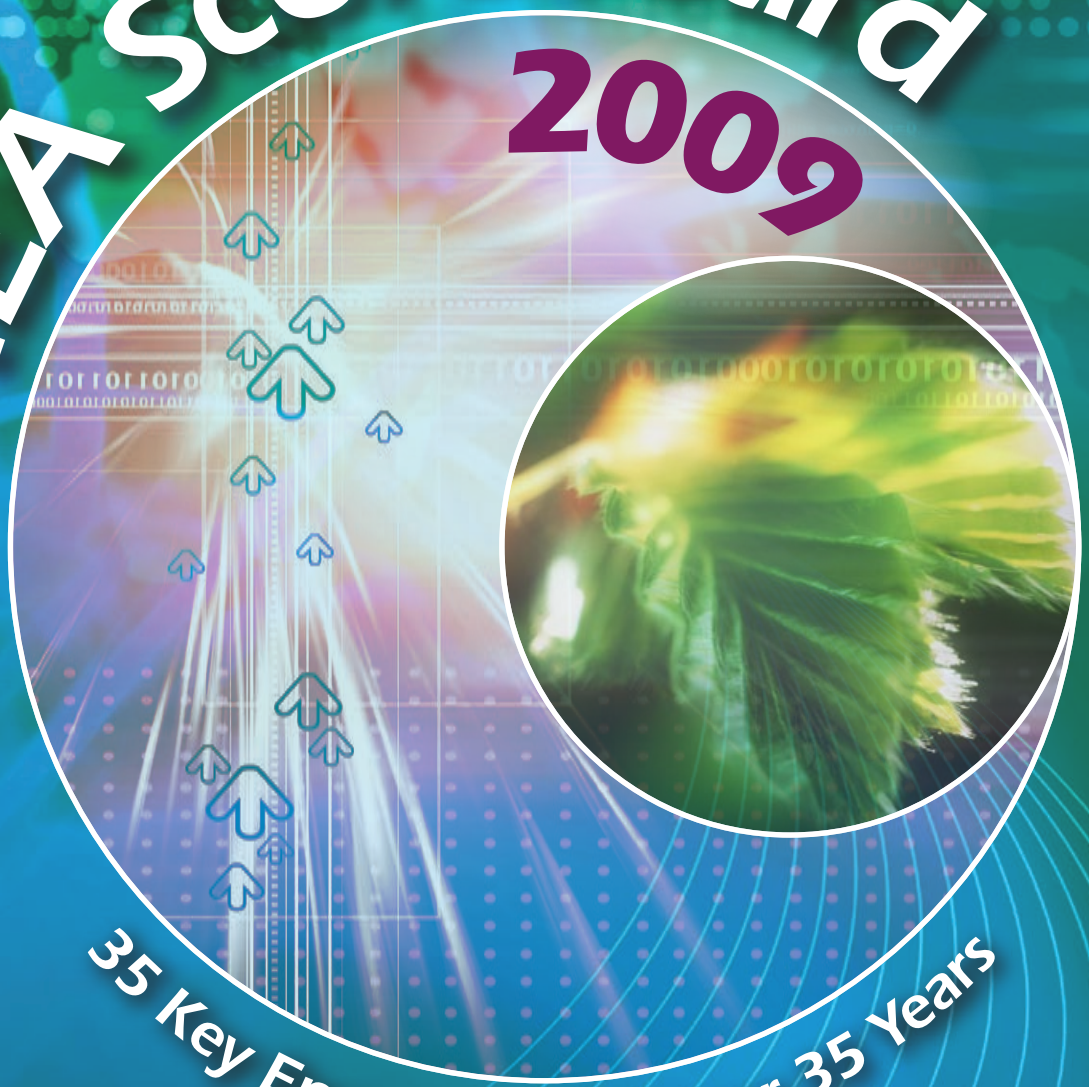
IEA Scoreboard 2009



35 Key Energy Trends over 35 Years

International Energy Agency

IEA Scoreboard 2009

35 Key Energy Trends over 35 Years

Both the world economy and the global energy scene have dramatically evolved since the International Energy Agency (IEA) was founded 35 years ago. To respond proactively to these changes, all IEA member countries have agreed to "create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment".

Measuring and assessing how much has been done by member countries over the years to follow their underlying principles is not an easy task. Each country is unique in terms of economy, geography, climate, energy resources, etc. Taking into account some of these specificities, the *IEA Scoreboard 2009* is a first attempt to compare what has been achieved by member countries in diversifying their energy mix, in promoting non-fossil fuels and energy efficiency, in encouraging research and development, and, more generally, in creating a policy framework consistent with their shared policy goals.

Since the *IEA Scoreboard 2009* is published in conjunction with the 35th anniversary of the IEA, 35 themes, ranging from diversification to prices, show how IEA member countries have performed in their efforts to attain energy security, environmental protection and economic growth. This book, which combines statistical rigour with easy access and readability, should become a popular tool for policy makers, energy analysts and journalists. It is an ideal resource for anyone who would like to have a quick overview of energy development in IEA member countries over the last 35 years. The publication also includes selected energy-related statistics for over 140 countries, economies and regions in the world.

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IEA Scoreboard 2009

35 Key Energy Trends over 35 Years

International Energy Agency

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-eight of the thirty OECD 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 international oil markets.
- To provide data on other aspects of international energy markets.
- 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, including relating to climate change.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

35 years 1974•2009

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.

International Energy Agency (IEA)
9 rue de la Fédération, 75739 Paris Cedex 15, France

Foreword

In 1974, many countries were reliant on domestic coal production. LNG carriers were just starting their voyage. There was no oil production in the North Sea. Nuclear energy was confined to a small number of countries. Who was talking about wind energy, solar cells or biofuels?

In 1974, the industry sector was by far the largest energy consumer. "Bigger and faster" was the motto for cars. The services sector was still "developing"; offices had mammoth mainframe computers; and no one had yet heard of compact discs, mobile phones, plasma screens or laptops. In 1974, "liberalisation of the market" was a term not yet associated with the electricity and gas sectors. Crude oil prices surged to about USD 10/bbl. The Rio Summit and the Kyoto Protocol were not envisioned – there was no perceived need.

Thirty-five years later, the world has changed dramatically and so has the energy sector. Coal mines have closed in many countries but multiplied in others. Natural gas markets are globalising. Oil is flowing by millions of barrels from the North Sea. Nuclear, wind energy, photovoltaic energy, bio-ethanol and fuel cells are now common topics in energy discussions.

Cars are downsizing and industries are delocalising. Chips and PCs have replaced the mammoth. Telephone wires have become broadband data links and home cinemas with surround sound have replaced black and white televisions. Laptops, the internet and microwave ovens are things we can no longer live without. Markets have been liberalised; crude oil reached USD 148/bbl in 2008; and *some truths are starting to become inconvenient*.

All countries, both actors in and spectators of these changes, need to adapt constantly to this fast-evolving environment. This is particularly true for member countries of the International Energy Agency (IEA). Although they no longer dominate markets, the IEA as a whole still represents the largest share of global energy production and consumption among major countries and regions.

In 1974, 15 countries joined together to establish the International Energy Agency. From the beginning these IEA member countries were determined to reduce their dependence on imported oil by undertaking long-term efforts on diversification and conservation of energy, on accelerated development of alternative sources of energy and on research and development in the field of energy. **Nineteen years later, in 1993**, IEA Ministers, then 24 strong, again showed their vision by adopting the "Shared Goals" to help create an environment in which the energy sectors of their economies could make the fullest possible contribution to sustainable economic development. They also recognised the significance of increasing global interdependence on energy and sought to promote the efficient operation of international energy markets and encourage dialogue with all participants.

This 35th Anniversary year of the IEA is the right time for an assessment of all that has been done over the years by the IEA member countries, now 28, to live up to the underlying principles of the Shared Goals. This is not an easy task; each country is unique in terms of economy, geography, climate and energy resources. The graphs and the underlying data should, therefore, not be seen as a measure of government performance but more as indicative of evolutionary trends toward common goals and objectives.

Although this assessment is far from exhaustive, the history contained in these pages demonstrates that vision and effective policy can lead to significant changes. Major progress has been made in the energy policy of IEA member countries over the last 35 years. More remains to be done, of course. I am confident that should an *IEA Scoreboard 2044* be published on the occasion of the Agency's 70th Anniversary, it would highlight continued marked progress toward the Shared Goals of energy security, environmental protection and economic growth – as well as broader engagement worldwide.

Nobuo Tanaka
Executive Director

Acknowledgements

The idea and vision for preparing an IEA Scoreboard publication, along the lines of the *OECD Science, Technology and Industry Scoreboard* publication, were initiated by Mr. Nobuo Tanaka, Executive Director of the International Energy Agency (IEA).

The *IEA Scoreboard 2009* publication was designed and managed by Mr. Jean-Yves Garnier, Head of the Energy Statistics Division (ESD), with the effective co-ordination and support of Ms. Karen Tréanton, Head of the Energy Balances, Prices and Taxes and CO_2 Emissions Section in ESD. Mr. Olivier Lavagne d'Ortigue, and, at an early stage, Mr. David Wilkinson, greatly contributed to the preparation of the data and the graphs published in the document.

The *IEA Scoreboard 2009* is first and foremost a collective and across-the-Agency production. All Offices and Divisions have been closely associated with the publication at one stage or another, especially in providing text and comments on fields for which they hold responsibility.

Although it is difficult to list all those who have contributed to the publication, special acknowledgments go to IEA Deputy Executive Director Richard Jones for his political support, and to Ms. Jane Barbière, Mr. Richard Baron, Ms. Madeleine Barry, Mr. Fatih Birol, Mr. Pierpaolo Cazzola, Mr. Hugo Chandler, Ms. Anne-Sophie Corbeau, Mr. Ian Cronshaw, Mr. François Cuenot, Ms. Muriel Custodio, Ms. Zuzana Dobrotkova, Mr. Paul Dowling, Mr. Jason Elliott, Mr. Paolo Frankl, Mr. David Fyfe, Ms. Rebecca Gaghen, Ms. Delphine Grandrieux, Mr. Neil Hirst, Mr. Didier Houssin, Mr. Henning Lohse, Mr. Eduardo Lopez, Mr. François Nguyen, Mr. Pawel Olejarnik, Mr. Cédric Philibert, Ms. Kristin Pittman, Ms. Carrie Pottinger, Ms. Roberta Quadrelli, Ms. Mieke Reece, Mr. Brian Ricketts, Mr. Ralph Sims, Ms. Sylvie Stephan, Ms. Cecilia Tam, Mr. Peter Taylor, Ms. Nathalie Trudeau and Mr. Aad van Bohemen for their valuable inputs, comments and support.

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The IEA Secretariat would also like to acknowledge the indirect contribution of all energy statisticians in IEA member countries and elsewhere in the world who spend time and effort to provide policy makers and analysts with the most timely and comprehensive data possible. Without their invaluable work and commitment, the *IEA Scoreboard 2009* and many other publications could not be put together.

