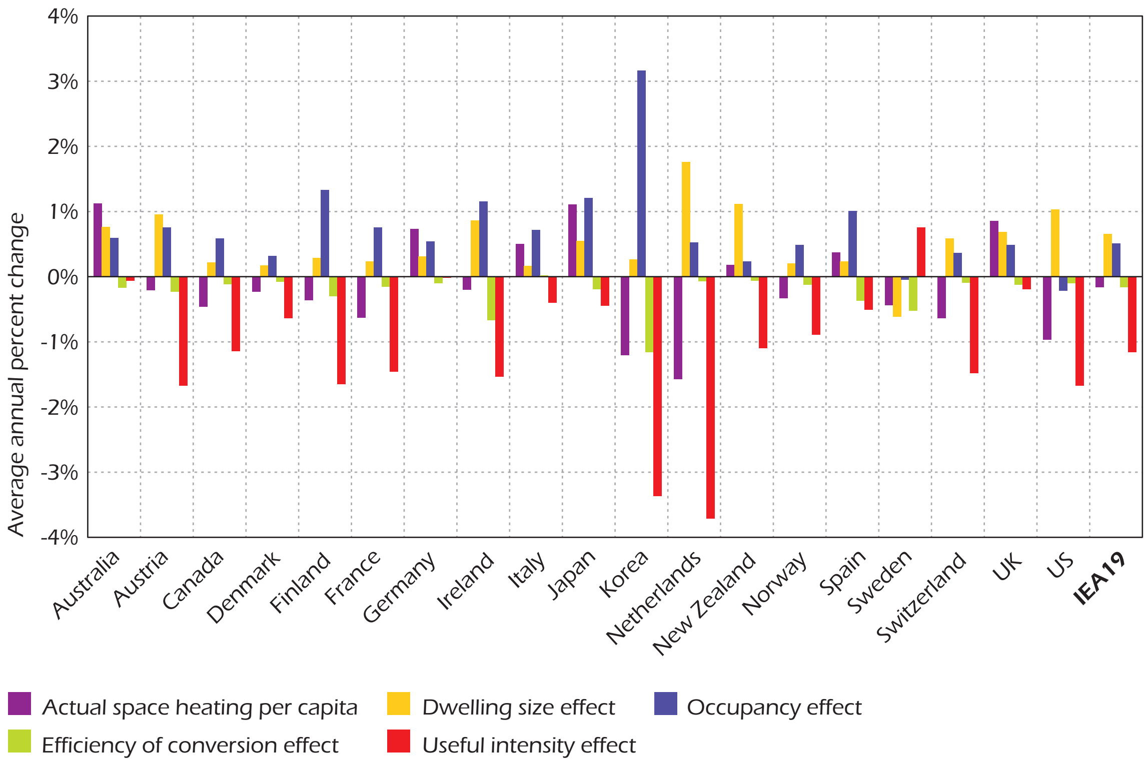
Figure 4.3 ▶ ***Household Energy Use by End-Use, IEA19***



Source: IEA indicators database.

More disaggregate indicators have been developed to investigate the trends in the two most important household end-uses: space heating and appliances. Several factors affect energy consumption for space heating in households, including dwelling size, the number of occupants, the efficiency of heating equipment and the demand for useful energy per unit of area heated (useful energy intensity). The impacts of these effects can be investigated through a decomposition analysis (Figure 4.4). For most countries, larger dwelling sizes and fewer occupants per dwelling have tended to drive up energy demand for space heating. From 1990 to 2005, larger dwelling sizes in the IEA19 countries led to an average annual increase of 0.7% in energy demand. The reduction in the occupancy of each household puts upward pressure on demand for space heating because a larger number of dwellings are required to house a given population and the heating needs of a given dwelling are not necessarily reduced because fewer people are living in it. Overall, lower occupancy rates increased energy demand by 0.5% per year.

Figure 4.4 ▶ ***Decomposition of Changes in Space Heating per Capita, 1990 - 2005***



Source: IEA indicators database.
Note: Energy use for space heating per capita has been corrected for yearly climate variations.

On average, higher demand for space heating in the IEA19 has been offset by two factors: efficiency gains derived from lower conversion losses in heating technologies (only the impact of fuel switching is considered) and a significant reduction in the useful energy intensity for space heating (primarily as a result of improved insulation). Lower conversion losses led to energy demand reductions of 0.2% per year. The useful intensity effect caused a 1.2% reduction per year. The overall effect has been a small average annual reduction (-0.2%) in actual space heating per capita in the IEA19 countries from 1990 to 2005.

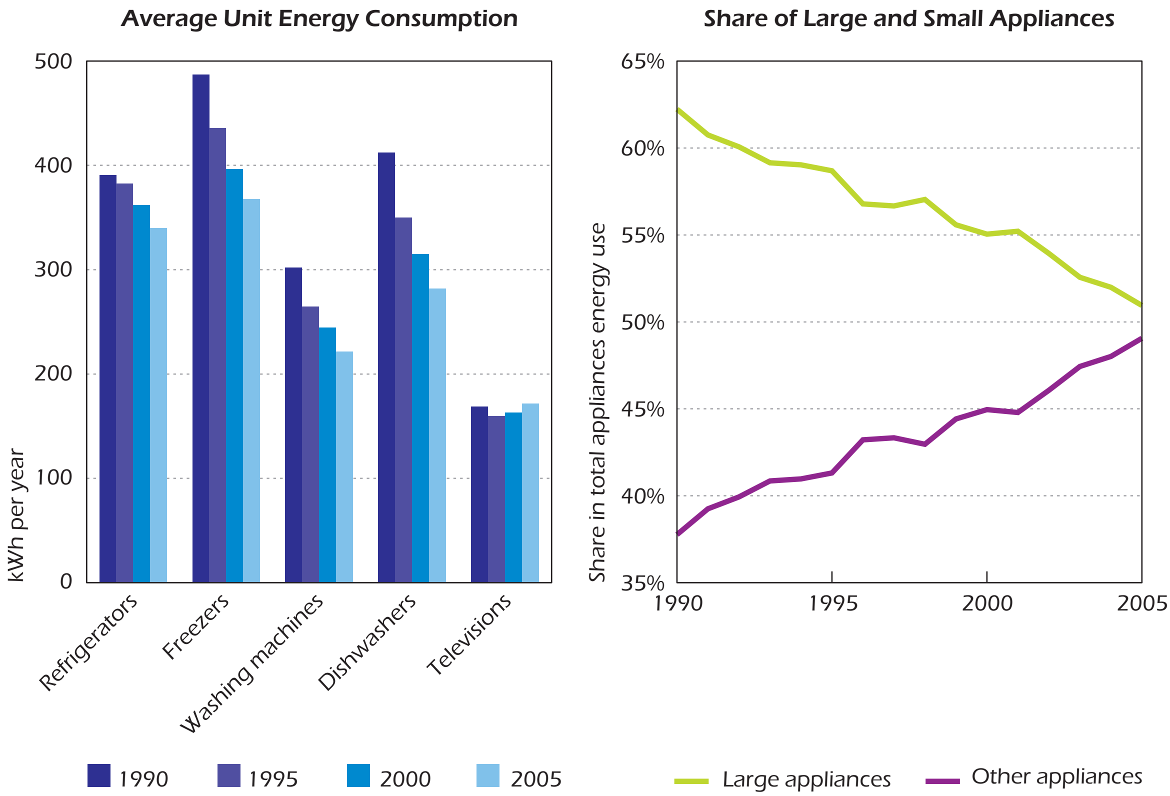
Most countries followed a similar pattern. The tendency for higher energy demand – caused by fewer occupants and larger homes – was offset by lower conversion losses and, more importantly, a decline in the useful intensity of space heating. Energy efficiency policies, such as mandatory building codes and minimum energy performance standards for heating equipment, can play an important role in improving the overall efficiency of meeting space heating needs. However, separately identifying the impact on energy use of such policies goes beyond what can be analysed by the current set of space heating indicators.

Appliances are another important energy end-use in the household sector. Electricity use for household appliances in the IEA19 grew by 57% from 1990 to 2005, driving the overall increase in household electricity demand. In 2005, electricity consumption in appliances was 59% of total household electricity use.

Information on the breakdown of appliances energy use is not available on a consistent basis, even across the IEA; several countries have no data. However, some data are available for large appliances such as refrigerators, freezers, washing machines, dishwashers and televisions. Currently, these five major appliances account for around 50% of household electricity consumption in appliances in the IEA. However, this share is declining as the most rapid increase in appliance energy consumption comes from increasing ownership of a wide range of mostly small, miscellaneous appliances such as personal computers, mobile phones, personal audio equipment and other home electronics. In some countries, air conditioning is also a key factor.

The declining share of large appliances in total appliance electricity demand has been significantly helped by policies implemented in many IEA countries, including minimum energy performance standards, appliances labelling and voluntary agreements with industry. The impacts of these energy efficiency programmes can be seen in data that show marked improvements in unit energy consumption (UEC). As an example, Figure 4.5 shows the average unit energy consumption for five large appliances (left) and the share in total energy consumption of large and small appliances (right) in a group of 15 European countries (EU15).

Figure 4.5 ▶ ***Energy Consumption of Appliances, EU15***



Source: ODYSSEE.

Note: Large appliances include refrigerators, freezers, washing machines, dishwashers and televisions.

With the exception of televisions, all these appliances have shown a significant decrease in average unit energy consumption since 1990. In the case of refrigerators and freezers, the average unit energy consumption has declined even though the appliances themselves have become larger. For televisions, energy efficiency gains have been outstripped by the consumer trend towards larger screens, which use more energy. However, total energy consumption in the EU15 fell only in the case of refrigerators and washing machines. For other appliances, improved UEC has been more than offset by higher levels of ownership and use.

Analysing these trends in more detail requires appliance-specific data at the country level. The information needed includes:

- diffusion data: stock (ownership) and sales of new appliances;
- unit energy consumption (combines both power consumption and usage) for the stock and new appliances; and
- other relevant attributes, such as technology type, usage patterns, volumes, sizes.

An example of this kind of indicator has been developed for televisions. Televisions have been chosen because the rate of ownership continues to grow in most IEA countries and, coupled with significant changes to the technology, this has made televisions a rapidly growing user of energy across the IEA. Hence, new policies targeting televisions, such as minimum energy performance standards and energy labelling for both stand-by power and on-mode consumption, are now being developed and implemented. In order to assess the efficiency of these policies and to better inform decision-makers on the reduction potential, comprehensive and comparable data on televisions are required.

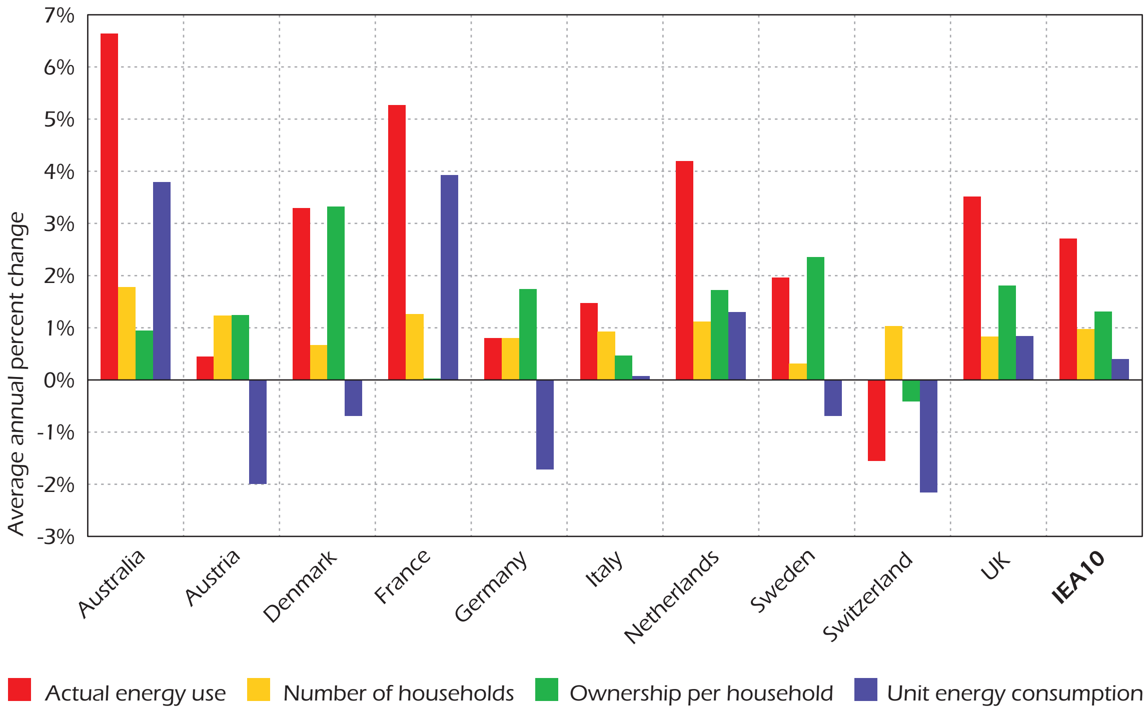
Figure 4.6 presents, for a group of 10 IEA countries (IEA10) for which the information is available, how television energy use and its key drivers have changed since 1990. An important driver of television energy use is the rate of ownership. Except for Switzerland, all of the countries analysed show an increased number of televisions per household. The changes in energy use will also depend on the UEC, which in turn is affected by the power consumption and the hours of use. Since the primary television is usually turned on for more hours than a second or third set, a high ownership rate can lead to a lower average UEC per television. For example, the United Kingdom has the highest ownership rate, but a low average UEC; on the other hand, France has a relatively low ownership rate but one of the highest average UEC.

The overall UEC for the IEA10 increased by 0.4% per year over the period from 1990 to 2005. One of the factors contributing to this increase has been a change in the technologies used in televisions. The cathode ray tube (CRT) technology accounted for almost 100% of the market shares in 1990, but new technologies such as plasma and liquid crystal display (LCD) televisions are now rapidly gaining popularity. Whereas CRT televisions were limited in their maximum size, the new technologies overcome this restriction and are offering much larger screen sizes, which require more energy.

Providing an in-depth analysis of the changes in television energy use, allowing an evaluation of the policies targeting this appliance, would require more detailed information than is currently collected on a routine basis by most countries. Such information should include the efficiency and ownership rates of the different technologies, usage patterns and details of the sale and turnover rates of televisions.