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HIGHLIGHTS

- *Overall, the world is becoming less energy intensive but needs more energy on a per capita basis. Over the last 35 years, global energy demand rose by 96% compared to a 167% growth in GDP and a 66% growth in population.*

- *Despite decreases of their share in global energy consumption (from 59% to 44%) and production (from 38% to 29%), IEA member countries still represent the largest share in both when assessing major countries and regions.*

- *IEA member countries have successfully diversified their energy mix in production, supply and sectoral consumption. The combined share of oil, coal and natural gas dropped in both total energy production (from 90% to 74%) and total primary energy supply (from 93% to 82%). However, for both production and supply, the drop mostly occurred in the 1970s and the1980s. The share of oil has been more than halved in all sectors but transport; oil has been almost phased out in electricity generation. All countries but two have decreased the share of oil in total primary energy supply (TPES).*

- *Major development programmes for nuclear energy in the 1970s and 1980s - and more recently for non-hydro renewables, mainly wind – have largely contributed to the defossilisation of energy production and supply of IEA member countries. Nuclear accounted for 43% of the growth in IEA energy production since 1974; renewables, including hydro and biomass, accounted for 15% of the growth.*

- *IEA member countries have successfully established, maintained and improved an efficient emergency response system to provide security against oil supply disruptions. Total crude oil and petroleum stocks in IEA member countries at the end of March 2009 were the equivalent of 162 days of the previous year's net imports, well above the 90-day requirement, but down from more than 180 days in 1985.*

- *Energy efficiency measures and programmes have contributed to a dramatic reduction in the energy consumption of IEA member countries; based on data available for 11 IEA member countries, the savings could be as high as 58%. However, it should be noted that energy efficiency gains have dropped considerably over this period. Gains were about 1.9% per year from 1974 to 1990; subsequently, lower energy prices and a relative slowdown in the implementation of efficiency measures have effectively halved annual gains to only 1%.*

- *Despite the defossilisation of the energy mix, IEA CO_2 emissions from fuel combustion increased by 17% between 1990 and 2007. Only eight IEA member countries reduced their emissions in real terms. IEA member countries present the highest average CO_2 emissions per capita among the major countries and regions analysed, but have the lowest average CO_2 emissions per GDP.*

- *IEA member countries have successfully launched numerous Implementing Agreements (open to IEA non-member countries and industry, as well as international organisations) to accelerate research, development and demonstration (RD&D) of energy technologies. However, total public sector budgets for energy RD&D have declined sharply in real terms compared to the early 1980s. Moreover, the share of energy RD&D in total research and development has dropped significantly – from 12% in 1981 to 4% in 2008.*

- *Detailed, comprehensive and timely data are the basis for any sound energy policy. IEA member countries have successfully reversed the trend toward lower-quality data observed in the early 2000s. However, additional effort is needed to increase transparency in order to offer analysts and policy makers a valid assessment of the energy situation in IEA member countries and in the world.*

Executive summary

This first edition of the *IEA Scoreboard*, published on the occasion of the 35th anniversary of the International Energy Agency (IEA), offers an excellent opportunity to review the evolution of the energy situation in IEA member countries.

The publication brings together the latest data on energy production and demand, stocks, trade, prices, carbon dioxide (CO_2) emissions from fuel combustion, and research, development and demonstration (RD&D) budgets. The primary objective is to assess what IEA member countries have achieved in creating national policy frameworks that are consistent with the aims of the IEA Shared Goals (see Annex 1), particularly in terms of diversifying energy mixes, promoting non-fossil fuels, and encouraging research and development.

Reflecting the increased globalisation of the energy market, the *Scoreboard* opens with an analysis of supply and demand trends worldwide. It highlights specific developments in seven regions, including the IEA as a whole, and three increasingly important participants in energy markets: China, India and the Russian Federation.

Subsequent chapters examine how IEA member countries have adapted their supply-demand situation to the fast-evolving energy market in line with the principles of the IEA Shared Goals. Each chapter focuses on a specific goal; when data are available, the assessment is enlarged from IEA member countries to include China, India, the Russian Federation and, more broadly, the world.

IEA in the world

During the past three and half decades, most of the countries and regions outside the IEA have experienced economic growth rates higher than that of the IEA. As a consequence, the share of IEA in global GDP has decreased since 1974 – from 81% to 74% using market exchange rates and from 63% to 51% using purchasing power parities.

The share of the IEA in global energy demand has experienced an even larger decrease - from 59% to 44% – due to three main factors: delocalisation of some energy-intensive industries; an increase of the relative importance of services in IEA economies; and faster deployment of energy efficiency policies.

A large part of the decrease in the IEA share of energy demand has been taken over by rapid economic growth in China, which more than doubled its share over the period and accounted for 16% of global demand in 2007.

Although often associated with energy consumption, the collective of IEA member countries is still the largest energy producer when assessing the major countries and regions – even though its share in global production fell from 38% in 1974 to 29% in 2007. In fact, the IEA is the largest producer for all fuels but two: oil (second behind the Middle East) and coal (second behind China). The IEA is also the largest net importer of energy.

Energy consumption per capita has increased in almost all countries and regions around the world, yet significant differences remain in both consumption per capita and energy intensity. Average energy consumption per capita in IEA member countries is about 5 toe: this is the largest of all regions, and is more than twice the world average and almost ten times the average for India. Nonetheless, IEA member countries also have the lowest energy intensity due to a much higher GDP per capita.

Diversity within the energy sector

IEA member countries successfully diversified their energy production, which grew by 52% since 1974. Nuclear contributed to 43% of the growth, followed by natural gas, coal and renewables. Oil accounted for only 6% of the growth. As a consequence, the share of oil in total IEA production dropped from 28% to 20% while the share of nuclear surged from 2% to 16%.

Between 1974 and 2007, IEA TPES grew by 45% – about three times less than GDP growth. This shows a decoupling of energy demand from economic growth, which can be attributed to a larger share of services in the economy and savings resulting from energy efficiency measures. IEA member countries have also been successful in diversifying their TPES: the share of oil dropped from 51% to 37%, while that of nuclear surged from 2% to 11%. All IEA member countries but two have reduced the share of oil in their supply. Conversely, all countries but two have increased their share of natural gas.

The displacing of oil consumption by other fuels has been spectacular in some sectors. In the commercial and public services sector, the share of oil dropped from 42% to 13%; industry and residential sectors also experienced significant shifts. Oil has been almost phased out in electricity production.

Transport is the only sector in which the share of oil is virtually unchanged, at around 95%. Transport has become the largest of the four main energy-consuming sectors, primarily as a result of decreased demand in industry.

Ability to respond promptly to energy emergencies

Total IEA energy demand grew by 1 600 Mtoe since 1974, while total net imports increased by only 450 Mtoe. Despite increased energy production in all but four IEA member countries, and despite diversification towards nuclear and renewables, the IEA as a whole remains highly dependent on imported fossil fuels.

In 1974, energy self-sufficiency for the IEA as a whole was 66%; after a slight dip, it rose to 76% in 1984 but fell back to approximately the original level (69%) in 2008. Self-sufficiency varies from fuel to fuel. For coal, the overall IEA self-sufficiency reaches 90%, but for oil it is only 37%.

To cope with possible oil supply disruptions, IEA member countries have successfully established, maintained and improved an effective emergency response system. Total crude oil and petroleum stocks in IEA member countries at the end of March 2009 were the equivalent of 162 days of the previous year's net imports, well above the 90-day requirement. However, in 1985 these countries had total stocks of more than 180 days.

Development of economic non-fossil fuel: nuclear and renewables

The IEA member countries have successfully defossilised their energy mix by developing large nuclear and renewables programmes. Nuclear generation rose most rapidly in the 1980s, then more gradually in the early 1990s (very little growth occurred in the 2000s).

Although 12 IEA member countries do not currently have commercial nuclear generating capacity, nuclear accounted for 22% of total IEA electricity production in 2008 (up from 5% in 1974).

The share of renewables in IEA TPES has increased from 5% in 1974 to 7% in 2008, primarily because of dramatic development of wind and solar programmes in recent years in many IEA member countries. The impact of these programmes is particularly impressive when looking at electricity generation. Between 1990 and 2008, wind electricity production increased by 48 times; in 2008, wind turbines produced 11% of total IEA renewable electricity.

Biomass, mainly wood and agro-residues, still represents the largest renewables contribution to energy supply of IEA member countries. Hydro continues to rank second, despite relatively little development since 2000. Other renewables, such as geothermal and more recently biofuels, also contribute to the relative growth of renewables in the energy mix of IEA member countries.

Improved energy efficiency

Many IEA member countries have made considerable effort to collect the basic data needed to assess the contribution of energy efficiency policy in the relative decrease of energy consumption. However, as such data are not yet available for all member countries, this analysis can only be conducted for a limited number of countries (varying from 11 to 21 depending on the sectors).

Disaggregated indicators built from the data available show that IEA member countries have been quite successful in promoting energy efficiency. Improved energy efficiency is the main driver behind the decoupling of energy consumption and GDP in IEA member countries. Without the efficiency improvements that occurred between 1974 and 2006, energy consumption in the 11 countries for which complete detailed data are available would have been 58% higher in 2006 than it actually was.

Energy efficiency gains for a group of 11 IEA member countries (for which data were available) were about 1.9% per year from 1974 to 1990. Unfortunately, between 1990 and 2006, the gains decreased significantly to only 1% per year, coinciding with lower real energy prices.

All sectors have experienced energy efficiency gains. In freight transport, energy intensity (expressed as energy consumption per tonne-kilometre) declined by 5% between 1990 and 2006; the intensity of passenger transport (expressed as energy consumption per passenger-kilometre) decreased by 6%. In the residential sector, efficiency of large appliances has been improved but more effort must now be directed toward efficiency of small appliances (*e.g.* personal computers and other home electronics) which now represent the largest share of household energy consumption.

Environmentally sustainable provision and use of energy

It is increasingly clear that energy production and use will play key roles in moving toward an environmentally sustainable future. Total IEA CO_2 emissions from fuel combustion increased by 17% between 1990 and 2007; this growth is less than the 45% increase in TPES, due to the relatively higher contribution of nuclear and renewables in the energy mix. Oil remains the largest source (42%) of IEA CO_2 emissions, especially in transport. Coal (mostly consumed in power generation) accounts for 35% and natural gas for 22%.

All IEA member countries but one have reduced their emissions per GDP, but only 13 have reduced their emissions per capita. Only eight countries have reduced their absolute level of emissions since 1990.

Undistorted energy prices

Liberalisation of energy markets has made information on energy prices and taxes less transparent. This lack of transparency arises from the rapid changes in prices (to reflect primary energy price fluctuations and volatility, or to adjust to competition), as well as from increased confidentiality due to negotiated prices.

On an ex-tax basis, a 63% difference is observed between the average lowest price and highest price for gasoline in IEA member countries; the difference surges to 350% when comparing total gasoline prices (including taxes). These figures reflect a wide range of taxation policies among IEA member countries; data show that the tax component is not linked to a country's volume of imports or its dependency rate.

Continued research development and market deployment

IEA member countries have been successful in promoting research and development through Implementing Agreements, which are open to non-member countries and industry, as well as to international organisations. There are currently 42 Implementing Agreements encompassing a wide range of areas including fossil fuels, renewables, buildings, electricity, industry, transport and fusion.

However, total public sector budgets for energy research, development and demonstration (RD&D) in IEA member countries have declined in real terms over the past 35 years, with 2008 nominal levels only slightly above 1976 budgeted levels. Moreover, the share of energy RD&D in total research and development has declined significantly from 12% to 4% since 1981. The overall decline masks the fact that the share of RD&D budgets has steadily increased in some areas (efficiency, renewables) but decreased in others (fission and fusion).

A few words on energy statistics

With the globalisation of energy markets, there is a growing need for more transparency to analyse the evolution of the markets in terms of production, trade, stock changes and consumption. This implies a need for more detailed, complete and timely data – and for greater transparency on the part of all market players. Several initiatives, including the Joint Oil Data Initiative (JODI) – launched in the early 2000s – have contributed to improving the quality and availability of data worldwide. But more needs to done.

Since the early 2000s, major progress has been observed in the coverage and the quality of energy statistics in IEA member countries. Prior to that time, liberalisation of the market and reduction in the resources allocated to statistics had lowered the overall quality of energy statistics.

IEA member countries are facing new challenges, including identifying priority areas and monitoring progress in energy efficiency, assessing development of renewables, and better tracking trade flows of energy. IEA member countries must, therefore, continue their efforts to increase transparency in order to be able to offer analysts and policy makers a valid assessment of the energy situation in IEA member countries and in the world.

IEA in the world

IEA in the world

Population and gross domestic product

▶ Several factors affect trends in energy demand in a given country and across the world. Population and gross domestic product (GDP) are two major drivers; thus, it is important to start by assessing their influence on the evolution of global energy demand over the last 35 years.

▶ Global **population** has grown by 66% to reach over 6.6 billion people. Population has more than doubled in the Middle East and in Africa. In absolute terms, Africa has experienced the highest growth (557 million), followed by India (524 million). Growth across all IEA member countries was only 223 million, of which 88 million occurred in the United States.

▶ As a result of growth patterns, the share of the IEA member countries in global population decreased (from 21% to 16%), as did that of China (from 23% to 20%). Shares of all the other regions increased, with the strongest growth occurring in Africa (from 10% to 15%).

▶ Over the same period, global **GDP** (as measured by market exchange rate or **MER**) grew by 167%, more than double that of the population. This translates into a large increase in wealth per capita. All the regions experienced strong growth, but the strongest occurred in China where GDP has been multiplied by a factor of 16. India and other Asia followed with a factor of six. GDP for IEA member countries as a whole rose by a factor of "only" 2.5.

▶ In 1974, IEA member countries dominated global GDP, accounting for 81% of the total. Because of more modest growth, their share decreased somewhat to 74%. The United States represented 39% of total IEA GDP, followed by Japan with 18%. Due to strong GDP growth, China experienced the highest growth in share, from 1% to 7%.

▶ Comparison using **GDP** in purchasing power parities (**PPP**) further highlights the impressive growth of some developing countries in recent years. PPP takes into account the relative cost of living and inflation rates. By PPP measures, China is the world's second-largest economy behind the United States (by MER, it ranks third after the United States and Japan).

▶ Based on GDP expressed in PPP terms, IEA member countries currently account for 51% of global wealth compared to 63% in 1974. The share of China was multiplied by almost six (from 2.7% to 16.5%) and that of India doubled (from 3.2% to 6.6%). Stronger growth in both population and GDP in IEA non-member countries has clearly influenced trends in the evolution of the global energy demand.

▶ *Sources*

- *National Accounts of OECD Countries*, Volume 1, 2009, OECD.
- *World Development Indicators*, 2009, the World Bank.

▶ *For further information*

- *World Energy Outlook*, 2009, IEA.

Two means to measure GDP: market exchange rates and purchasing power parities

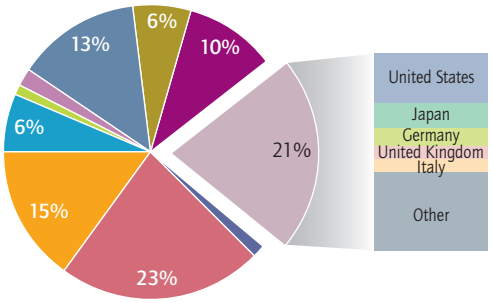
Economists generally use two means of measuring of GDP in constant dollars: market exchange rates (MER) and purchasing power parities (PPP). GDP based on MER uses the "official" exchange rates, but does not necessarily reflect the relationships between the internal purchasing powers of currencies. Thus, MER may distort inter-country comparisons of GDP and GDP components.

By contrast, PPPs measure the amount of a given currency needed to buy the same basket of goods and services (traded and non-traded) as one unit of the reference currency. By adjusting for differences in price levels, PPPs can, in principle, provide a more reliable indicator than MERs of the true level of economic activity globally or regionally. Conversions based on MERs typically underestimate the value of domestic economic activity and the output of developing countries relative to the industrialised economies. PPP rates can deviate by a large amount from the MER between two currencies.

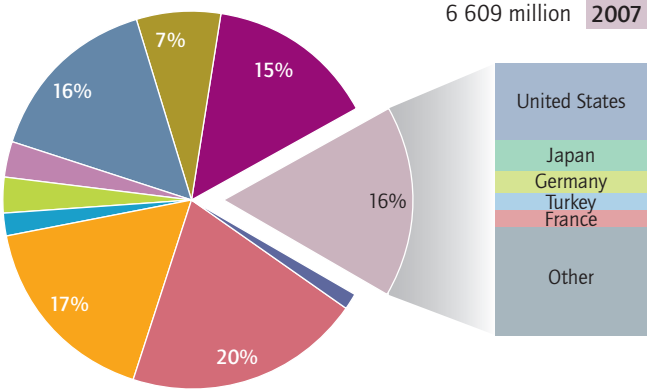
Despite strong growth in absolute terms, the share of IEA member countries in global GDP has fallen sharply since 1974, primarily due to faster growth elsewhere in the world.

Population

1974 3 989 million

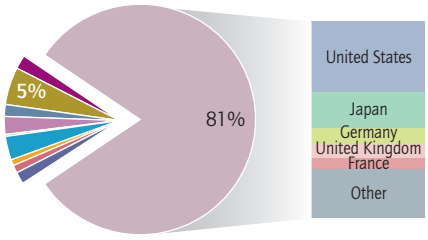


6 609 million **2007**

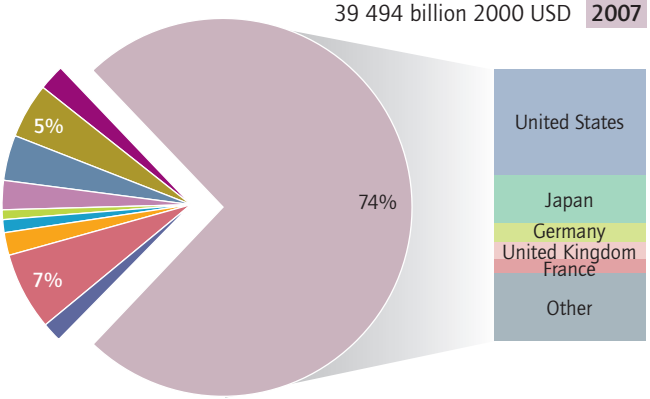


GDP

1974 14 797 billion 2000 USD

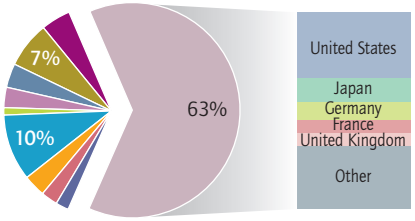


39 494 billion 2000 USD **2007**

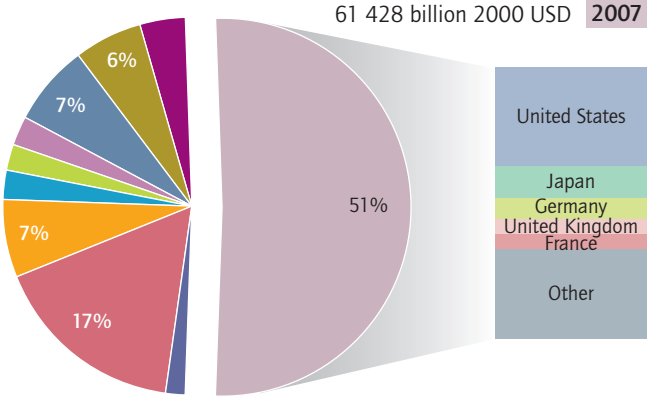


GDP PPP

1974 20 214 billion 2000 USD



61 428 billion 2000 USD **2007**



IEA · OECD non-IEA · China · India · Russian Federation* · Non-OECD Europe + FSU* · Middle East · Asia** · Latin America** · Africa

** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2007, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

Energy production: total, coal and oil

▶ Over the last 35 years, the average global energy supply (often referred to as demand) per capita rose by 0.5% per year – significantly less than global GDP per capita which rose by 1.5% per year This means that even though the world economy is becoming less energy intensive, the world needs more energy on a per capita basis and in absolute terms. To meet the demand of a population that grew by 66%, global energy production rose by 96%, from 6 300 million tonnes of oil equivalent (Mtoe) in 1974 to 12 300 Mtoe in 2008.

▶ Growth of production has varied widely from fuel to fuel and from region to region. Oil is still the main energy fuelling the world economy, but its share in total energy production fell dramatically from 47% in 1974 to 33% in 2008. Shares rose for both coal (from 24% to 28%) and natural gas (from 16% to 21%). Nuclear experienced the highest growth in relative terms (from 1% to 6%), but had the lowest growth in absolute terms. Nuclear production grew by 640 Mtoe, much less than half that of either coal or natural gas.

▶ In relative terms, the collective of IEA member countries is still the largest energy producer of the countries/regions reflected in this report, although their share in global production decreased from 38% in 1974 to 29% in 2008. The IEA share fell for all fuels except renewables and waste. Development of wind and solar programmes in IEA member countries was greater than the growth of biomass (mainly fuelwood) in many developing countries.

▶ In 1974, IEA member countries were the main world producer for all fuels except crude oil (second behind the Middle East) and renewables (on par with China). In 2008, the IEA was still the largest gas and nuclear producer. As a result of policies implemented by many member countries, the IEA is the now largest producer of energy from renewables. The IEA remained the second-largest producer of crude oil (behind the Middle East). China replaced the IEA as the largest producer of coal.

▶ The composition of global **coal** production has changed remarkably since 1974. Exports of coal have almost doubled, yet the bulk of coal produced is still consumed domestically, mainly in power generation and industry. To meet strong growth in electricity demand and industrial output, China now produces more coal than all IEA member countries combined. In 2008, China and the IEA together accounted for 73% of world coal production. Other large producers include India, other Asian countries (*e.g.* Indonesia and Vietnam) and the Russian Federation, which has experienced a drop in production.