This kind of data is important because key attributes of televisions and other electronic appliances can change more quickly than for traditional appliances. Therefore countries need to be vigilant in tracking developments and extend their end-use analyses to cover a wide range of household appliances.

Figure 4.6 ▶ ***Factors Affecting Energy Use by Televisions, 1990 - 2005***



Source: IEA indicators database.

SERVICES

Summary

- ▷ Service sector energy consumption was 27 EJ in 2005. CO_2 emissions, including indirect emissions from the use of electricity, were 2.6 Gt CO_2. 73% of service sector energy use is in OECD countries, even though energy consumption in this sector grew by more than 50% in non-OECD countries between 1990 and 2005.

- ▷ The energy mix of the service sector varies significantly between regions and countries. Most OECD countries rely on electricity and natural gas, with oil also important in the OECD Pacific region and Mexico. In contrast, coal use is significant in China and South Africa while, in India, the consumption of biomass dominates. In Russia, district heating is still widespread.

- ▷ Aggregate indicators of energy use per value-added (VA) and energy use per unit of floor area can be used to track the energy intensity of the sector. Whereas energy use per VA decreased for many IEA countries, the picture for energy use per unit of floor area was more mixed, with some countries showing increases and others decreases.

- ▷ Looking at the reasons for these different trends requires energy consumption and activity data disaggregated by sub-sector and, if possible, end-use. However, such data are scarce, even for IEA countries. The limited information available shows that as there is a wide variation in sub-sectoral energy intensities, structural effects can be important in determining the overall trends in service sector energy use.

- ▷ Countries should put more effort into collecting comparable disaggregated information for the service sector to facilitate better analyses of the trends in energy use and efficiency.

Introduction

The service sector includes activities related to trade, finance, real estate, public administration, health, education and commercial services. Understanding the evolution of energy use and CO_2 emissions in this sector ideally requires detailed data by end-use (heating, cooling, lighting, etc) and by sub-sector (public administration, health, retail, hotels, education, etc). However, information at this level of detail is currently very limited, even for IEA countries. It has been possible to develop aggregate indicators based on VA and on floor area for a number of IEA countries. Sub-sectoral information for three countries (Canada, Japan and the United States) has been used to demonstrate some insights that can be gained from more disaggregated analysis.

Global Trends

In 2005, final energy consumption in the service sector was 27 EJ. The CO_2 emissions associated with this energy use, including indirect emissions from electricity, were 2.6 Gt CO_2. Globally, service sector energy use increased by 37% between 1990 and 2005. In OECD countries the rise in energy consumption was 32%, whereas it was 53% in non-OECD countries. Despite the slower increase in energy use in the OECD, in 2005 these countries still accounted for 73% of global energy consumption in this sector.

Electricity is by far the most widely used energy commodity in services, with a global share of 47% in 2005. Electricity use has increased by 73% since 1990 and this has been the main factor driving the global increase in energy consumption in this sector. This reflects the growing importance of electricity-using devices such as lighting, office equipment and air conditioning. Increased access to electricity may also have played a role in some developing countries.

There are substantial differences in the service sector energy mix amongst countries and regions (Figure 5.1). Electricity and natural gas are the dominant final energy commodities in many OECD countries, with oil also an important fuel in the OECD Pacific region, Mexico and China.[14] Biomass is still heavily used in India, accounting for 50% of total final consumption in services. Direct coal use retains a significant share in both China and South Africa. In Russia 50% of services energy demand is met by district heating.

The main factor affecting energy use in the service sector is the level of economic activity, which in this chapter is represented by value-added output.[15] Higher economic activity leads to increases in the stock of buildings and to more people being employed in the sector. Both these effects lead to an increased demand for energy services.

For a group of 21 IEA countries it has been possible to collect data on VA, with floor area information also available for a subset of 11 countries (see Annex A for country coverage). This has allowed the calculation of two alternative measures of energy intensity: energy use per unit of VA and energy use per unit of floor area (Figure 5.2).[16] In most countries, total final energy consumption in the service sector grew less rapidly than economic activity between 1990 and 2005. Therefore, according to this indicator, final energy intensity for the IEA11 fell by 15% over this period.

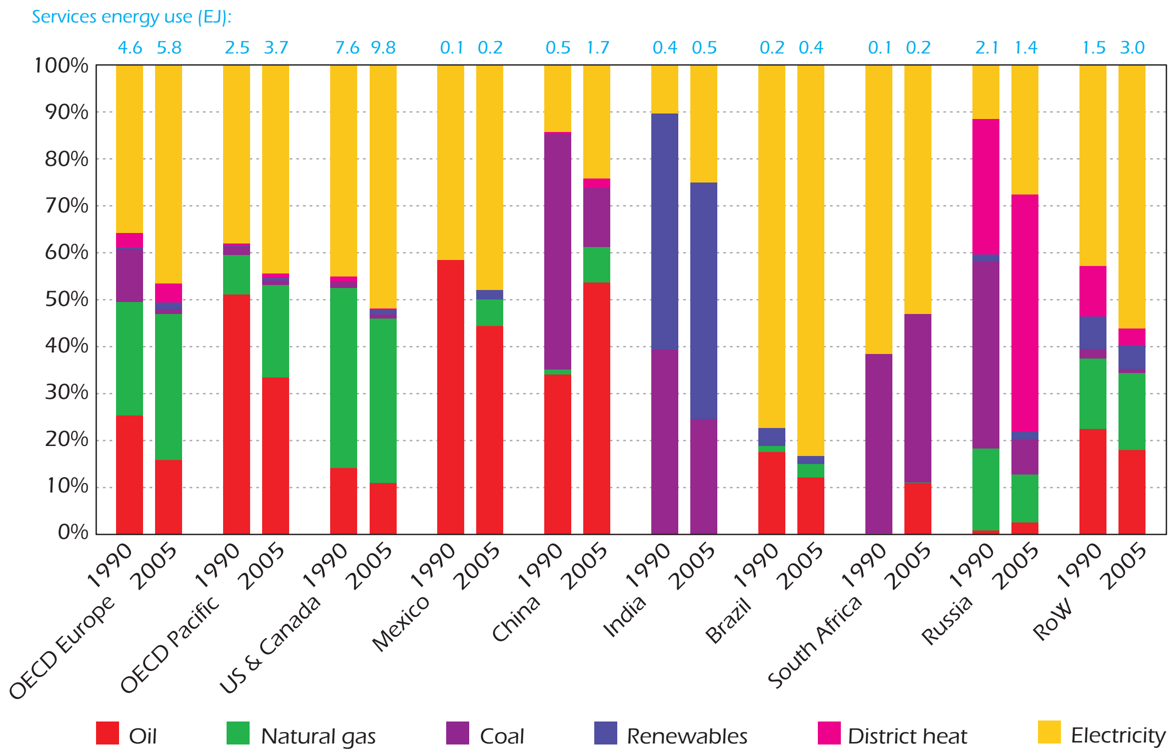
Interpreting this trend with respect to changes in energy efficiency is difficult, particularly in the absence of more detailed structural information. Different service sector activities can produce very different levels of economic output while consuming nearly the same amount of energy. For example, 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.

14. Oil appears to currently account for 50% of final energy use in China, but this share may be inflated by a statistical convention that includes some commercial transportation in the service sector.

15. Value-added of output expressed in constant 2000 USD at purchasing power parity.

16. Figure 5.2 shows energy use per unit of VA, with VA converted to USD using PPP. If instead, VA is converted to USD using MER, the trends in energy intensity are the same. However, the way countries compare to one another can be different. Using VA at PPP, the energy intensity in 2005 varies from 0.6 MJ per USD in the United Kingdom to 1.8 MJ per USD in Canada. When using VA at MER, the intensity varies from 0.6 MJ per USD in Japan to 2.2 MJ per USD in Canada.

Figure 5.1 ▶ ***Services Energy Use by Energy Commodity***



Sources: IEA, 2007c; IEA, 2007d; IEA estimates.

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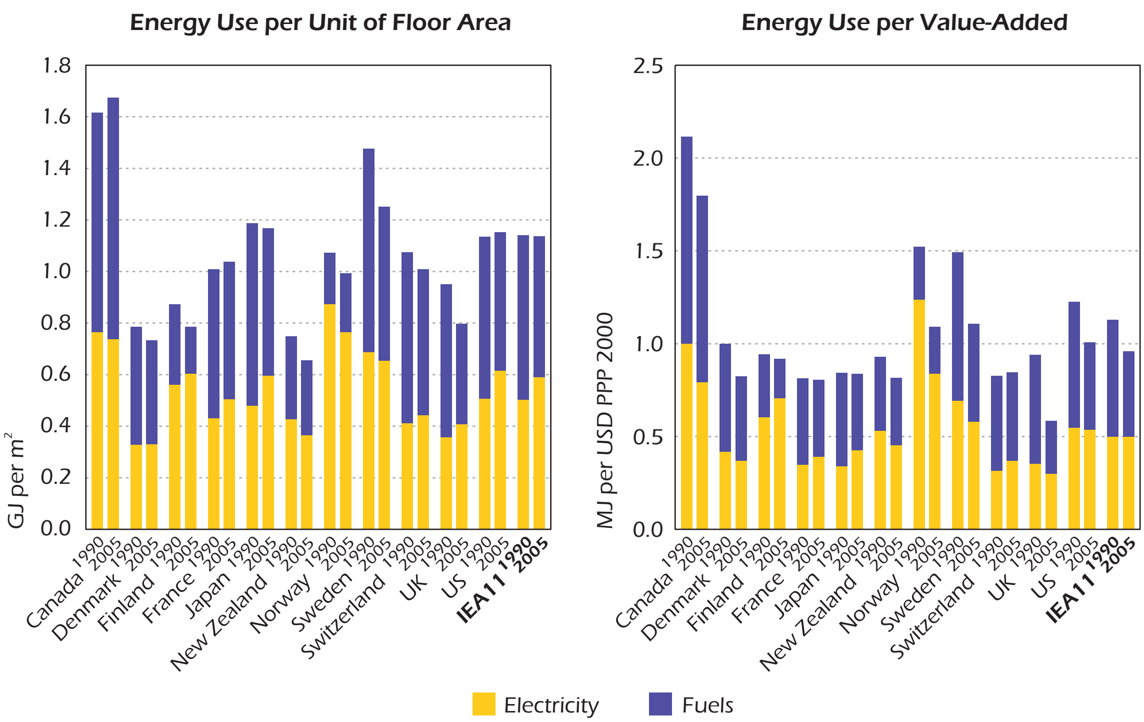
Figure 5.2 ▶ ***Measures of Energy Intensity in the Service Sector***



Source: IEA indicators database.

An alternative indicator of energy intensity for services is total final energy use per unit of floor area. In most countries, it fell at a lower rate than final energy use per unit of VA. However, important differences are evident in the trends for electricity and other fuels. For the IEA11, fuel use per unit of floor area fell by 14% between 1990 and 2005. In contrast, electricity use per unit of floor area increased by 17%. As fuels are used mainly for space heating, this decline largely represents savings in space heating energy per unit of floor area. Higher electricity use in many countries can be explained by the growth of electricity end-uses such as lighting, office equipment and space cooling.

In order to provide a full analysis of the factors underlying the changes in intensity and the different intensity levels amongst countries, more detailed information on the type of service activities, the different technologies and equipments use and the state of the building stock is required.

Disaggregate Indicators

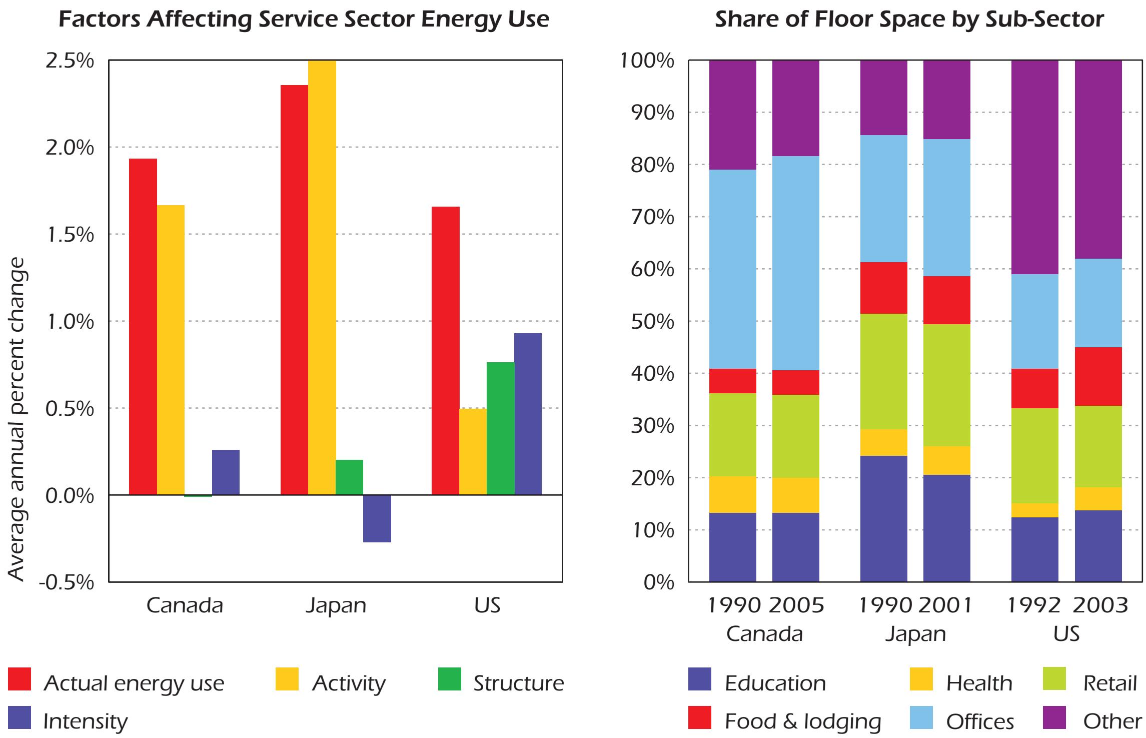
While the availability of detailed service sector data is poor in most IEA countries, information on energy consumption and floor area disaggregated by sub-sector exists for Canada, Japan and the United States. This information can be used as a starting point in understanding how structural differences, expressed in terms of the share of total floor area by sub-sector, affect the developments in service sector final energy use. Unfortunately, the data available are not disaggregated on a consistent sub-sectoral basis between countries, the definition of the sub-sectoral activities are not necessarily comparable nor are the data available for all years in some cases. Furthermore, the analysis does not take climate variations into consideration as the data required are not available for all countries. The results should therefore be treated as illustrative of the insights that can be gained from more detailed analysis.

The available data indicate that on a per floor area basis the health and food and lodging sub-sectors are some of the most energy intensive of the service sector. Thus an increase in the relative share of these sub-sectors would tend to increase the overall energy per unit of floor area of the sector. These effects can be analysed further by using a decomposition approach to separate and quantify the impacts of changes in activity (floor area), structure (share of floor space by sub-sector) and energy intensities (final energy use per unit of floor area) on services final energy use.

The results show that in both Canada and the United States, energy use has been rising more quickly than floor space, increasing the overall energy intensity of the sector (Figure 5.3). However, the reasons for these increases are different. In the case of Canada, structural effects have played almost no role as the share of floor space for most sub-sectors has remained unchanged. It has been the increases in sub-sectoral intensities that have driven up the overall energy intensity of the sector. In contrast, structural effects have played an important role in the United States, with a significant increase in the share of floor area of both health and food and lodging, two of the more energy intensive sub-sectors. In Japan, overall energy use per floor area declined as reductions in the energy intensity of individual sub-sectors more than offset the impacts of structure (which again tended to increase energy consumption).

These results demonstrate the importance of disaggregated information for the service sector to analyse trends in energy use and efficiency. The IEA is continuing to work with countries to improve the availability of more detailed information.

Figure 5.3 ▶ ***Impact of Structure on Service Sector Energy Use***



Sources: Natural Resources Canada; US Energy Information Administration; Energy Data and Modelling Centre, IEEJ, Japan.
Notes: The period analysed is different for each country. For Canada it is 1990 to 2005, for Japan 1990 to 2001 and for the United States 1992 to 2003. The Other category includes warehouse and storage, religious worship, recreational buildings (*e.g.* sports complexes and theatres) and all other types of commercial buildings.

TRANSPORT

Summary

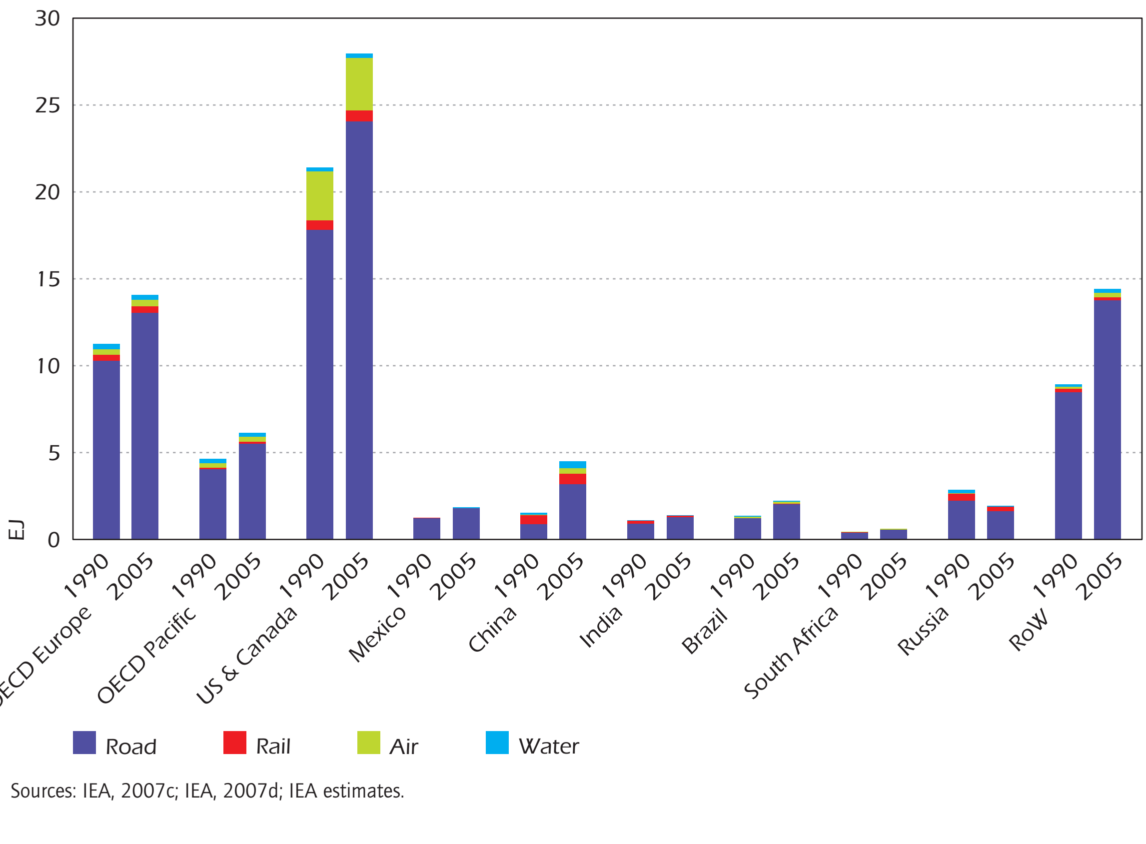
- Between 1990 and 2005, global final energy use in transport increased by 37% to 75 EJ. The associated CO_2 emissions increased to 5.3 Gt CO_2. Transport energy use grew most quickly in non-OECD countries.
- Road transport, accounting for 89% of the total, is by far the main contributor to the increase in overall transport energy consumption. Between 1990 and 2005, road transport energy use increased by 41%.
- The transport sector includes two main sub-sectors, passenger and freight, impacted by different underlying factors. In order to properly analyse trends in overall transport energy use and efficiency, separate sets of indicators are needed for each sub-sector. However, the necessary data to do this are currently only available for a group of 18 IEA countries (IEA18).
- Detailed analysis for the IEA18 shows that passenger transport energy use was 30 EJ in 2005, a 24% increase compared with 1990. The associated CO_2 emissions were 2.1 Gt CO_2. Cars are by far the largest energy user accounting for 87% of the overall passenger transport energy use. In terms of energy mix, oil products as a whole totalled 99% of this consumption.
- The main factor driving increased passenger transport energy use is the level of underlying activity. Passenger travel in the IEA18, as measured by passenger-kilometres, increased by 30% between 1990 and 2005. Passenger air transport increased most quickly, followed by car travel.
- The overall energy intensity of passenger transport decreased by 5% between 1990 and 2005 with all modes, except ships, showing decreases. In the case of cars, improvements in the efficiency of engine technologies were partially offset by the increased weight of cars and congestion-related effects.
- Energy use in freight transport for the IEA18 was 13 EJ in 2005, an increase of 27% since 1990. The associated CO_2 emissions were 1.0 Gt CO_2. The freight sub-sector is again almost totally reliant on oil products, mostly diesel. Trucks are the main energy user in freight transport, accounting for 82% of total energy consumption.
- Freight haulage, as measured by tonne-kilometres, increased by 34% between 1990 and 2005, mostly driven by an increase in trucking.
- The overall energy intensity of freight transport declined by 5% between 1990 and 2005 as reductions in the intensity of individual modes more than offset the increased share of energy-intensive trucking. In the case of trucks, the reduction in the energy intensity of trucking was most strongly influenced by an increase in load factors.
- More detailed information, disaggregated by the weight and size of vehicles, in both the passenger and freight sub-sectors would help improve the analysis of energy use and efficiency for the transport sector.

Introduction

The transport sector includes the movement of people and goods by road, rail, sea and air. Pipelines and international air and marine transport are excluded from the analysis. In this chapter, the term "cars" is used to refer collectively to all light-duty vehicles including cars, mini-vans, sport utility vehicles (SUVs) and personal-use pick-up trucks.

Trends in global transport energy use and associated CO_2 emissions are presented, disaggregated by mode. More detailed analysis of these trends requires passenger and freight transport to be analysed separately since they are impacted by different underlying factors. However, the necessary disaggregated information is only available for a group of 18 IEA countries (see Annex A for country coverage). For these countries, indicators that examine energy use per passenger-kilometre or per tonne-kilometre are developed. Decomposition analyses are also performed to separate and quantify the different factors impacting car and truck energy use.

Figure 6.1 ▶ ***Transport Energy Use by Mode***



Sources: IEA, 2007c; IEA, 2007d; IEA estimates.

Global Trends

Between 1990 and 2005, transport energy consumption increased by 37% to 75 EJ, and was the fastest growing end-use sector. The associated CO_2 emissions rose broadly in line with this increased energy use to reach 5.3 Gt CO_2. Road transport is by far the largest energy user and accounted for 89% of total transport energy use in 2005.

It is also the main contributor to increased transport energy use. While non-road modes increased their energy consumption by 13% between 1990 and 2005, road transport energy use rose by 41%.

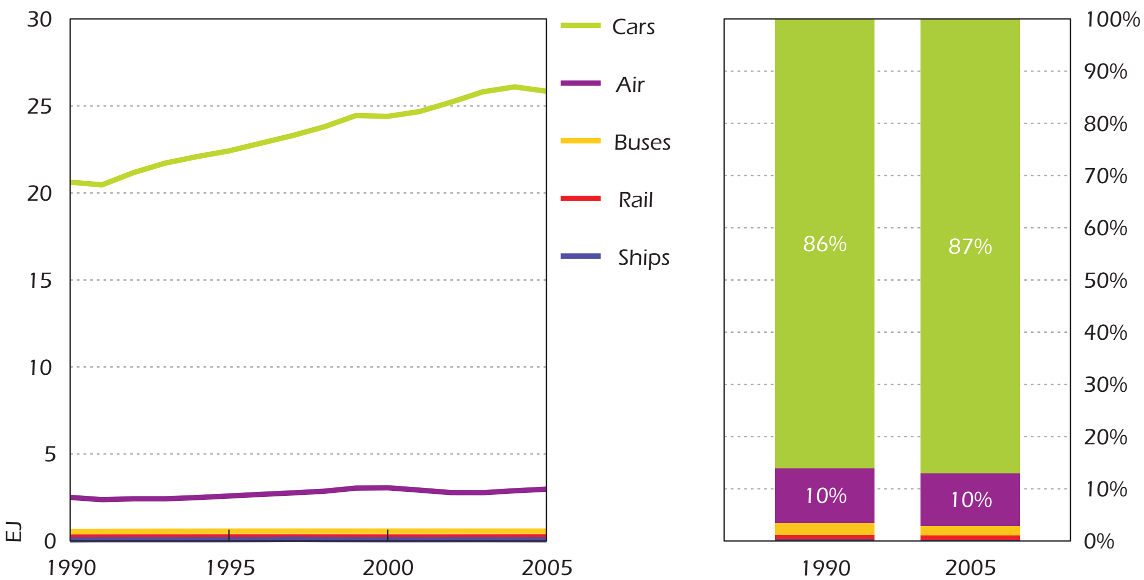
Trends in energy use by transport mode vary significantly amongst countries and regions. On average, the growth in non-OECD countries (+55%) was faster than in OECD countries (+30%). The large increase in non-OECD countries is in part attributable to the rapid economic growth of several major countries, creating increased personal disposable incomes, higher vehicle ownership and increased need for freight transportation. For instance, passenger travel tripled in China, while freight haulage more than doubled. As a result China almost tripled its use of energy for transport purposes and was responsible for 33% of the overall growth in non-OECD countries. Of the countries and regions analysed, Russia is the only one showing a decline in transport energy consumption between 1990 and 2005, due to the major economic restructuring that took place in the early and mid-1990s.

Disaggregate Indicators

Passenger Transport

In a group of 18 IEA countries for which disaggregated information is available, passenger transport energy use increased by 24% between 1990 and 2005, to reach 30 EJ (Figure 6.2). The shares of the different modes of passenger transport in final energy use have changed little since 1990. Cars are by far the largest energy users in all the countries analysed, accounting on average for 87% of total passenger transport energy use. Buses, passenger rail and passenger ships were together responsible for a further 3% of final energy use. Approximately 10% of passenger transport energy consumption was in domestic airplanes.

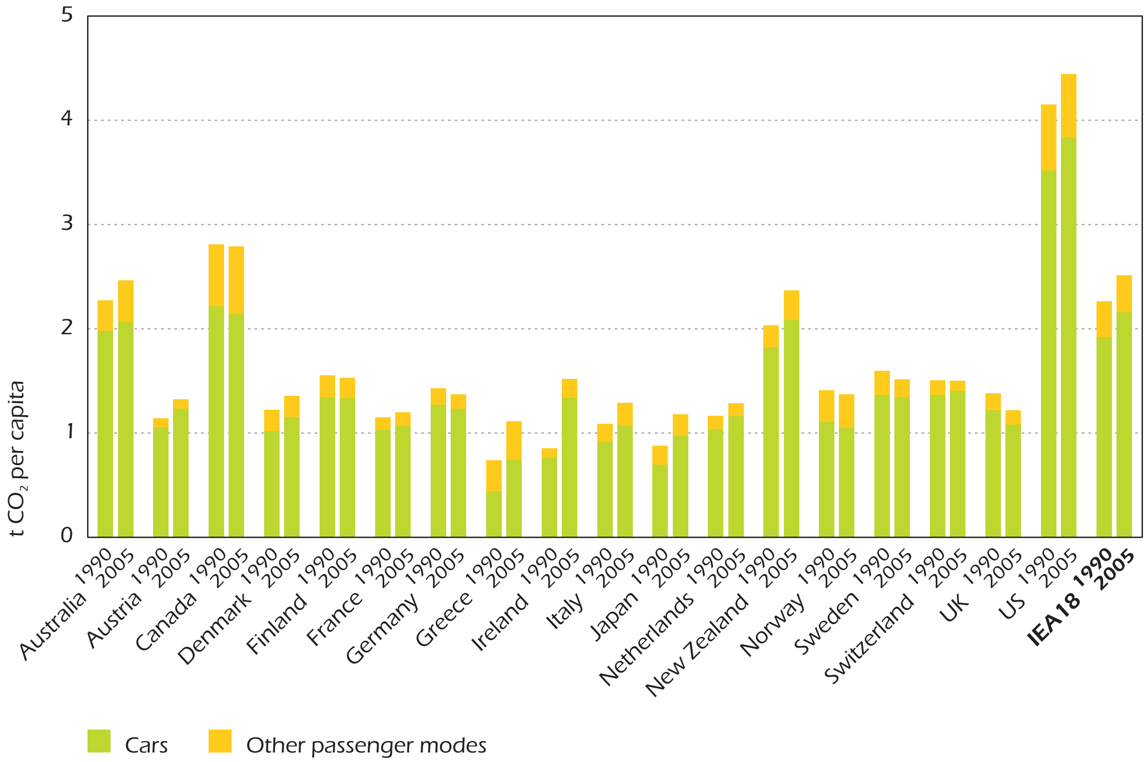
Figure 6.2 ▶ ***Passenger Transport Energy Use by Mode, IEA18***



Source: IEA indicators database.