▶ Global **oil** production rose less than other fossil fuels, largely because it was relatively more mature in 1974 and countries have since diversified their energy mixes. Major exploration and exploitation programmes in Africa, Latin America, China and other parts of the world have led to a diversification in the zones of production. As a result, shares of the three main producing regions have significantly decreased. In 1974, the Middle East, the IEA and the Russian Federation accounted for roughly three-fourths of global production; in 2008, they represented only 62%.

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *World Energy Outlook*, 2009, IEA.

Calculation of the primary energy equivalent

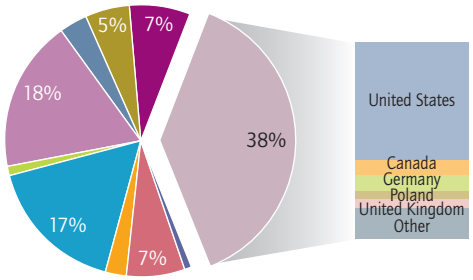
*In order to calculate energy balances which use the net heat content of one tonne of crude oil as a reference unit, it is necessary to estimate the production of certain energy sources that are not combusted (*e.g. *hydro, solar, wind, geothermal and nuclear). These estimates are based on the primary energy equivalent of the energy generated by that source, although the method and assumptions used in the calculation will affect the shares of the various sources in total energy production.*

The IEA Secretariat has adopted the "physical energy content" method to calculate the primary energy equivalent. For hydro, wind and solar PV, the primary energy equivalent is the physical energy content of the electricity generated. If no country-specific information is available, the IEA Secretariat assumes an efficiency of 10% for geothermal electricity, 50% for geothermal heat and 33% for nuclear.

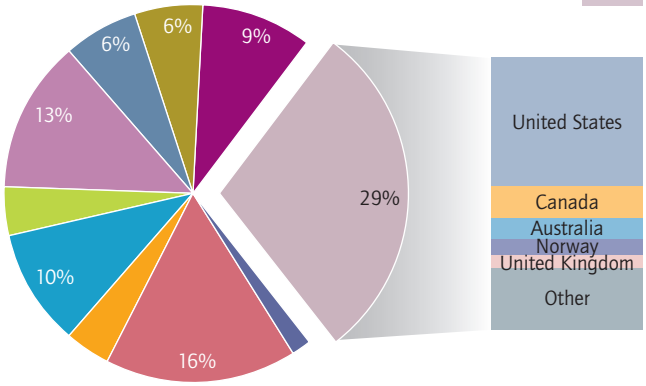
IEA member countries are often associated with high energy consumption; collectively, they are also the biggest overall energy producers, second for coal behind China and second for oil behind the Middle East.

Total energy production*

1974 6 294 Mtoe

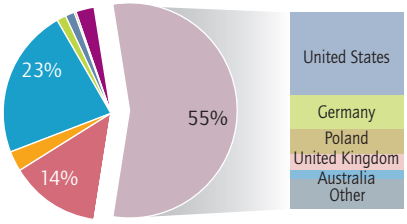


12 308 Mtoe **2008**

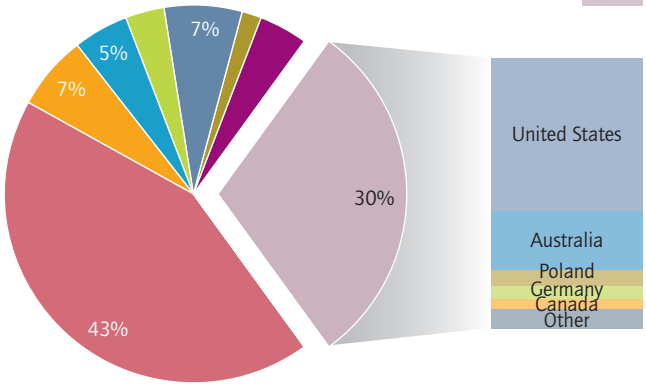


Coal production

1974 1 482 Mtoe

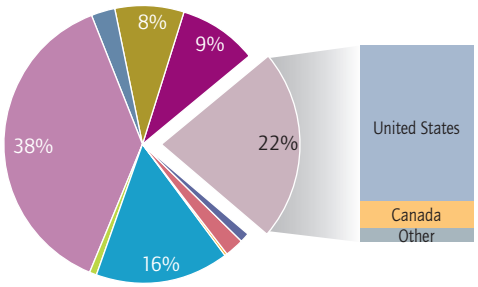


3 430 Mtoe **2008**

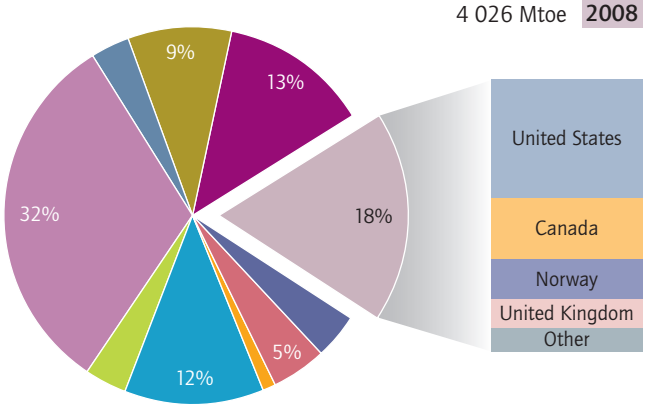


Oil production

1974 2 940 Mtoe



4 026 Mtoe **2008**



IEA · OECD non-IEA · China · India · Russian Federation** · Non-OECD Europe + FSU** · Middle East · Asia*** · Latin America*** · Africa

** Also includes heat pumps and heat from chemical processes.*
*** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2008, Non-OECD Europe + FSU excludes the Russian Federation.*
**** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico*

Energy production: natural gas, nuclear and renewables

▶ **Natural gas** has seen the second-largest increase (rising by 1 600 Mtoe or 156% since 1974) in global production in absolute terms, after coal (1 950 Mtoe) and before oil (1 100 Mtoe). This rapid growth can be attributed to several factors. Natural gas has a lower environmental impact than coal or oil. Capital expenditure for new infrastructure is lower and lead times for production are shorter than for other fuels. In addition, increased use of liquefied natural gas (LNG) and long-distance pipelines have facilitated development of more remote gas fields.

▶ Many regions (Asia, Latin America, Africa and the Middle East) have greatly increased natural gas production to meet increases in domestic power generation and to supply growing gas exports worldwide. Production in IEA member countries, still largely dominated by the United States, has increased from 690 Mtoe to 920 Mtoe since 1974. However, since this increase is much less than in other regions, the IEA share of total gas production fell by about one-half - from two-thirds to one-third.

▶ With 20% of global production, the Russian Federation was the largest gas producer in 2008, followed by the United States (18%), the Middle East (12%) and Africa (7%, primarily from Algeria, Egypt and Nigeria).

▶ In relative terms, **nuclear** energy has experienced the largest growth in production, a ten-fold increase since 1974. At that time, nuclear was very little developed and accounted for 1% of the world total energy production. Notable increases have since been seen in several IEA member countries, the Russian Federation and China, mostly during the 1980s and 1990s. Nuclear now accounts for 6% of global energy production and for 16% of production in IEA member countries. Three countries, the United States (31%), France (16%) and Japan (9%), accounted for more than half of global nuclear production in 2008.

▶ By contrast, energy production from **renewables and waste** is very well-distributed globally. Renewable consumption varies from traditional biomass (for cooking and heating) to hydropower, wind and solar. Although renewables have gained much attention, their share (13%) of the world's energy is unchanged since 1974 – even though total energy production has doubled.

▶ In 2008, as in 1974, combustible renewables (biomass) accounted for most (77%) of the global production of renewables, followed by hydropower (18%) and others (5%, primarily geothermal, wind, solar, etc.).

▶ These aggregate numbers obscure several underlying trends. As people in developing countries become richer or move to cities, they often switch from traditional biomass for cooking and heating to modern energy sources such as kerosene, liquefied petroleum gases (LPG), natural gas and electricity. Some countries have developed modern renewables (such as hydro, wind, solar and biomass for power generation, as well as biofuels) in an effort to replace fossil fuels, limit their imports and de-carbonise the energy supply.

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *Natural Gas Information*, 2009, IEA.
- *Electricity Information*, 2009, IEA.
- *Renewables Information*, 2009, IEA.

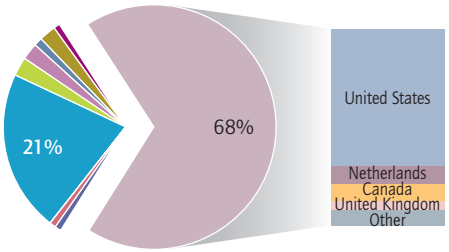
Difficulties in obtaining accurate data on biomass production

The quality of data available on biomass production varies depending on the energy source. For example, data are accessible and fairly accurate on bio-ethanol and biodiesels blended with oil products, and for biogases (such as landfill gas and sewage sludge gas) used to generate electricity. By contrast, solid biofuels (such as fuelwood) are often used on a non-commercial basis and consumption must be estimated through household surveys. Other solid biomass produced as industry by-products (e.g. *wood chips) are also difficult to measure, particularly if used on-site. These data issues are especially serious for IEA non-member countries.*

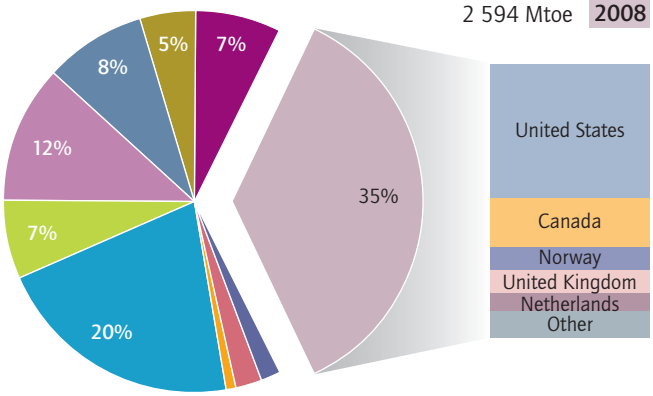
Nuclear and natural gas have experienced the highest growth in their share of global energy production since 1974. Renewables account for 13% of global energy production.

Natural gas production

1974 1 013 Mtoe

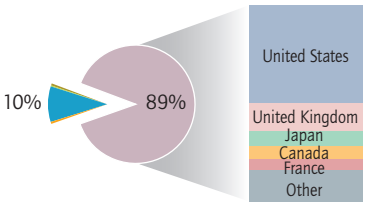


2 594 Mtoe **2008**

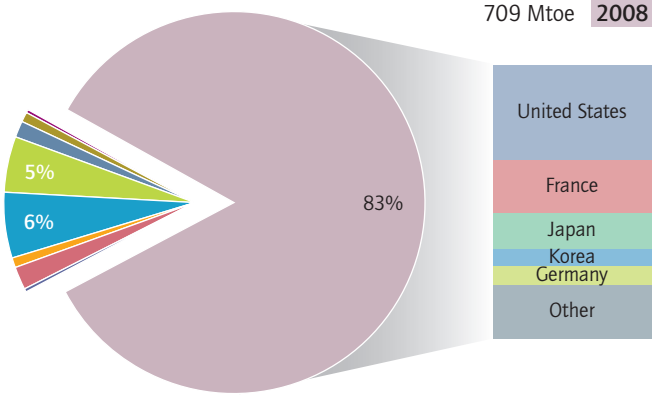


Nuclear production

1974 71 Mtoe

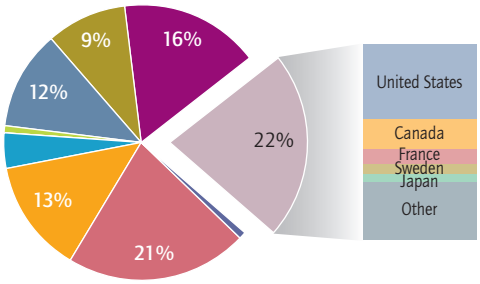


709 Mtoe **2008**

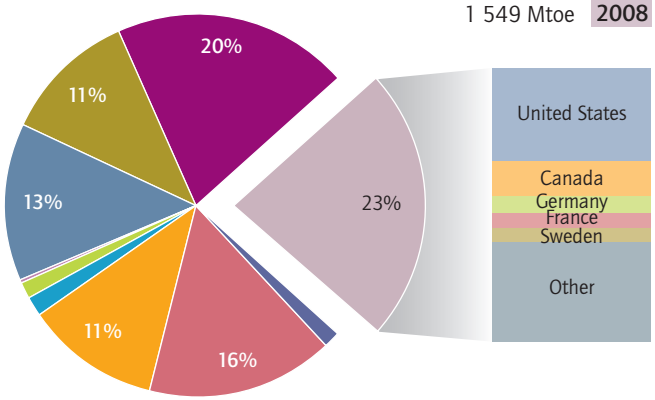


Renewables and waste production

1974 789 Mtoe



1 549 Mtoe **2008**



IEA | OECD non-IEA | China | India | Russian Federation* | Non-OECD Europe + FSU* | Middle East | Asia** | Latin America** | Africa

** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2008, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

Energy imports

▶ Global trade in fossil fuels experienced massive growth since 1974: coal trade increased by a factor of 3.8; oil (crude oil and petroleum products) trade by 1.8; and natural gas trade by 8.7.

▶ Together, IEA member countries remain the world's most significant importers of fossil fuels. However, their share of total coal, oil and natural gas imports has declined from 82% in 1974 to 67% in 2007. This reflects increased imports to other regions, particularly into countries across Asia.

▶ Japan remains the largest **coal** importer, even though its share of global trade fell from 30% in 1974 to 20% in 2007. Despite this declining share, Japan's coal imports grew by 150% over the survey period, reflecting two factors: in 1974, domestic mines were still operating and met one-quarter of demand; and overall demand has increased predominantly for the production of electricity and steel. Korea has experienced a period of rapid industrialisation and is now the world's second-largest coal importer, ahead of Chinese Taipei, India and Germany.

▶ **Oil** accounted for 89% of global trade in fossil fuels in 1974. Although its share had fallen to 71% by 2007, primarily due to stronger growth in coal and natural gas trade, it remains more than double that of coal and natural gas combined. Thus, oil maintains its position as the largest and most important fossil fuel commodity. The United States remains the largest importer by a wide margin, with imports more than triple those of Japan, the second-largest importer in 2007. In 1974, US imports accounted for 20% of all oil imports into IEA member countries. By 2007, US imports had grown 130% and its share of IEA imports had risen to 33%, a result of declining domestic production and rising demand.

▶ Many other IEA member countries are significant oil importers; two-thirds of global oil trade is imported into IEA member countries, down from 82% in 1974. Outside of the IEA, imports to China grew quickly to make it the third-largest oil importer; India is now in fourth place.

▶ **Natural gas** trade has grown strongly since 1974, by 6.8% per year (compared with 4.1% for coal and 1.7% for oil). Trade in natural gas, on an energy basis, surpassed trade in coal in 1990. This can be attributed to the collapse of the Former Soviet Union and the subsequent reporting of inter-country trade within that region. All IEA member countries have increased their natural gas use since 1974 and most have consequently increased their imports. On an aggregate basis, IEA imports of natural gas grew by a factor of 7.6.

▶ The United States was the world's largest natural gas importer in 1974, with imports coming entirely from Canada. US imports were subsequently overtaken by Germany and then Japan. In 1992, the United States regained the lead position when it increased imports to bolster a decline (7% since 1974) in domestic production. In 2007, net imports met 16% of US domestic natural gas demand.

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *Coal Information*, 2009, IEA.
- *Oil Information*, 2009, IEA.
- *Natural Gas Information*, 2009, IEA.

What is covered under imports and exports?

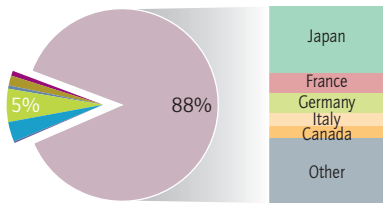
In principle, imports and exports are the amounts of energy that cross a country's national territorial boundaries, regardless of whether the transfer involves customs clearance. Theoretically, quantities in transit through a country should not be included in import/export calculations. The exception is electricity, the amounts of which are considered each time they cross national territorial boundaries; thus, electricity in transit figures as both an import and an export.

For practical reasons, the IEA Secretariat considers crude oil as coming from the country of first origin whereas refinery feedstocks and oil products are collected as coming from the country of last consignment.

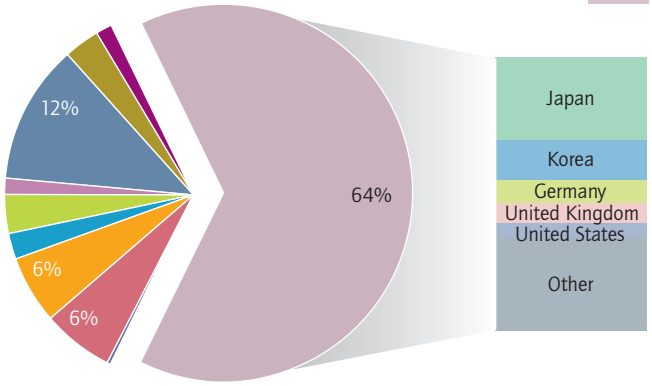
Although their share is decreasing, IEA member countries still account for at least two-thirds of the world's coal, oil and natural gas imports. Gas trade has grown by a factor of nine.

Coal imports

1974 156 Mtoe

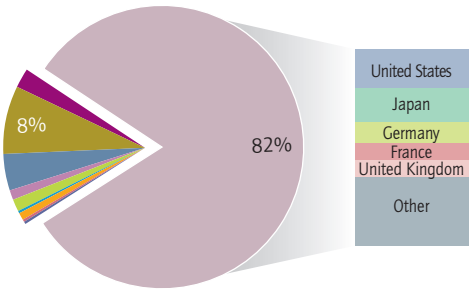


590 Mtoe **2007**

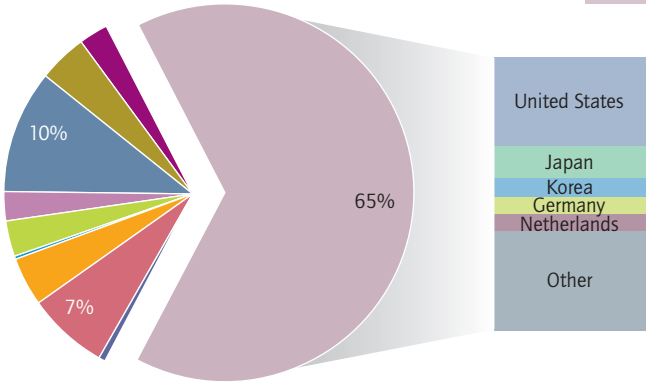


Oil imports

1974 1 889 Mtoe

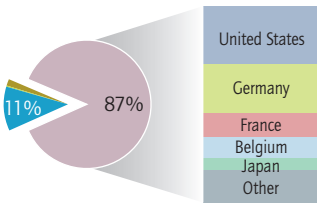


3 323 Mtoe **2007**

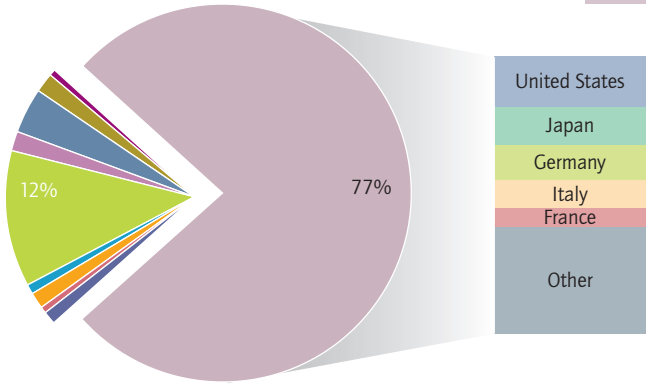


Natural gas imports

1974 87 Mtoe



758 Mtoe **2007**



IEA · OECD non-IEA · China · India · Russian Federation* · Non-OECD Europe + FSU* · Middle East · Asia** · Latin America** · Africa

** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2007, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

Energy exports

▶ The pattern of fossil fuel exports changed markedly between 1974 and 2007, with a trend towards greater diversity. More countries have become coal exporters and the Middle East no longer dominates oil exports (its share declined from 53% to 31%). Natural gas exports, once dominated by the Netherlands and Canada, now reflect many new exporting countries with no dominant supplier.

▶ In 1974, the United States was the world's largest **coal** exporter, with amounts more than double those of second-place Australia. Poland and Germany were also significant exporters, mainly meeting demand from other European countries. By 2007, a very different picture emerged. The United States and Europe accounted for a relatively small share of coal exports (exports from the Netherlands were mainly transhipments). Australia became a dominant exporter, accounting for 26% of global exports (and 55% of coking coal exports). Important new non-IEA suppliers also entered the market, notably Indonesia, Colombia, South Africa and China. With declining coal production in IEA Europe, the Russian Federation became an important exporter to this region.

▶ Although **oil** exports have grown less strongly (1.5% per year) than coal (4.3%) and natural gas (6.7%), they remain four to five times larger than those of gas or coal. Middle Eastern oil exports declined by 6% between 1974 and 2007, and now account for a smaller share of global oil exports. Increased exports from countries bordering the North Sea, as well as from Africa (notably Angola and Algeria, but also others) and North America, contributed to growth in oil trade and to greater diversity of supply.