Passenger transport remains almost exclusively dependent on oil products, which constitute 99% of final energy use. Although there has been little switching away from oil in passenger transport, the fuel mix has undergone some important changes in recent years. Most significant has been the increased use of diesel in cars in Europe. As a result the share of diesel in passenger transport energy use in the IEA18 has increased from 9% in 1990 to 14% in 2005.

Figure 6.3 ▶ ***Passenger Transport CO_2 Emissions per Capita***



Source: IEA indicators database.

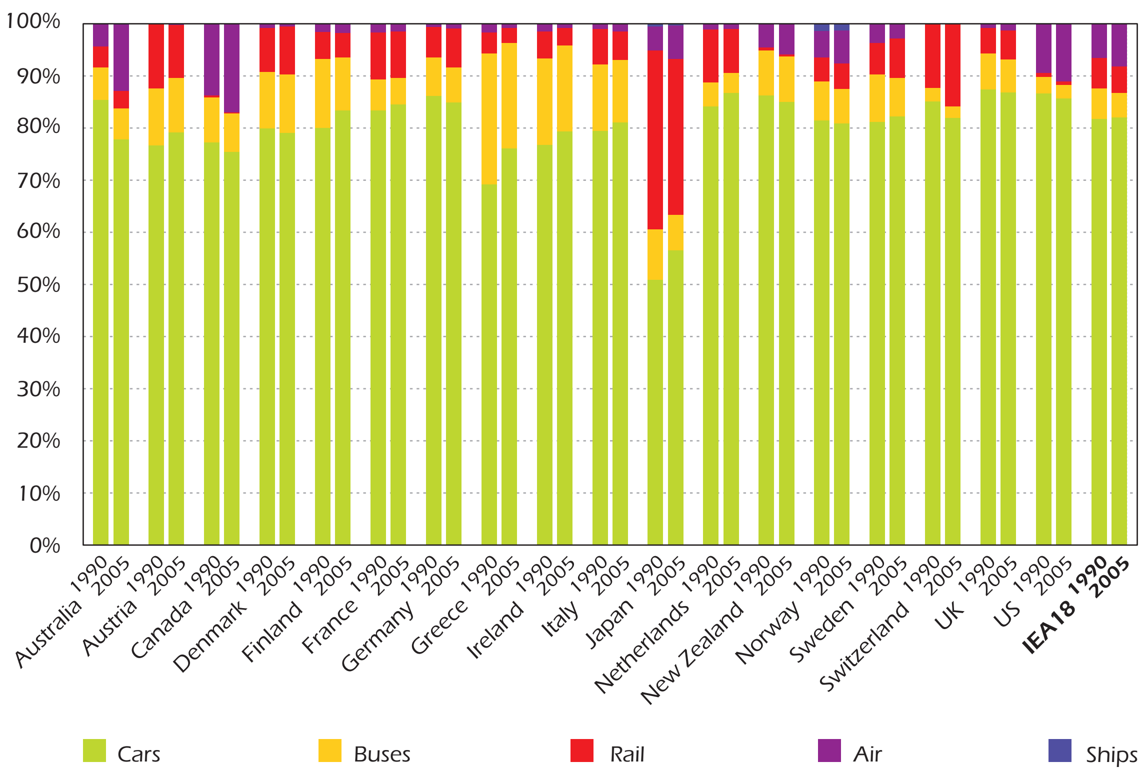
Higher passenger transport energy use has led to a 23% increase in associated CO_2 emissions since 1990. The strong link between energy use and emissions is due to the almost total reliance on oil-based fuels for cars, buses and airplanes. Examining passenger transport emissions on a per capita basis reveals interesting differences amongst countries in both the levels and trends (Figure 6.3). CO_2 emissions per capita in several European countries remained relatively stable or even decreased over the period. In contrast, Greece and Ireland showed sharp increases in their emissions per capita, largely due to a strong growth in car use. The level of CO_2 emissions per capita in Australia, Canada and the United States are the highest in IEA18, reflecting a combination of longer travel distances and larger and heavier vehicles.

In order to understand better these trends in energy use and CO_2 emissions, it is necessary to examine the link with the underlying drivers. Many diverse factors have an impact on the level of energy use and CO_2 emissions, such as travel patterns, income level, car ownership rate and average fuel economy.

Passenger travel activity in the IEA18 increased steadily between 1990 and 2005. The strongest per capita increases were in car passenger travel (+1.1% per year) and air travel (+2.7% per year). In contrast, per capita passenger travel by buses and trains decreased slightly over this period. The level of passenger transport per capita varies widely from country to country. Countries with a high density of population, such as Japan and the Netherlands, have significantly lower levels of travel per capita than low-density countries such as Australia, Canada and the United States.

Trends in the share of passenger transport by mode are shown in Figure 6.4. Cars clearly dominate the overall modal split in all IEA18 countries. On average, they accounted for 82% of total passenger-kilometres in both 1990 and 2005. Yet the share of car travel differs from country to country, reflecting diverse demographic and geographic characteristics, as well as different levels of provision for urban and intercity transport. Between 1990 and 2005, air travel was the fastest growing mode of passenger travel. Buses and trains each accounted for about 5% of the total passenger travel in 2005, slightly lower than in 1990.

Figure 6.4 ▶ ***Share of Total Passenger Travel by Mode***



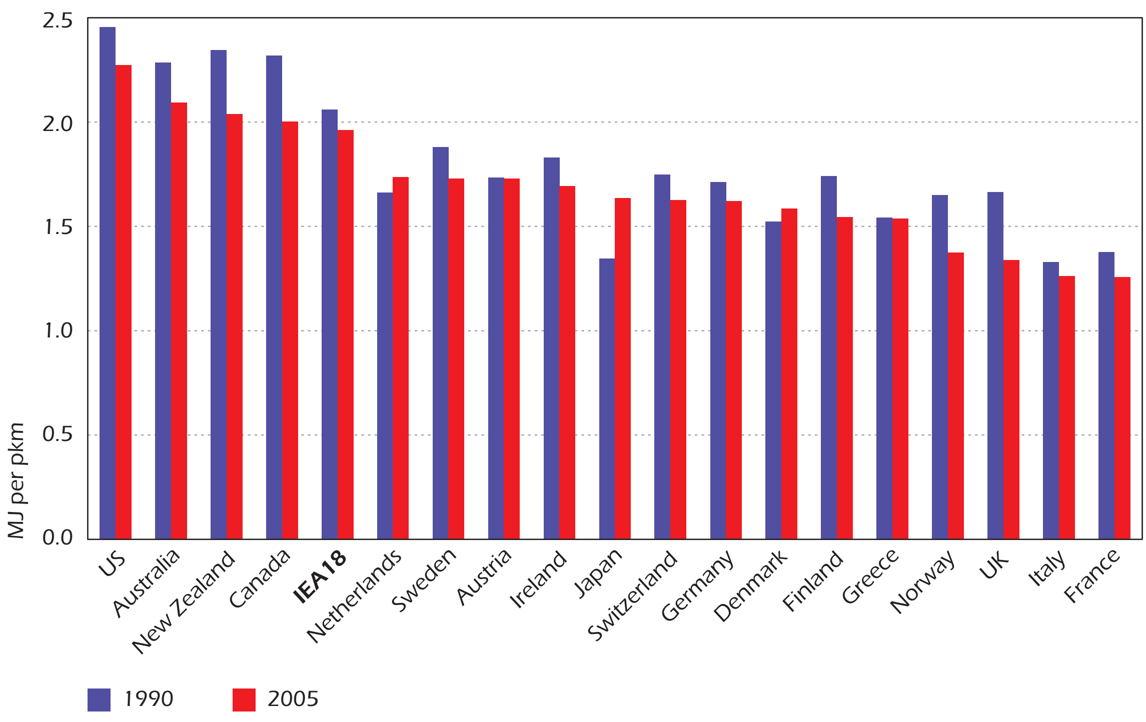
Source: IEA indicators database.

Japan stands out because of the large share of passenger-kilometres travelled by rail, which accounted for 34% in 1990 and 30% in 2005. This large share is due to a strong urban and regional rail system developed over the previous decades. European countries are characterised by a significant share of public passenger transport (primarily buses and trains), especially if compared to Australia, Canada, and the United States. In these three countries, air passenger shares grew to well above 10%

in 2005, making air travel second in importance to cars. However, it should be noted that the information for European countries excludes pan-European air travel (the data include only domestic passenger air trips).

Combining information on passenger energy use and activity, Figure 6.5 shows the trends in energy use per passenger-kilometre by country, aggregated across all modes. These trends are influenced by both the energy intensity of each mode and by the share of that mode in a particular country. For most countries, energy use per passenger-kilometre is declining. Reductions in the energy intensity of individual modes have been more than enough to offset the impact of increasing shares of car and air travel, which are more energy intensive. The only exceptions are Japan, Denmark and the Netherlands, where energy use per passenger-kilometre has increased. For Japan this can be attributed to both a falling share of rail (to the benefit of cars) and to an increase in the energy intensity of cars (at least until recent years). For the Netherlands, the reasons are higher levels of car ownership, coupled with virtually no change in their energy intensity.

Figure 6.5 ▶ ***Energy Use per Passenger-Kilometre Aggregated for All Modes***



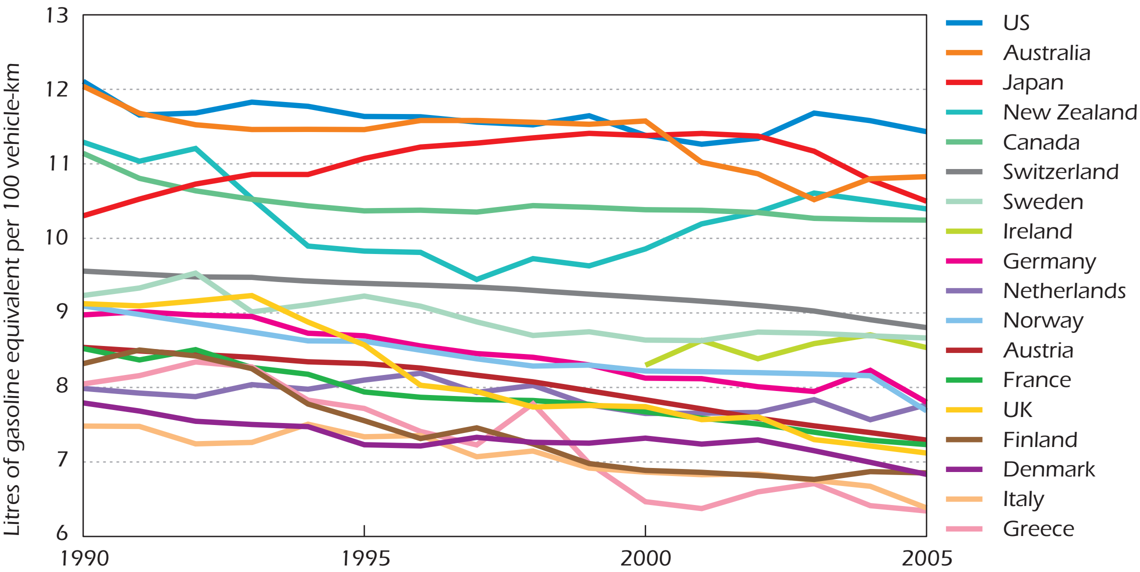
Source: IEA indicators database.

As cars are the most important energy user in passenger transport, it is interesting to look at more detailed indicators for this mode. Starting with average "on-road" fuel intensities, Figure 6.6 reveals wide variations in the levels and trends amongst countries. The results reflect a number of unrelated factors such as vehicle technologies and the effect of driving conditions.

The average fuel intensities of cars decreased in most countries between 1990 and 2005. In Europe, this was due to a combination of factors. The 1990s were characterised by the widespread diffusion of vehicles equipped with electronic control systems for fuel management and by stronger consumer demand for more efficient cars – a reaction to high fuel prices. Since the early 2000s, intensities declined further in Europe as a result of increased sales of direct-injection diesel cars. Despite a small decrease, the fuel intensity of cars in North America remained higher than in other IEA18 countries, at nearly 11.5 litres of gasoline equivalent per 100 vehicle-kilometres. High levels of fuel intensity also characterised Australia, New Zealand and Japan. In Japan, until the late 1990s, efficiency improvements of new vehicles had been offset by an increase in vehicle weight and congestion-related effects.

The increasing weight of vehicles has been another factor offsetting improvements in the underlying efficiency of new car engine technologies. Over the last 15 years, the average size and weight of the stock of cars increased as larger and heavier vehicles, such as SUVs, became more popular. This trend, combined with additional safety features also increasing weight, has tended to raise the energy consumption of cars. Data for Canada show that, in 2005, light trucks such as SUVs accounted for one-third of all cars, up from a share of one-fifth in 1990. In the United States, the stock of passenger cars remained almost stable between 1990 and 2005, while that of light trucks nearly doubled. In European countries, the number of cars with an engine capacity greater than two litres has more than doubled since 1990. In contrast, Japan reported a much lower increase in the weight of cars, mainly because of the effective regulation of fuel efficiency under the Top Runner programme, which came into effect in the late 1990s.

Figure 6.6 ▶ ***Average Fuel Intensity of the Car Stock***

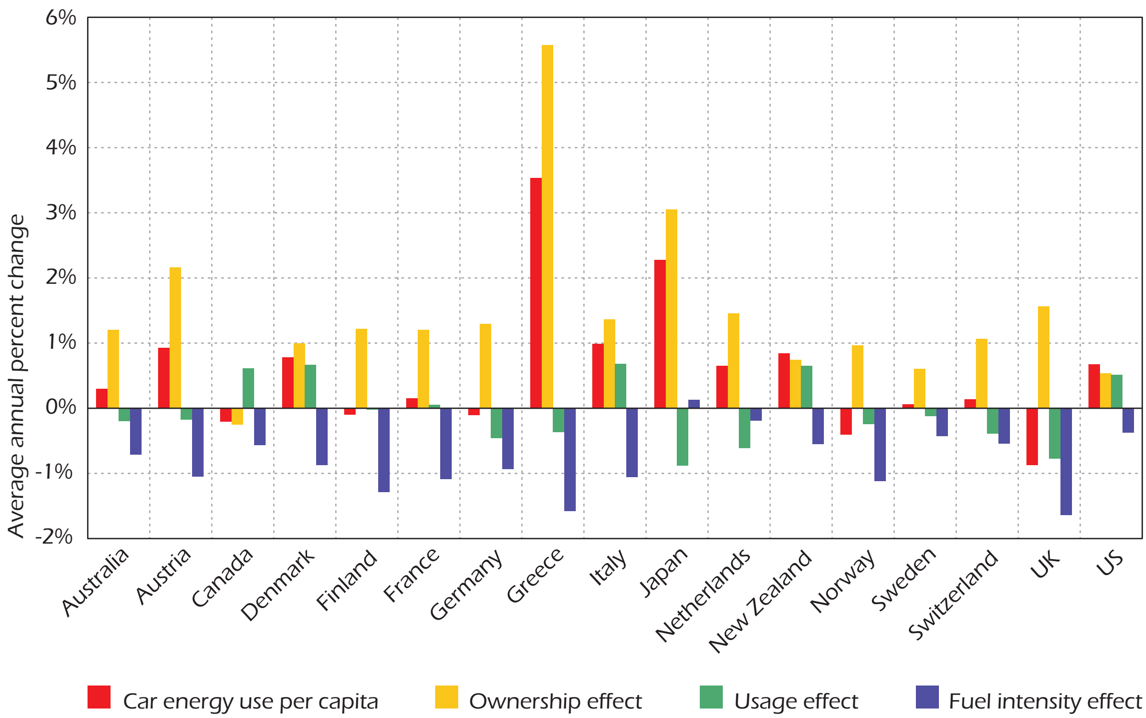


Source: IEA indicators database.

By combining data on fuel intensities with information about car use and ownership it is possible to examine how different factors influence car energy use across countries (Figure 6.7). All countries, with the exception of Canada, showed increases in car ownership. Greece and Japan showed the strongest growth, albeit rising from comparatively low ownership levels in 1990. For most countries, the growth in car ownership tended to increase per capita car energy consumption by about 1% per year. The impact of car usage (*i.e.* the distance travelled by each car) on per capita energy consumption is more varied across countries. In six countries, the distance travelled by each car increased. However, car usage actually fell in 11 of the countries analysed. In these countries, the trend toward households owning more than one car means that journeys are shared between cars. As a result, travel per car tends to fall.

Together, car ownership and usage give the total distance travelled per capita. For most countries, reductions in the fuel intensity of cars were not sufficient to offset the increases in car ownership and car use. Thus, car energy use per capita increased in most IEA18 countries. The exceptions to this were Canada, Finland, Germany, Norway and the United Kingdom. In these countries, the effect of significant reductions in energy intensity were augmented by falling car usage (except in Finland, which showed a small increase), which more than offset increases in car ownership. In Japan, fuel intensities increased slightly as the impacts of increased vehicle weight and congestion offset improvements in engine efficiency.

Figure 6.7 ▶ ***Decomposition of Changes in Car Energy Use per Capita, 1990 - 2005***



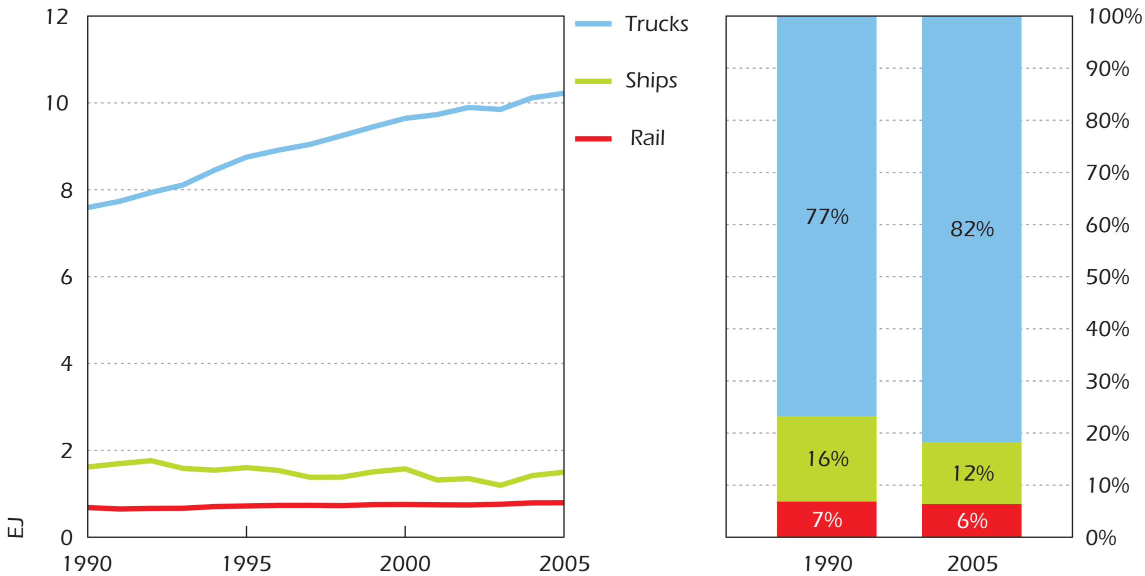
Source: IEA indicators database.

Freight Transport

Detailed information on freight transport energy use and activity is also available for a group of 18 IEA countries. For the IEA18, freight transport accounted for 30% of total transportation energy use in 2005. Between 1990 and 2005, energy use in freight transport increased by 27% to 13 EJ and associated direct and indirect CO_2 emissions increased by 26% to 1.0 Gt CO_2.

The strong growth in freight energy use was almost entirely due to higher energy demand for trucking, which increased by 35% (Figure 6.8). Trucks increased their share of total freight transport energy consumption to 82% in 2005. Total final energy consumption for rail freight increased by 16%, but its share of energy use declined to 6%. In contrast, both the absolute amount and the share of energy use for water freight declined so that in 2005 it accounted for 12% of freight energy use.

Figure 6.8 ▶ ***Freight Transport Energy Use by Mode, IEA18***



Source: IEA indicators database.

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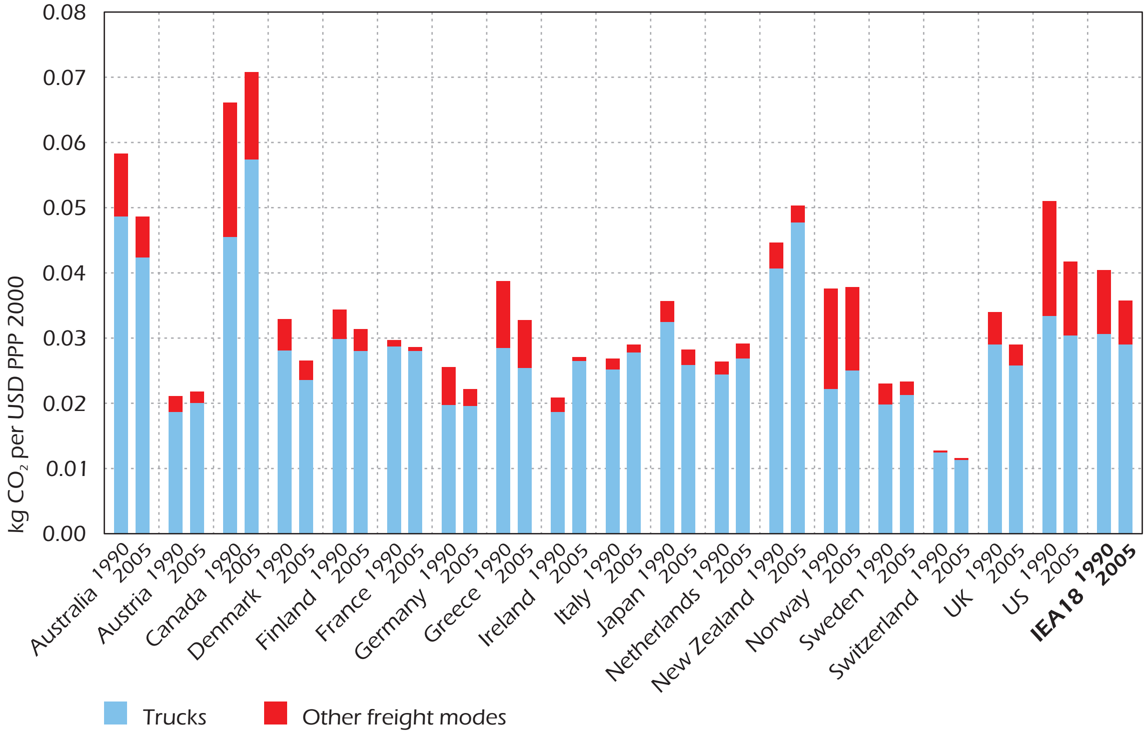
Oil dominates the freight transport sector, accounting for 99% of the total final energy consumption, most of which is diesel. In 2005, diesel was the dominant fuel for trucks with a share of 87%, whereas ships used mainly diesel (40%) and heavy fuel oil (59%). Rail transport energy use is split between diesel (88%) and electricity (12%).

The pattern of CO_2 emissions from freight transport reflects the dominance of trucking. Figure 6.9 presents CO_2 emissions from freight haulage per unit of GDP (converted to USD at PPP) for the IEA18 countries, split into truck and other (rail and shipping). There is considerable variation among countries, which reflects a combination of three factors: the volume of freight haulage per GDP; the share of the various freight modes; and the energy intensity (energy per tonne-kilometre) of each mode. Canada has the highest emissions per GDP, largely as a result of long haulage distances. In contrast, Switzerland, Austria and Sweden have much lower emission intensities due to a combination of significantly shorter haulage distances and lower than average energy intensities.[17]

17. Using GDP converted to USD at MER would change the way some countries compare with each other. Nevertheless, Canada still has the highest emissions per GDP and the three countries with lowest emissions intensities are unchanged. However, the spread amongst countries increases and is from 0.09 kg of CO_2 per USD in Canada to 0.01 kg of CO_2 per USD in Switzerland.

Figure 6.9 ▶ ***Freight CO_2 Emissions per Unit of GDP, IEA18***



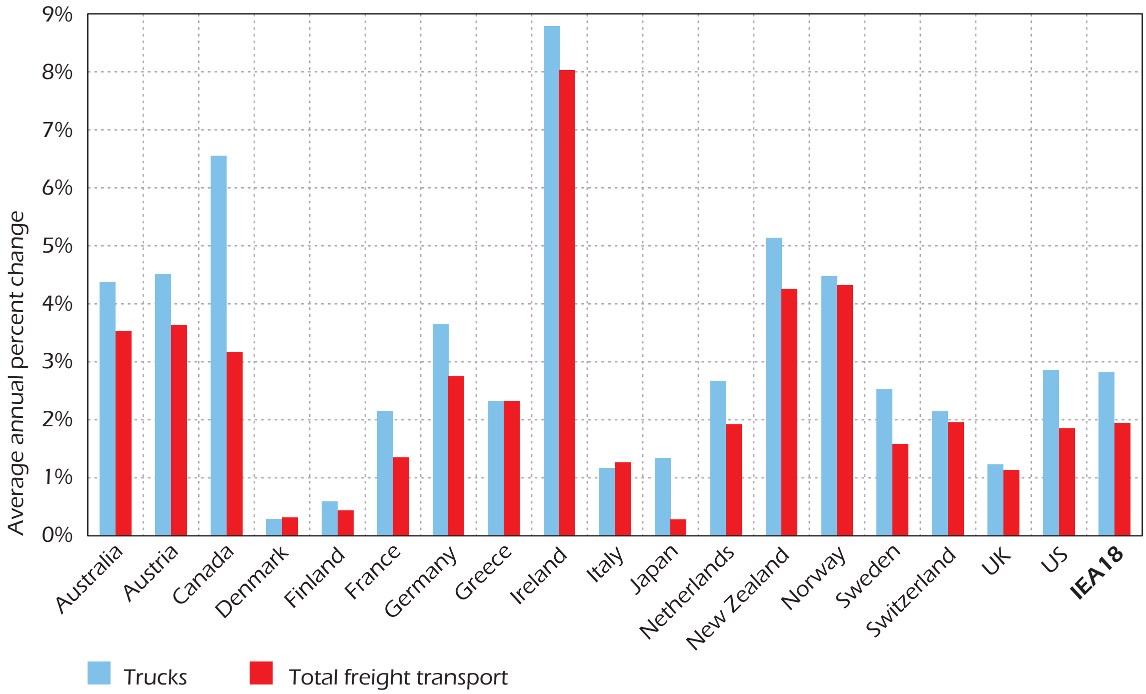
Source: IEA indicators database.

In 2005, rail and ships accounted for a significant portion of CO_2 emissions in Norway, the United States, Greece and Canada. All IEA18 countries, except these four, have experienced an increase in the share of emissions from trucks between 1990 and 2005. The differences amongst countries in the levels and changes in energy use and CO_2 emissions can be further explored by looking at some of the key underlying drivers, including the level of freight transport activity and the share and energy intensity of the different freight modes.

Freight transport activity, measured in tonne-kilometres, went up by 34% between 1990 and 2005 in IEA18 countries. Trucking activity increased in all IEA18 countries and trucking was the fastest growing freight mode in most of them. The highest increase in trucking was seen in Ireland, driven by the very rapid expansion of the Irish economy. GDP in Ireland increased at an average annual rate of 6.5% between 1990 and 2005. Trucking also increased substantially in large countries with low population densities such as Canada, New Zealand and Norway. Rail and shipping activity increased in many countries.