▶ Trade in **natural gas** grew by 6.7% per year between 1974 and 2007; it now accounts for 16% of all trade in fossil fuels on an energy basis. The gas market evolved from a domestic to a regional market, then expanded to the global scale. This reflects the increased capacity for trade via pipelines (including very long lines such as the 3 500-km TransCanada pipeline and the 4 200-km Yamal-Europe pipeline from the Russian Federation) and through the use of dedicated tankers for transport of liquefied natural gas (LNG). LNG accounted for 25% of natural gas trade in 2007.

▶ Since 1974, growth in natural gas exports from the Middle East, North America, North Africa, the Russian Federation and Central Asia has been supplemented by new exports from countries bordering the North Sea, as well as Indonesia, Malaysia, Nigeria, Egypt, Trinidad and Tobago, and Australia. These new players have brought greater diversity to supply. With rising natural gas demand in IEA Europe (including for power generation), the Russian Federation has become the dominant exporter to this region.

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *Coal Information*, 2009, IEA.
- *Oil Information*, 2009, IEA.
- *Natural Gas Information*, 2009, IEA.

Imports and exports of electricity and renewables

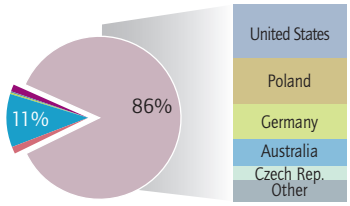
Global trade of electricity is significantly lower than that of fossil fuels, in terms of both amount and distance. In 2007, for instance, imports and exports of electricity were only 10% of the global coal trade (on an energy basis). Most electricity trade occurs between neighbouring countries, such as exports of hydroelectricity from Paraguay to Brazil, or exports of nuclear electricity from France to bordering countries.

Trade of combustible renewables and waste is even more limited: in 2007, it equated to only 10% of electricity trade (or 1% of coal trade). Of these products, biofuels are the most traded, with a large portion being exports from Brazil.

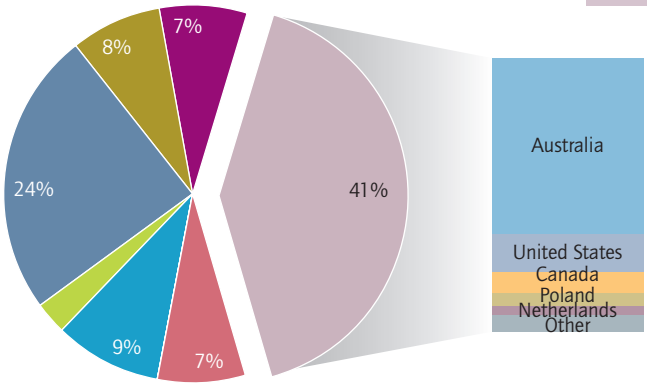
The growth in fossil-fuel trade has been accompanied by a greater diversity of exporting countries. For coal, exports from IEA and FSU countries together dropped from 97% to 53% of global trade.

Coal exports

1974 148 Mtoe

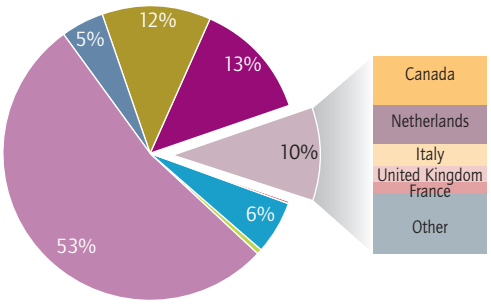


603 Mtoe **2007**

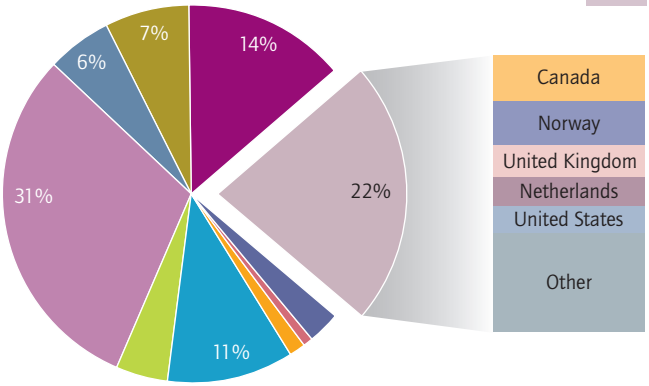


Oil exports

1974 1 995 Mtoe

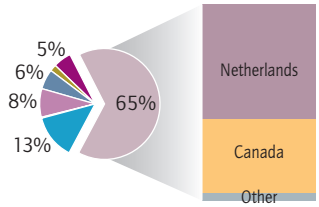


3 242 Mtoe **2007**

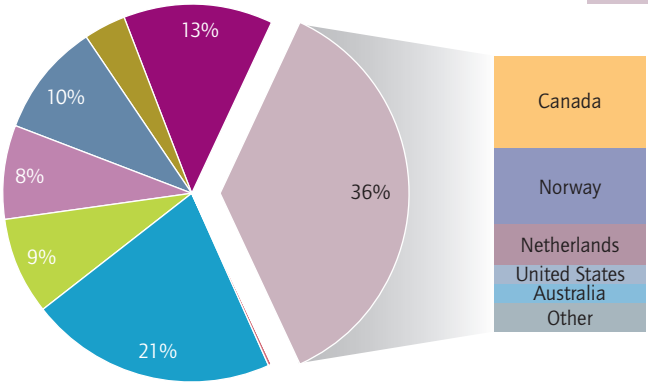


Natural gas exports

1974 87 Mtoe



743 Mtoe **2007**



IEA · OECD non-IEA · China · India · Russian Federation* · Non-OECD Europe + FSU* · Middle East · Asia** · Latin America** · Africa

** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2007, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

Total primary energy supply by region

▶ Global total primary energy supply (TPES) has almost doubled since 1974, rising to 12 000 Mtoe in 2007. Growth has been much stronger in IEA non-member countries (+171%) than in IEA member countries (+46%). As a result, more energy is now consumed outside the IEA than inside the IEA. Overall, the IEA share dropped from 59% in 1974 to 44% in 2007.

▶ China, which accounted for 7% of global TPES in 1974, grew rapidly to represent 16% in 2007 and is now a close second to the United States at 19%. India (5%), other Asia (6%) and the Middle East (5%) saw strong increases in their respective shares.

▶ Strong growth in energy consumption in IEA non-member countries should not mask the still large disparities in energy consumption per capita. IEA member countries, with their greater wealth and access to energy services, have an average **per-capita energy consumption** of about 5 toe – more than twice the world average and almost ten times that of the average for India.

▶ The Middle East and China have experienced the highest growth in energy consumption per capita since 1974. Per-capita consumption tripled for both, reflecting increasing wealth associated with the exploitation of vast domestic energy reserves and/or major economic development.

▶ Africa and India have the lowest energy consumption per capita and the lowest electrification access. They also have the highest rates of people living in poverty. The strong link between poverty and lack of access to electricity is well documented. Improving access to electricity is one of the most effective ways to alleviate poverty.

▶ The **energy intensity** of an economy is a measure of how much energy is required to produce each unit of national revenue (in this report, measured using the US dollar or USD). It is usually expressed in tonne of oil equivalent (toe) per unit of GDP, using either MER or PPP. There is no direct correlation between energy consumption per capita and energy intensity: for example, IEA member countries have the highest consumption per capita, but the lowest consumption per GDP. With more economic output deriving from less energy-intensive sectors (*e.g.* the services sector) and with generally more energy-efficient equipment, the energy intensity of IEA member countries is about half that of the global average.

▶ In 1974, China's economy was driven by manufacturing and export: almost 3 toe were needed to produce USD 1000 of GDP (MER) and the country's energy intensity was almost seven times the global average. Today, China's energy intensity is less than 1 toe per USD 1000 of GDP, largely due to efforts to restructure the economy, strong wealth creation and the introduction of energy efficiency programmes (it should be noted that China still exceeds the global average by a factor of 2.5). India has achieved similar improvements in energy intensity. The Russian Federation now has the highest TPES per GDP.

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *World Energy Outlook*, 2009, IEA.

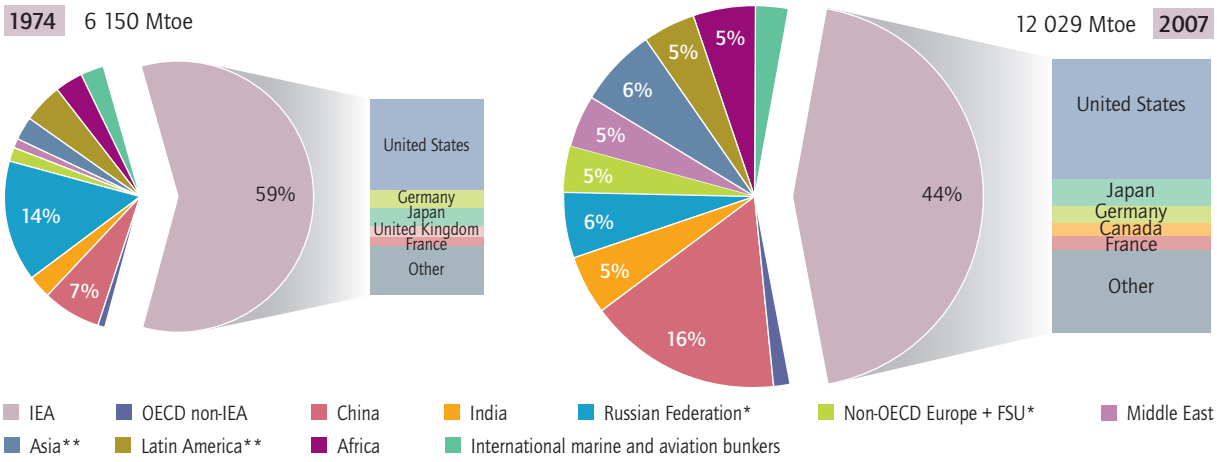
What is TPES?