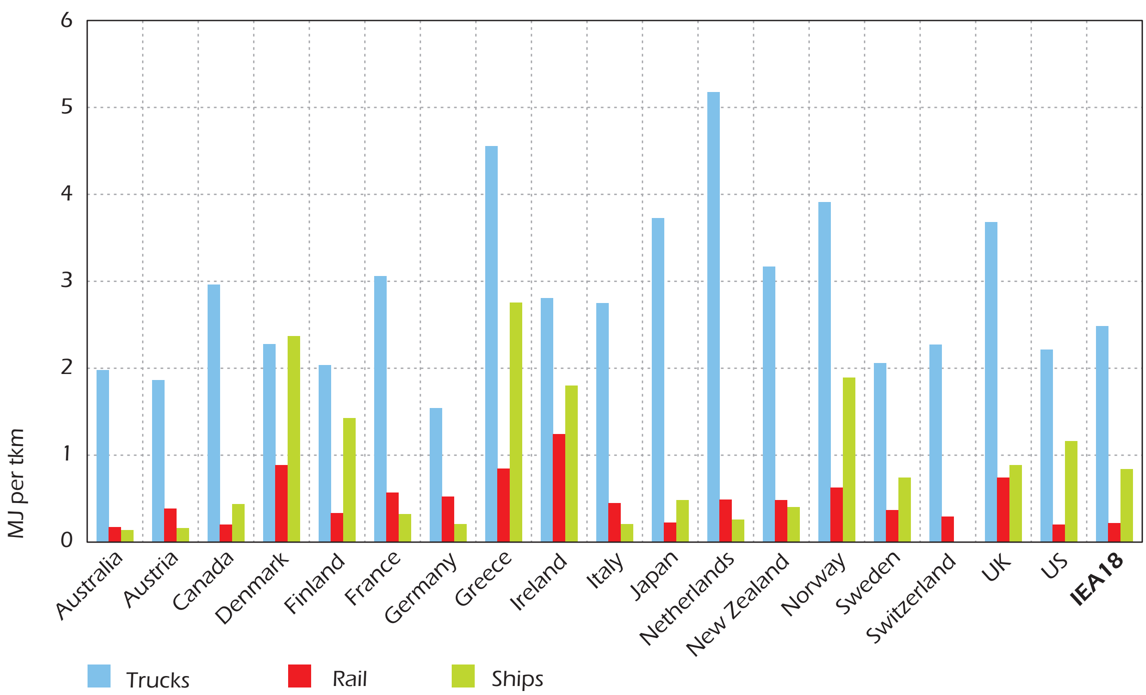
The energy intensities of trucks, ships and rail vary significantly, with trucks being the most intensive (Figure 6.11). On average, trucks use between two and 17 times more energy than rail to move one tonne of goods a distance of one kilometre. The large range for the energy intensity of truck freight can partly be explained by the type of goods moved, the size and geography of the country, the average load factors as well as the split between urban delivery trucks and long-haul trucks, which are much larger and less energy intensive.

Figure 6.10 ▶ ***Average Annual Percent Change of Freight Tonne-Kilometre by Mode, 1990 - 2005***



Source: IEA indicators database.

Figure 6.11 ▶ ***Freight Transport Energy Use per Tonne-Kilometre by Mode, 2005***



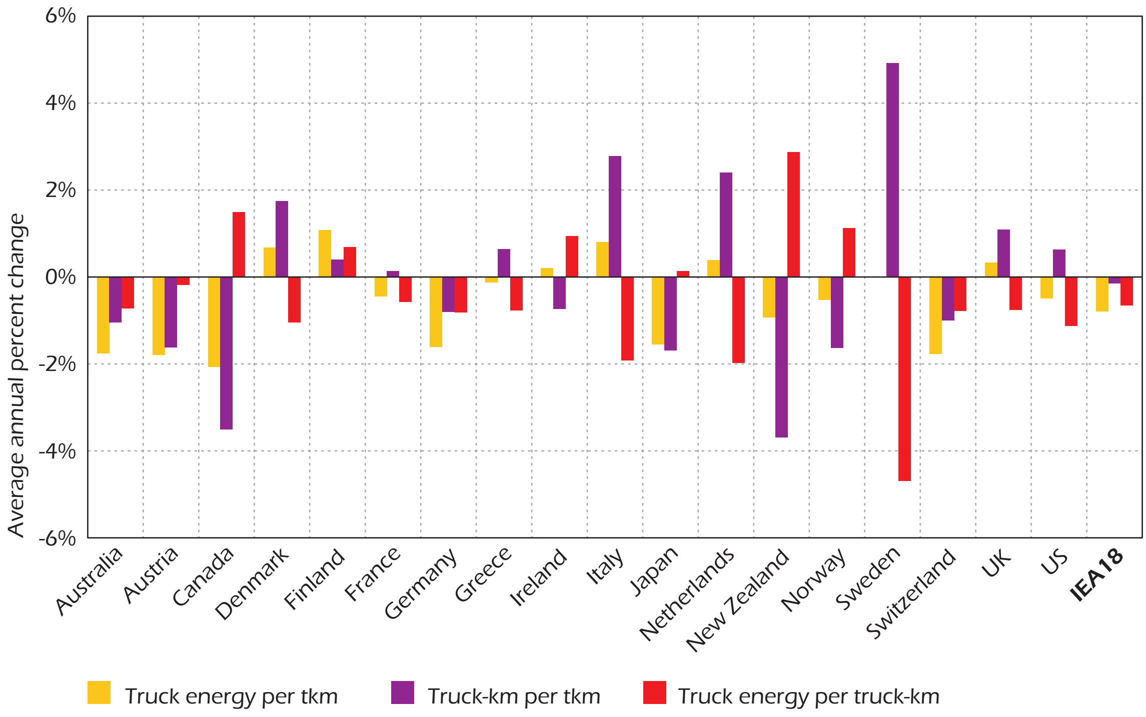
Source: IEA indicators database.

6

The difference in the energy intensity among modes has some important implications for trends in freight energy consumption. First, because of its much higher energy intensity, growth in road freight haulage will have a more significant impact on energy use than growth in freight transport by rail or ships. Second, intensity reductions in trucking will result in higher energy savings than intensity reductions in rail and ships or than modal switching between these two modes. Therefore, the increase in freight energy use in Canada and New Zealand can partly be explained by the relatively high growth of the trucking activity.

The aggregate freight energy intensity for the IEA18 has been remarkably stable over time, showing only a slight decline (-0.4% per year) between 1990 and 2005. Trends in the aggregate energy intensity of freight haulage reflect the balance of two opposing trends. On one hand, there has been a steady decline in the energy intensity of individual modes (trucking, rail and shipping) over time. On the other hand, the growing share of trucks (with their higher energy intensity) in the modal mix has pushed the intensity higher.

Figure 6.12 ▶ ***Decomposition of Changes in Truck Energy Intensity, 1990 - 2005***



Source: IEA indicators database.

As trucking dominates freight transport use, it is interesting to look in more detail at the factors affecting the overall energy intensity of truck freight haulage. These include: the load factor (average load per vehicle); the share of short-haul freight; vehicle fuel efficiency; driving behaviour; traffic congestion; maximum allowable truck weight; and the availability and quality of the infrastructure for freight transport. In order to better assess the impact of such factors, a decomposition analysis of the overall energy intensity has been performed (Figure 6.12). The factors for which consistent information are available across countries are the truck-kilometres per tonne-kilometres (which is the inverse of the load factor) and the vehicle energy intensity. This reveals that the overall energy intensity of trucking was most strongly influenced by the evolution of load factors. For half of the countries analysed an increase in load factors (*i.e.* a decrease in truck-kilometres per tonne-kilometre) led to a decline in truck energy intensity (measured as truck energy per tonne-kilometre). In Finland, France and the United States, changes in vehicle energy intensity had a greater impact on trucking energy intensity than did the evolution of load factors.

ELECTRICITY GENERATION

Summary

- Electricity production was responsible for 32% of total global fossil fuel use in 2005, accounting for 132 EJ. It was also the source of 41%, or 10.9 Gt, of energy-related CO_2 emissions. Improving the efficiency of electricity production therefore offers a significant opportunity for reducing dependence on fossil fuels, which helps to combat climate change and improve energy security.
- A set of indicators has been developed to analyse the energy efficiency of electricity production from fossil fuels on a global level and for a number of key countries. The technical potentials for energy and CO_2 savings from improving the energy efficiency of electricity production are also calculated.
- The global average efficiencies of electricity production are 34% for coal, 40% for natural gas and 37% for oil. For all fossil fuels, the global average efficiency is 36%. Wide variations are seen in efficiencies amongst countries, with OECD countries typically having the highest efficiencies. The level of efficiency has been slowly improving in recent years in most countries.
- However, significant fuel and CO_2 savings potential still exists. Across all fossil fuels the technical fuel savings potential is between 21 EJ and 29 EJ per year, with an associated CO_2 reduction potential of 1.8 Gt CO_2 to 2.5 Gt CO_2 per year. The largest savings are from improving the efficiency of coal-fired plants, which alone could provide savings of between 15 EJ and 21 EJ (1.4 Gt CO_2 to 2.0 Gt CO_2). On a regional basis, just less than half the global savings would come from OECD countries, with the remainder from developing and transition countries.

Introduction

Most of this publication has focused on the use of indicators to examine patterns and trends of energy consumption and energy efficiency in end-use sectors. However, indicators can also be used to examine the energy efficiency of energy supply. This chapter presents a number of indicators that are used to analyse the levels and trends of energy efficiency in public electricity production (also known as main activity production) and the technical potential for fuel and CO_2 savings resulting from improved efficiency. The analysis is based on IEA statistics and includes public electricity plants and public combined heat and power (CHP) plants.

Electricity production accounts for 32% of total global fossil fuel use and around 41% of total energy related CO_2 emissions. Improving the efficiency with which electricity is produced is therefore one of the most important ways of reducing the world's dependence on fossil fuels, so helping both to combat climate change and improve energy security. Additional fuel efficiency gains can be made by linking electricity generation to heating and cooling demands through high efficiency CHP systems (*e.g.* in industry and for district heating).[18] Fuel and CO_2 savings

18. The potential for carbon savings from increased use of combined heat and power in industry is analysed in IEA, 2007a and is calculated to be between 110 Mt CO_2 and 170 Mt CO_2 per year.

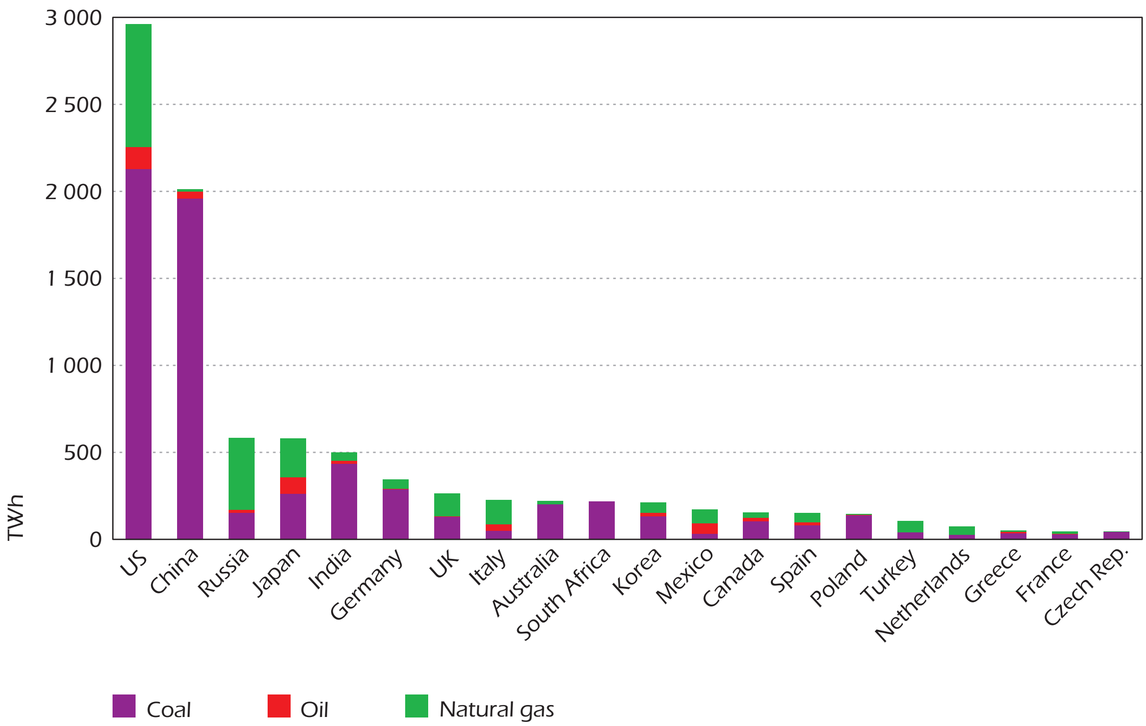
can also be achieved through replacing fossil-fuelled electricity production with electricity generation from renewable or nuclear energy, but these savings are not analysed here.

Fossil-Fuelled Electricity Production and Fuel Mix

Fossil fuels are the source of 66% of global public electricity production. The share in OECD countries is slightly lower at 61%, while in developing and transition countries it averages 72%. The share of electricity production from fossil fuels in individual countries varies considerably. Countries with a high share of fossil fuel use for public electricity production include Poland (98%), South Africa (94%), Luxembourg (93%), Australia (93%), Ireland (93%), Greece (89%), the Netherlands (89%), Portugal (84%), Italy (83%), China (82%) and India (80%).

The 20 countries shown in Figure 7.1 account for 80% of current global electricity production from fossil fuels (coal, oil and natural gas). The United States and China have by far the highest absolute levels of fossil-fuelled electricity production, together accounting for 44% of the global total. Many OECD countries also have significant electricity production from fossil fuels, as do Russia, India and South Africa. Globally, most fossil-fuelled electricity production is from coal (63%), followed by natural gas (29%) and oil (9%).

Figure 7.1 ▶ ***Electricity Production by Fossil Fuels in Public Electricity and CHP Plants, 2005***



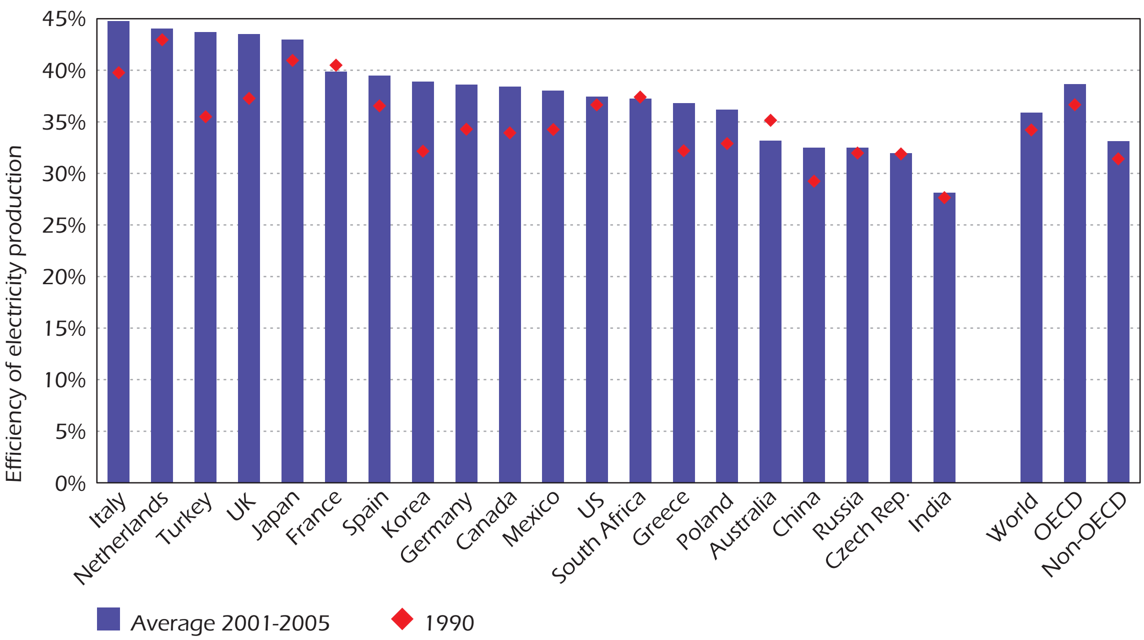
Sources: IEA, 2007c; IEA, 2007d.

Efficiency of Fossil-Fuelled Electricity Production

Country average efficiencies for electricity production from coal, natural gas and oil have been calculated for the period 2001 – 2005.[19] These show that the current global average efficiencies of electricity production are 34% for coal[20], 40% for natural gas and 37% for oil. These efficiencies by fuel have then been combined to give the weighted average efficiencies for all fossil fuels for the period 2001 – 2005 (Figure 7.2).

The global average efficiency of all fossil-fuelled electricity production is 36%. The figure is somewhat higher in OECD countries at 39%, while in non-OECD countries it is 33%. Average efficiencies amongst the 20 countries analysed range from 28% in India to 45% in Italy. Since 1990, the average efficiency of global fossil fuel production has increased by almost two percentage points. Nearly all countries have experienced improved efficiencies.

Figure 7.2 ▶ ***Efficiency of Electricity Production from Fossil Fuels in Public Electricity and CHP Plants***



Source: IEA, 2007c; IEA, 2007d.

7

The overall efficiency of fossil-fuelled electricity production in countries is strongly influenced by the mix of fuels used. Countries with a large share of natural gas generally have much higher average efficiencies than countries that mainly rely on coal and oil. Similarly, for many countries an increasing share of natural gas in the

19. These country average efficiencies are for electricity production from both electricity only and CHP plants. In CHP plants the combined production of heat and electricity is more efficient in terms of the use of primary energy compared to separate production of heat and electricity. However, heat extraction causes the energy efficiency of electricity production to decrease. The loss of efficiency depends on the temperature of the heat extracted. To account for this, a correction for heat extraction is applied when calculating the efficiency of electricity production from CHP plants (see Annex A for more details).

20. Other work by the IEA under the Gleneagles Plan of Action reports that, worldwide, coal-fired power plant efficiency averages 28% in 2004 on a net output basis using gross calorific values. By doing the appropriate conversions, these two reported efficiencies can be shown to be entirely consistent with one another.

electricity production mix has been the main factor driving up efficiencies over time. One exception to this is Russia, where the efficiency of gas-fired electricity production, at 33%, is low compared to the world average. Thus the overall efficiency of Russia's fossil-fuelled electricity production (71% of which is gas) is very similar to that of China (of which 97% is from coal). In both countries, there are significant potentials for improving the efficiency of electricity production.

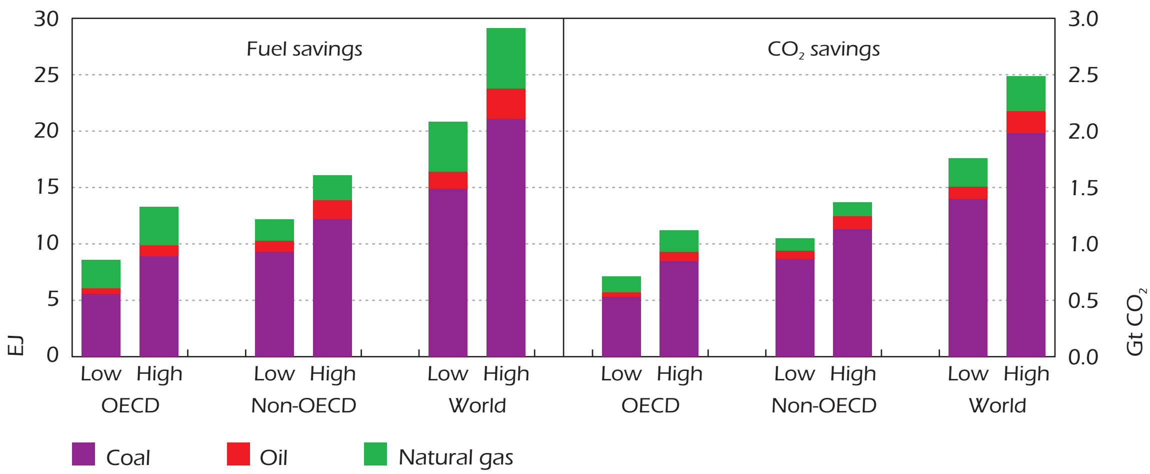
Energy Savings Potential from Improving Efficiency

Substantial energy and CO_2 savings potential are available from improving the energy efficiency of fossil-fuelled electricity production.[21] The savings are calculated for both a "Low" and a "High" savings case, as follows:

- ▷ the Low savings case assumes that all countries produce electricity at the highest efficiencies currently observed for the countries studied (43% for coal and oil and 55% for natural gas); and
- ▷ the High savings case is calculated on the basis that all countries produce electricity at efficiencies that represent best practice for new power plant (48% for coal, 50% for oil and 60% for natural gas).

The results (which do not consider the impacts of fuel switching) show that across all fossil fuels the "technical" fuel savings potential from improving efficiency is 21 EJ to 29 EJ per year, with a CO_2 reduction potential of 1.8 Gt CO_2 to 2.5 Gt CO_2 per year (Figure 7.3). Not surprisingly, the largest savings are from improving the efficiency of coal-fired plants, which alone provides savings of 15 EJ to 21 EJ (1.4 Gt CO_2 to 2.0 Gt CO_2). Looking at the regional breakdown of savings, it can be seen that less than half the global savings are from OECD countries. This underscores the importance of improving the efficiency of power production in developing and transition countries, as well as in developed countries.

Figure 7.3 ▶ ***Technical Fuel and CO_2 Savings Potentials in 2005 from Improving the Efficiency of Electricity Production***



Source: IEA analysis.

21. These calculations do not include fuel and CO_2 savings from increased use of combined heat and power plants.

CONCLUSIONS AND FURTHER WORK

Key Messages

- Results from IEA indicator analysis show that improvements in energy efficiency over the past three decades have played a key role in limiting global increases in energy use and CO_2 emissions. Analysis for 16 IEA countries reveals that improved energy efficiency since 1990 led to annual energy savings of more than 16 EJ in 2005, which is equivalent to 1.3 Gt of avoided CO_2 emissions and represents an estimated USD 180 billion of energy cost savings. However, the rate at which energy efficiency has improved since 1990 has been much slower than in the previous two decades. This rate will need to increase substantially in order to achieve a more secure and sustainable energy future.
- A large potential remains for further improvements in energy efficiency across all sectors. For instance, the application of proven technologies and best practices on a global scale in industry could save between 25 EJ and 37 EJ per year (1.9 Gt CO_2 to 3.2 Gt of CO_2 emissions per year). In public power generation, if all countries produced electricity at current best practice levels of efficiency then the fuel savings would be between 21 EJ and 29 EJ per year (with CO_2 savings of about 1.8 Gt CO_2 to 2.5 Gt CO_2).
- Accelerating energy efficiency improvements is a crucial challenge for energy and climate policies. Governments must act now to develop and implement the necessary mix of market and regulatory policies, including stringent norms and standards. This should be complemented by efforts to drive down the CO_2 intensity of electricity production by moving towards a cleaner technology mix. The IEA has presented a list of high-priority energy efficiency policy recommendations to help governments increase rates of energy efficiency improvement in buildings, appliances, lighting, transport, industry, power utilities and cross-sectoral areas.
- These findings show that energy indicators are an important tool for analysing interactions between economic and human activity, energy use and CO_2 emissions. They are particularly relevant for targeting and evaluating energy efficiency policies. Many IEA member countries already use energy indicators and they are also attracting increasing interest from other countries. The IEA role is to assist and internationalise these efforts by developing transparent and consistent international databases and methodologies and by collaborating with governments, industry and regional and international organisations.
- While there have been some improvements, the availability, timeliness, quality and comparability of energy data in many countries and sectors still create an obstacle to developing policy-relevant indicators. Governments should therefore work with the IEA to substantially improve their data collecting efforts across all sectors to optimise energy efficiency policy-making and evaluation.

Conclusions from the Current Analysis

In spite of the limitations of the data that are currently available, some important conclusions can be drawn from the indicators work that has been done so far. Firstly, for IEA countries the recent rate of improvement in energy efficiency across all sectors of the economy has been much lower than in previous decades. Substantially increasing the current rate of energy efficiency gains must be a key priority for policy-makers in their efforts to achieve a more secure and sustainable energy future. Similarly, developing and transition economies also need to enhance their efforts to improve energy efficiency to ensure that the current rate of energy intensity reductions in these countries continues and even increases, despite upward pressures on energy consumption from increasing wealth. All countries should share with one another their experiences of best practice policy approaches, as well as implementing the IEA list of high-priority energy efficiency policy recommendations.

Secondly, the results of the analyses for industry and electricity generation demonstrate large potentials for efficiency gains and CO_2 savings if proven technologies and best practices were to be applied globally. Realising these potentials would not be something that could be achieved in a short period, due to practical constraints relating to capital stock turnover. However, the analysis shows where the largest potentials for reductions are to be found and suggests where government policies, including policies for international technology co-operation, can most fruitfully be focused.

The Need for Better Data

The earlier chapters have demonstrated that the availability of good quality, timely, comparable and detailed power sector and end-use data, which builds on a sound statistical energy balance, is a prerequisite for establishing and maintaining a set of policy-relevant energy indicators.

Many IEA countries have already recognised the importance of a strong statistical foundation to support their energy indicator activities. Their efforts to collect and release more and better statistics have strengthened IEA work. For European countries the analysis has greatly benefited from the ODYSSEE energy efficiency indicators project, which is funded by the European Commission and country governments. Countries in other IEA regions have also established data collection processes for specific sectors. Consequently, for 22 IEA countries it is now possible to analyse data for two or more sectors. This represents two additional countries compared to the coverage of the analysis published in September 2007 and eight more than was available in 2004. Although these trends represent a significant improvement, more detailed analysis for IEA countries remains constrained by data quality and comparability.

The situation for non-IEA countries is more challenging still, with little or no detailed data available for most countries. As a result, for most sectors only aggregate information for these countries, taken from the IEA statistical balances, is presented in this publication. More detailed data are currently not available on a comparable basis. However, there are a number of promising developments, but these will take time to deliver results. Several non-IEA countries, notably in the Asia-Pacific Economic Cooperation (APEC), have embarked upon programmes to develop indicators that reflect their own situations. The IEA, together with the World Bank, is also currently working on projects with organisations in Mexico, China and South Africa, to develop energy efficiency indicators for these countries. Furthermore, the IEA is committed to continue working with interested countries on both indicators development and improvements to the underlying statistics.

Detailed energy data for industry poses a particular problem in both IEA and non-IEA countries. The industrial sub-sector data that countries report to the IEA are not sufficiently detailed or accurate to allow country comparisons based on physical indicators at an appropriate level of disaggregation. Industry can provide some of this information, but company-based data are subject to confidentiality problems associated with anti-trust legislation. There are some promising examples in which international industry associations are taking the lead to collect and disseminate information for their sector and the IEA is keen to strengthen its existing collaborations.

This last point raises the question of using official government data versus data collected from a variety of other sources. This issue is not specific to indicators but applies to any kind of statistics. However, as indicators can potentially be used to make comparisons across countries, it is particularly important that they use widely accepted and uniform system boundaries, data definitions and methodologies.

Thus a key conclusion from the current IEA indicators activities is the need for greater efforts from both governments and other stakeholders to improve the availability, timeliness, quality and comparability of the detailed end-use statistics needed to develop policy-relevant indicators. Failure to do so will limit the usefulness of indicators and will ultimately undermine the ability of analysts and policy-makers to develop, implement and monitor successful energy efficiency and other related policies. The future work programme of the IEA will address these issues.

Further Work

The IEA is committed to continue working with countries, international and regional organisations, industry and other stakeholders to develop more effective tools, such as energy indicators, to support energy efficiency policy-making and evaluation. Key next steps to achieve these goals are as follows.

▷ **Improved data reporting.** This would best be achieved through an agreed system of reporting for major developed and developing countries, working with both governments and industry. The current IEA indicator template could constitute a starting point to define a joint questionnaire on energy efficiency, similar to the existing five annual IEA energy statistics questionnaires on fuels and electricity.

▷ **Enhanced collaboration**. The IEA will build on existing collaborative activities to strengthen co-operation relating to energy efficiency data, methodologies and indicators development. Key partners include governments, the European Commission, the ODYSSEE network, APEC, the World Bank and industrial associations. A particular focus for future collaboration should be to continue supporting indicator activities in the rapidly expanding non-IEA economies.

- **Further indicator development**. Work will continue to improve the existing set of IEA indicators, including filling key gaps, notably through the following:
  - better coverage of key non-IEA countries;
  - further work on physical indicators for industry;
  - disaggregation of energy-use data in the service sector;
  - more detailed information on appliances;
  - continued work on resolving inconsistencies between countries regarding data definitions and boundaries; and
  - enhancement of the link between indicators and the assessment of key policies.
- **More effective implementation**. The IEA encourages member countries and others to use the indicators framework to support the implementation and evaluation of the IEA energy efficiency policy recommendations.

ANNEX A: DATA SOURCES, COUNTRY COVERAGE AND METHODOLOGY

Data Sources

Due to the diverse nature of the data needed for the disaggregated indicator analysis, the IEA indicator database is compiled from a range of national and international sources. To maintain comparability across countries, if possible, the data were taken from the following OECD or IEA statistics.