*Total primary energy supply (TPES) represents the total flow of fuel or energy in a national territory. In general, energy "supply" is often associated with energy "demand" or "consumption"; however, the concept of TPES differs from total final consumption (TFC) which excludes energy consumed by the energy sector for transformation (*e.g. *power plants and refineries) and by the energy sector itself as own use.*

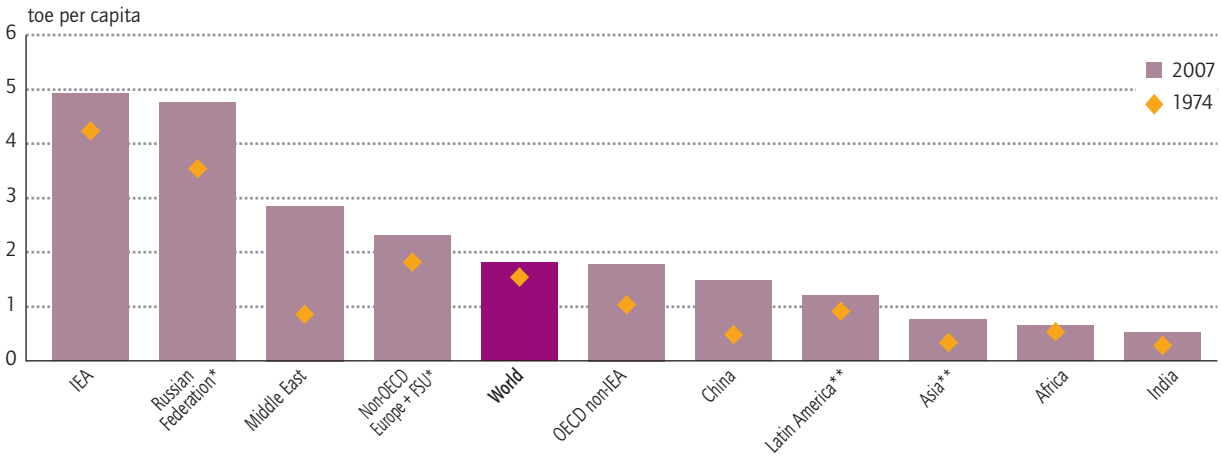
Various organisations have slightly different definitions of TPES. The IEA Secretariat defines it using the following equation: production + imports – exports – international marine bunkers – international aviation bunkers ± stock changes. For world total, the IEA does not subtract international marine and aviation bunkers.

Energy consumption per capita has increased in all regions; yet significant regional differences remain in both consumption per capita and energy intensity.

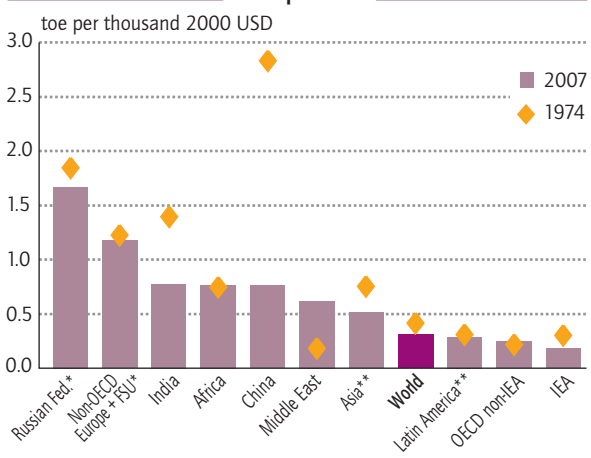
Total primary energy supply (TPES)



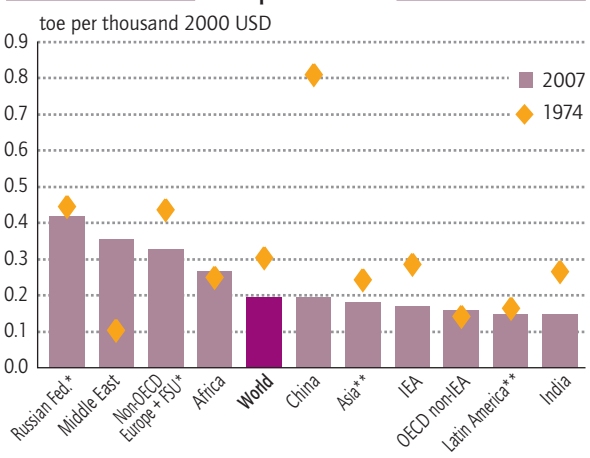
TPES per capita



TPES per GDP



TPES per GDP PPP



** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2007, Non-OECD Europe + FSU excludes the Russian Federation.*

*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

Primary energy supply by fuel

▶ Analysis of regional changes in primary fossil fuel supply over the past 35 years reveals two striking trends: the decreased importance of IEA member countries and the Russian Federation in the global picture; and the rise of Asian countries (led by China and India) driven by increasing populations and rising GDP.

▶ Since 1974, growth in supply for the three main fossil fuels is as follows: oil rose the least (+47%), coal supply doubled (+113%) and natural gas had the largest increase (+151%).

▶ The increase in global **coal** supply is largely due to an almost six-fold increase in both China and India for power generation and industry (particularly iron and steel production). China now accounts for 41% of global coal consumption: more than all IEA member countries combined and more than double that of the United States, the second-largest consumer. In 1974, the Russian Federation, together with other FSU economies, consumed 21% of global coal supply. Due to diversification towards oil and natural gas in its energy mix, the share of the Russian Federation alone dropped to 3% of global coal consumption in 2007.

▶ In 1974, IEA member countries consumed more than two-thirds of all **oil**, mainly in transport but also in residential, industry and power generation. Today, the IEA share is about half of global oil consumption, with the largest share in transport. The share of oil in residential and industry shows large decreases; oil in power generation has been almost completely phased out.

▶ With the exception of the Russian Federation, all regions have seen growth in their share in global oil consumption. The share of China has increased from 2% to 9%. The Middle East has seen its importance in global oil markets shift, from that of major oil exporter to also being a major oil consumer. This trend reflects large oil subsidies in many Middle Eastern countries, which keep domestic oil prices low and encourage domestic consumption. In turn, higher domestic consumption means that a smaller share of the increase in Middle East oil production is available to international oil markets.

▶ **Natural gas** consumption has also increased sharply in all regions. Growth has been fastest in developing countries, led by Asia and the Middle East (both with sizeable local reserves). As a result, the IEA share in global supply decreased, from 70% in 1974 to just below 50% in 2007.

▶ With 21% of the global natural gas consumption, the United States remains the largest gas consumer, ahead of the Russian Federation (15%) and the Middle East (10%). Globally, the bulk of natural gas is consumed in power generation, followed by industry and residential. Compared to its 41% share in global coal consumption and 9% in oil, China remains a modest natural gas user, consuming only 2% of total world demand.

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *World Energy Outlook*, 2009, IEA.

Imports and exports: an important component of supply

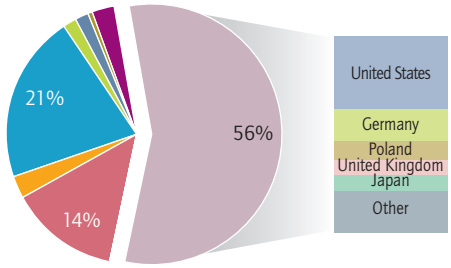
In 1974, the world was roughly divided into two main groups: energy consumers and energy producers. IEA member countries were mostly energy consumers (even though some produced significant quantities of energy) and major IEA non-member countries were energy producers (particularly regions such as the Middle East and Africa). International trade was relatively straightforward: producers exported fossil fuels to consumers.

Today, this distinction is disappearing. IEA member countries are still major consumers and non-IEA regions are still major producers. But many countries now play important roles on both sides of the market: they produce and export but also consume larger shares of what they produce. This has significant implications on the composition of supply between production, imports and exports.

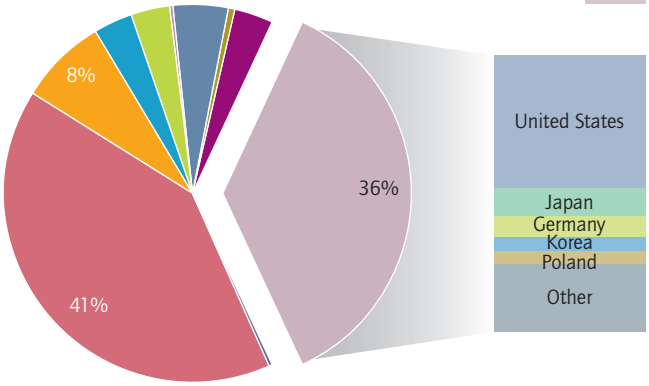
Global supply for fossil fuels is better distributed amongst regions now than in 1974, with the exception of coal supply which is largely dominated by China and IEA member countries.

Coal primary energy supply

1974 1 495 Mtoe

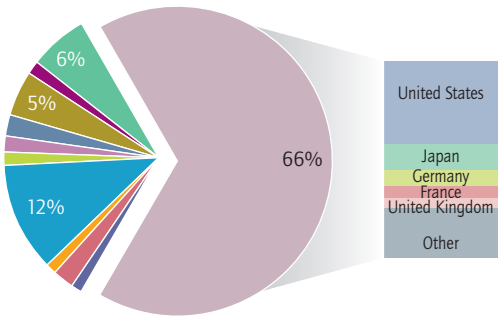


3 182Mtoe **2007**

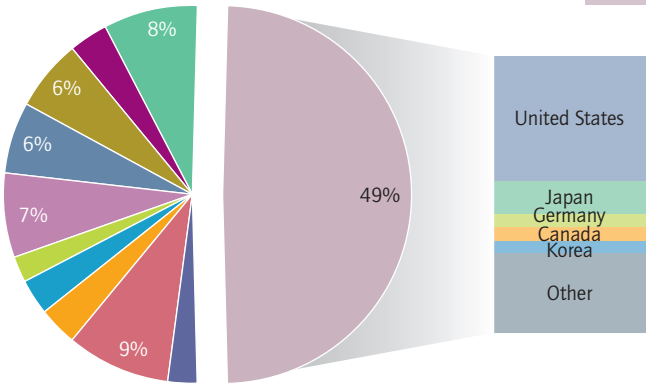


Oil primary energy supply

1974 2 778 Mtoe

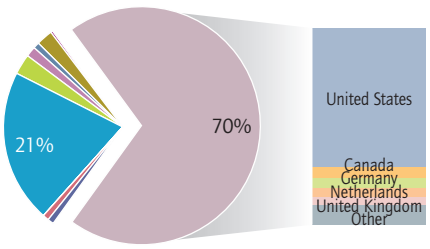


4 090 Mtoe **2007**

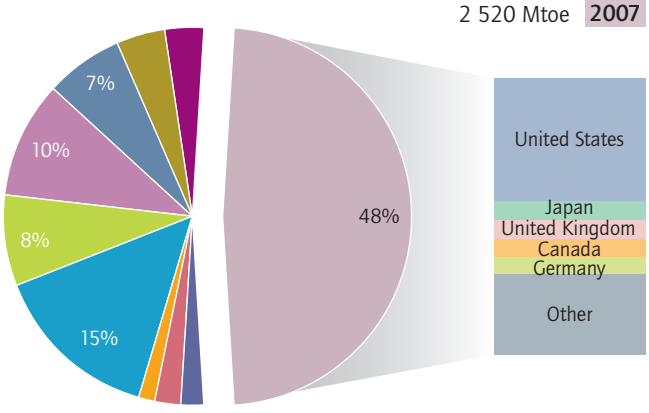


Natural gas primary energy supply

1974 1 004 Mtoe



2 520 Mtoe **2007**



IEA · OECD non-IEA · China · India · Russian Federation* · Non-OECD Europe + FSU* · Middle East · Asia** · Latin America** · Africa · International marine and aviation bunkers

** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2007, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

Total primary energy supply by region and by fuel

▶ When looking at the TPES of the world, the weight of the IEA member countries is clearly visible. Analysis of **world** TPES over the period 1974-2007, shows that oil was and still is the fuel of choice, although its share dropped both globally (from 45% to 34%) and for **IEA** member countries (from 51% to 38%). Coal remains the second fuel, with a share staying more or less stable (around 25% for the world and 22% for the IEA). Natural gas is the third most consumed fuel; its global growth (from 16% to 21%) was larger than the IEA increase (from 19% to 23%). The only difference in the world and IEA energy mixes is the respective places of nuclear and renewables. For the IEA, nuclear (11%) is ahead of renewables (7%). For the world, renewables (13%) remained a solid fourth, ahead of nuclear (6%).