- *Energy Balances of OECD Countries*, 2007, IEA
- *Energy Balances of Non-OECD Countries*, 2007, IEA
- *CO_2 Emissions from Fuel Combustion*, 2007, IEA
- *Energy Prices & Taxes*, 1st quarter 2008, IEA
- Mobility Modelling Database, IEA
- *National Accounts of OECD Countries*, 2007 Volume I, OECD
- *National Accounts of OECD Countries*, 2007 Volume II, OECD
- *The OECD STAN Database for Industrial Analysis*, 2008, OECD
- *OECD Main Economic Indicators*, 2008, OECD
- *OECD Economic Outlook*, no.80, OECD

The IEA also worked closely with the following national and international organisations and groups to obtain detailed energy and activity data for industry, households and transport.

- ODYSSEE project "Energy Efficiency Indicators", led by ADEME and supported by the EIE programme of the European Commission/DGTREN, or from national teams within this project[22]
- Eurostat Unit G4 "Energy Statistics" and JRC IPSC/Agrifish Unit/MARS-STAT Action
- Office of Energy Efficiency, Natural Resources Canada
- Energy Efficiency and Conservation Authority, Ministry of Economic Development, New Zealand
- Department of Energy (Energy Information Administration and Office of Energy Efficiency and Renewable Energy) and the Department of Transportation (Bureau of Transportation Statistics), United States
- Australian Department of Resources, Energy and Tourism; Bureau of Agricultural and Resource Economics; Australian Bureau of Statistics; Department of the Environment, Water, Heritage and the Arts; Bureau of Transportation and Regional Economics

22. The ODYSSEE national teams in the European countries covered in this study include; ADEME (France), ADENE (Portugal), AEA (Austria), AEA Technology (United Kingdom), DEA (Denmark), ECN (Netherlands), Econotec (Belgium), ENEA (Italy), FhG-ISI (Germany), IDAE (Spain), IFE (Norway), MOTIVA (Finland), SEI (Ireland) and STEM and Statistics Sweden (Sweden).

- ▷ Ministry of Economy, Trade and Industry and the Energy Data and Modelling Centre, Japan
- ▷ Swiss Federal Office of Energy, Department of the Environment, Transport, Energy and Communication

IEA Country Coverage

Many IEA countries have already recognised the importance of a strong statistical foundation to support their energy indicator activities. Their efforts to collect and release more and better statistics have strengthened the IEA work. Therefore, for each of 22 IEA countries it is now possible to analyse data for two or more sectors. This study considers energy use in those IEA countries for which consistent, detailed and long-term time series are available for a particular sector. Table A.1 summarises the country coverage by sector.

Table A.1 ▶ ***IEA Country Coverage by Sector***

	Overall Trends	Industry	Households	Services*	Transport	Long-Term Trends
Australia	✓	✓	✓	(✓)	✓	✓
Austria	✓	✓	✓	(✓)	✓	×
Belgium	×	✓	×	(✓)	×	×
Canada	✓	✓	✓	✓	✓	×
Denmark	✓	✓	✓	✓	✓	✓
Finland	✓	✓	✓	✓	✓	✓
France	✓	✓	✓	✓	✓	✓
Germany	✓	✓	✓	(✓)	✓	✓
Greece	×	✓	×	(✓)	✓	×
Ireland	×	×	✓	×	✓	×
Italy	✓	✓	✓	(✓)	✓	✓
Japan	✓	✓	✓	✓	✓	✓
Republic of Korea	×	✓	✓	(✓)	×	×
Netherlands	✓	✓	✓	(✓)	✓	×
New Zealand	✓	✓	✓	✓	✓	×
Norway	✓	✓	✓	✓	✓	✓
Portugal	×	✓	×	(✓)	×	×
Spain	×	✓	✓	(✓)	×	×
Sweden	✓	✓	✓	✓	✓	✓
Switzerland	✓	✓	✓	✓	✓	×
United Kingdom	✓	✓	✓	✓	✓	✓
United States	✓	✓	✓	✓	✓	✓
	IEA16	IEA21	IEA19	IEA11	IEA18	IEA11

* For services, data on both energy use and value-added are available for 21 countries. However, data for floor space are only available for a subset of 11 countries. Countries with a tick in brackets have value-added data but no floor space data and are not included in Chapter 5.

Methodology

Full details of the decomposition methodology used to separate and quantify the impacts of activity, structure and energy intensities on final energy use can be found in IEA, 2007b. More detailed information on the calculation of the energy efficiency indices for industry is contained in IEA, 2007a.

For the electricity sector, data on fuel inputs to public electricity plants and CHP plants and electricity and heat outputs from these plants are taken from IEA statistics. In the case of OECD countries the data are from IEA, 2007f, and for other countries they come from IEA, 2007d. The IEA statistics provide a consistent set of data for all countries in which:

- ▷ energy inputs for both electricity plants and CHP plants are based on net calorific values; and
- ▷ energy outputs are defined as gross production of electricity and heat. In the case of electricity, this is defined as electricity production including the auxiliary electricity consumption and losses in transformers at the power station.

The methodology used to calculate the energy efficiency of electricity production is then based on Graus, 2007 and Phylipsen, 1998. The energy efficiency (E) of electricity production is defined as:

$$E = (P + H \times s)/I$$

Where:

P = electricity production from public electricity plants and public CHP plants;

H = heat output from public CHP plants;

s = correction factor between heat and electricity, defined as the reduction in electricity production per unit of heat extracted;

I = fuel input for public electricity plants and public CHP plants.

In CHP plants the combined production of heat and electricity is more efficient in terms of the use of primary energy compared to separate production of heat and electricity. However, heat extraction causes the energy efficiency of electricity production to decrease. The loss of efficiency depends on the temperature of the heat extracted. To account for this, a correction for heat extraction is applied. As public CHP is mainly used to provide district heating the appropriate substitution factor lies somewhere between 0.15 and 0.2 (Phylipsen, 1998). In this analysis a value of 0.175 is used. It should be noted that when heat is delivered at higher temperatures (*e.g.* to industrial processes), the substitution factor can be significantly higher. However, the amount of high-temperature heat delivered to industry by public utilities is small in most countries.

ANNEX B: ABBREVIATIONS AND GLOSSARY

Abbreviations

BAT	Best available technology
BF	Blast furnace
BOF	Basic oxygen furnace
BPT	Best practice technology
CDQ	Coke dry quenching
CHP	Combined heat and power
CO_2	Carbon dioxide
COG	Coke oven gas
CRT	Cathode ray tube
DRI	Direct reduced iron
EAF	Electric arc furnace
EEI	Energy efficiency index
EJ	Exajoules (10^{18} Joules)
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom
G8	Group of Eight; member countries are Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States
GDP	Gross domestic product
GJ	Gigajoules (10^9 Joules)
GPOA	Gleneagles Plan of Action
Gt	Gigatonne (10^9 tonnes)
IEA	International Energy Agency; member countries are 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, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States
kg	Kilogram (10^3 gram)

kWh	Kilowatt-hour
LCD	Liquid crystal display
MER	Market exchange rate
Mt	Million tonnes (10^6 tonnes)
OECD	Organisation for Economic Co-operation and Development; member countries are Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, the Republic of Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States
OECD Europe	Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey and the United Kingdom
OECD Pacific	Australia, Japan, the Republic of Korea, New Zealand
OHF	Open hearth furnace
PPP	Purchasing power parity
RoW	Rest of the world
SUV	Sport utility vehicle
t	Tonne
TFC	Total final consumption
TWh	Terawatt-hour (10^{12} watt-hour)
UEC	Unit energy consumption
USD	United States dollar

Glossary

Activity refers to the basic human or economic actions that drive energy use in a particular sector. It is measured as value-added output for manufacturing and services, as population levels in the household sector, as passenger-kilometres for passenger transport and as tonne-kilometres for freight transport.

Basic oxygen furnace is a process where liquid hot iron metal is converted into steel, using oxygen injection.

Best available technology is taken to mean the latest stage of development (state-of-the-art) of processes, of facilities or of methods of operation which include considerations regarding the practical suitability of a particular measure for enhancing energy efficiency.

Biomass includes solid biomass such as wood, animal products, gas and liquids derived from biomass, industrial waste and municipal waste.

Black liquor is a recycled by-product formed during the chemical pulping of wood in the pulp and paper industry. In this process, lignin in the wood is separated from cellulose, with the latter forming the paper fibres. Black liquor is the combination of the lignin residue with water and the chemicals used for the extraction of the lignin and are burned in a recovery boiler. The boiler produces steam and electricity and recovers the inorganic chemicals for recycling throughout the process.

Blast furnace is a type of metallurgical furnace used for smelting. Fuel and ore are continuously supplied through the top of the furnace, while air (oxygen) is blown into the bottom of the chamber, so that the chemical reactions take place throughout the furnace as the material moves downward. The end products are usually molten metal and slag phases tapped from the bottom, and flue gases exiting from the top of the furnace. This type of furnace is typically used for smelting iron ore to produce hot metal (pig iron), an intermediate material used in the production of commercial iron and steel.

Blast furnace gas is produced in blast furnaces in the iron and steel industry. It is recovered and used as a fuel partly within the plant and partly in other steel industry process or in power stations equipped to burn it.

Car refers collectively to all light-duty vehicles including cars, mini-vans, sport utility vehicles (SUVs) and personal-use pick-up trucks.

Carbon intensity is the amount of CO_2 emitted per unit of energy use.

Chemical pulp is a thermo-chemical process in which chips are combined with strong solvents and heated under pressure to separate fibres from lignin. Spent liquor (black liquor) can be concentrated and burned for process heat.

Clinker is the partially fused product of a kiln which is ground to make cement.

Coal includes hard coal, lignite/brown coal and derived fuels (including patent fuel, coke oven coke, gas coke, BKB, coke oven gas and blast furnace gas). Peat is also included in this category.

Coke oven is a pyrolysis process for conversion of coal into coke.

Coke oven gas is a gaseous by-product of coke making.

Combined heat and power, also called cogeneration, is a technology where electricity and steam or electricity and hot water are produced jointly. This increases the efficiency compared to separate electricity and heat generation.

Decomposition is the analytical approach used to calculate the effects of various components (activity, structure and energy intensities) on aggregate energy use.

Direct reduced iron is a product made through chemical reduction of iron ore pellets in their solid state.

District heat is heat distributed from a central heating plant to buildings, factories, etc.

Dry kiln produces cement clinker using dry limestone feedstock.

Electric arc furnace is a furnace used for smelting of iron scrap and other metals using electricity.

Energy intensity is the amount of energy used per unit of activity. This publication uses changes in the energy intensity effect as a proxy for developments in energy efficiency.

Energy services imply the actual services for which energy is used, *e.g.* heating a given amount of space to a particular temperature for a period of time. In this study, a quantitative measure of energy service demand in a sector is determined by combining the activity and structure effects.

Final energy is the energy supplied to the consumer in each end-use sector, which is ultimately converted into heat, light, motion and other energy services. It does not include transformation and distribution losses.

Freight transportation includes the domestic haulage of goods by trucks, rail, ships and barges. In this study it does not include air freight transport and pipelines.

Fuel mix represents the share of various fuels such as coal, oil, natural gas, heat and electricity that make up final energy use.

Gasoline equivalent litre is a concept used to compare the energy content of gasoline and other road transport fuels (*e.g.* diesel) which have different calorific values than gasoline. In order to properly aggregate physical quantities of different fuels they are expressed in quantities energetically equivalent to a litre of gasoline.

Gross domestic product (GDP) is a measure of economic activity, defined as the market value of all final goods and services produced within a country (output approach). In this publication, GDP figures are given for calendar years, expressed in 2000 USD. The conversion from national currency to USD is done using either purchasing power parities or market exchange rates.

Households cover all energy-using activities in apartments and houses, including space and water heating, cooking, lighting and the use of appliances. It does not include personal transport.

Industry covers manufacturing, mining and quarrying of raw materials and construction. Power generation, refineries and the distribution of electricity, gas and water are excluded.

Manufacturing covers finished goods and products for use by other businesses, for sale to domestic consumers, or for export. Total manufacturing is divided into the following key industries: food, beverages and tobacco; paper, pulp and printing; chemicals; non-metallic minerals; primary metals; metal products and equipment; and other manufacturing. The fuel-processing industries and fuels used as feedstock are not included.

Natural gas includes gas works gas but excludes natural gas liquids.

Naphtha is a feedstock destined either for the petrochemical industry, *e.g.* ethylene manufacture or aromatics production, or for gasoline production by reforming or isomerisation within the refinery.

Mechanical pulp is a process requiring the grinding and shaving of wood chips. Primarily used for low-grade papers, mechanical pulping has a high yield but results in a pulp that contains substantial impurities that limit its use.

Oil comprises crude oil, natural gas liquids and petroleum products, such as heavy fuel oil, gas/diesel oil, liquefied petroleum gas, motor gasoline and kerosene.

Other fuels include geothermal and solar. The "Other" category is very small in the end-use sector.

Passenger-kilometres are a measure of transport activity and are calculated by multiplying the number of kilometres a vehicle travels by the number of passengers. For example, if a vehicle carries two passengers for one kilometre then it has travelled two passenger-kilometres (but only one vehicle-kilometre).

Passenger transport includes the movement of people by road, rail, sea and air. Road transport is sub-divided further into cars and buses. In this study, only domestic air and sea travel are included; international air and sea travel are not covered.

Power generation refers to electricity production in electricity only plants and combined heat and power plants. Only public plants are included in this publication.

Primary energy equivalent is an energy measure that accounts for losses in the production of final energy carriers (*e.g.* losses in electricity production).

Renewables comprise biomass and animal products (wood, vegetal waste, ethanol, animal materials/wastes, etc.), municipal waste and industrial waste.

Savings refer to the difference between the hypothetical energy use (or hypothetical CO_2 emissions) and actual energy use (or actual CO_2 emissions).

Services include activities related to trade, finance, real estate, public administration, health, food and lodging, education and commercial services.

Shaft kiln is a vertical kiln for cement making.

Structure represents the mix of activities within a sector, *e.g.* shares of each sub-sector in manufacturing, energy end-uses in households, or the modal mix in passenger and freight transport.

Steam cracking is a petrochemical process in which saturated hydrocarbons are broken down into smaller hydrocarbons. It is the principal industrial method for producing the olefins (ethylene, propylene, and butadiene).

Tonne-kilometres are a measure of freight transport activity. For example, if a truck carries a load of two tonnes for one kilometre then it has travelled two tonne-kilometres (but only one vehicle-kilometre).

Useful energy is calculated as final energy minus losses estimated for boilers, furnaces, water heaters and other equipment in buildings. It is used for estimates of heat provided in space and water heating.

ANNEX C: REFERENCES AND FURTHER READING

References

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