▶ In 1974, **China**'s TPES was dominated by two fuels: coal and renewables accounted for 84% of the energy mix. The share of coal has since increased (from 46% to 66% in 2007) while the share of renewables fell dramatically (from 38% to 12%). This drop is largely due to Chinese urbanisation, an increase in purchasing power and a move away from traditional fuels (mainly wood). The share of oil went up slightly (from 14% to 18%). Current shares of natural gas (3%) and nuclear (1%) are slightly higher, but both remain marginal energy sources.

▶ The drop in the share of renewables in TPES has been even more spectacular in **India** (from 61% in 1974 to 29% in 2007). In relative terms, renewables (biomass) have been displaced by the growth of coal (from 24% to 41%) and oil (from 14% to 24%), even though the overall supply of renewables doubled over the period. The spectacular growth in the share of coal in India (which outpaces even that of China) can be explained by massive electrification programmes, primarily through coal-fired power plants.

▶ The evolution of TPES in the **Russian Federation** and the **Middle East** warrants special attention. Traditionally, coal was the fuel of choice in the Former Soviet Union (FSU): in 1974, it accounted for 36% of the FSU TPES. Spectacular development of natural gas, in all sectors of the economy, has since dramatically changed the ranking of shares. In 2007, natural gas represented 55% (up from 24%). Over the same period, coal dropped from 36% to 15%. Similarly, strong growth effectively doubled (from 23% to 45%) the share of natural gas supply in the Middle East, making natural gas a close second to oil, which has seen its share drop (from 74% to 52%).

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *World Energy Outlook*, 2009, IEA.

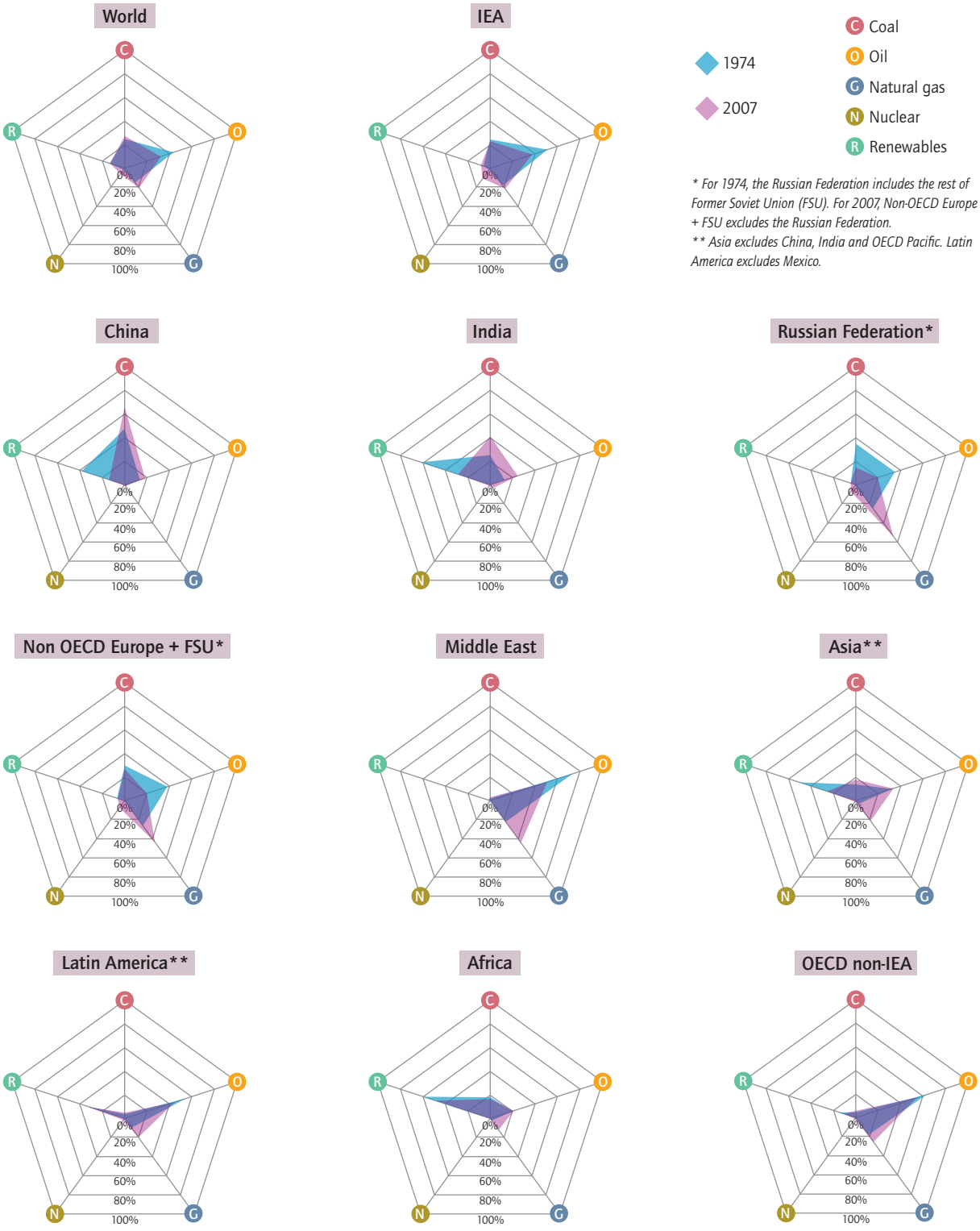
How to read a "spider web" diagram

Spider web diagrams (also known as radar charts) use a sequence of equi-angular spokes, called radii, to represent each of the relevant variables. Drawing a line to connect the data values for each spoke gives the plot a star-like appearance that can be used to answer the following questions: What variables are dominant for a given observation? Which observations are most similar, i.e. *are there clusters of observations? Are there outliers?*

The spider web diagrams on the following page illustrate the evolution of the fuel mix in TPES, over the period 1974-2007, for selected countries and regions. The spokes represent shares of coal, oil, natural gas, nuclear and renewables. Comparing the blue (1974) and purple (2007) lines within individual diagrams and across the entire set highlights regions and countries that have experienced significant changes in their energy mixes.

The energy mix, globally and for the IEA, has remained fairly stable since 1974. Major shifts occurred for China and India (more coal), and for the Russian Federation and the Middle East (more natural gas).

TPES by fuel and by region in 1974 and 2007



** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2007, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

Electricity production

▶ Global electricity production has more than tripled over the past 35 years – its pace of growth outstripping global energy production, which has a little less than doubled. Several factors contributed to the higher growth in electricity production. In developed countries, strong increases in electricity consumption are due to penetration of larger and new appliances, computers and videos, air conditioning and electrical heating. In developing countries, increased demand results from large urban and rural electrification programmes.

▶ In fact, the impact of the electrification programmes and higher purchasing power in developing countries overtook the increase in developed countries. As a consequence, the share of IEA member countries in global electricity production declined from a little more than two-thirds in 1974 to just one-half in 2007.

▶ China experienced a dramatic growth of its share of global electricity production, from 3% in 1974 to 17% in 2007. It is now the second-largest electricity producer, just behind the United States (22%). Japan is the third producer (6%) followed by the Russian Federation (5%) and India (4%). The share of India is increasing at a very rapid rate and the country will soon become the third-largest producer.

▶ The energy mix for global electricity production has seen a significant shift since 1974, even though the share of fossil fuels remained roughly stable at just above two-thirds. The share of natural gas increased from 12% to 21%, and has largely displaced oil, the share of which fell from 23% to 6%. Coal is, by far, the largest contributor to electricity production. In fact, its share grew from 37% to 42%, reflecting dramatic electricity growth in China and India, and the importance of coal in the electricity mix of these countries.

▶ A notable shift is also observed in the shares of non-fossil fuels in electricity production. The share of nuclear increased significantly (from 4% to 14%) as a result of a large-scale development of nuclear facilities primarily in (but not limited to) IEA member countries. Nuclear has more than compensated for the sharp decline (from 23% to 16%) of the share of hydro. The drop in hydro's share reflects the fact that many hydro sites have been in place since the 1970s (or even before) and few major new dams were built over the period.

▶ The electricity generation mix for IEA member countries roughly mirrors the global mix, but with slightly less oil and hydro, and slightly more nuclear. In 2007, just over 60% of IEA electricity production was based on fossil fuels (coal 38%; natural gas 21%; and oil 4%). Nuclear and hydro accounted for 22% and 12%, respectively. The share of non-hydro renewables had increased from almost no production in 1974 to 4% (mainly from wind).

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *Electricity Information*, 2009, IEA.
- *World Energy Outlook*, 2009, IEA.

From production to consumption: own use and losses

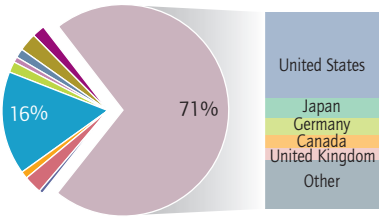
Electricity production includes quantities that are consumed by energy industries (referred to as "own use") for activities such as fuel mining and extraction, electricity generation, and operation of oil refineries, combined heat and power (CHP) or heat plants, pumped storage, etc. It also includes quantities that are lost in the transmission and distribution of electricity. By contrast, own use and losses are not included as part of electricity consumption.

*Distribution losses, which can be quite large, include both technical and non-technical losses (*e.g. *pilfering). On average, losses represent about 6% of electricity production in IEA member countries and in China. Figures in several non-IEA regions range between 11% and 16%, but can reach as high as 30%.*

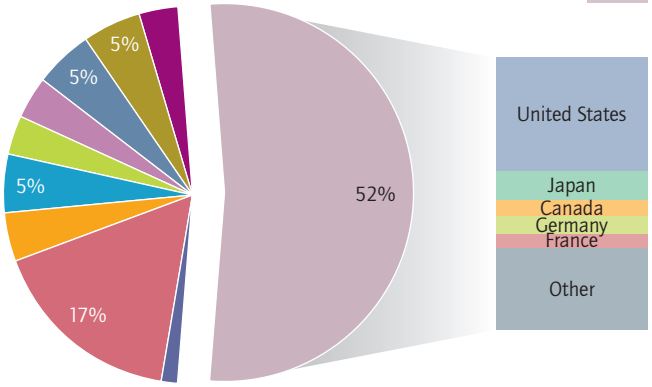
Coal remains the predominant fuel for producing electricity, but use of natural gas is growing quickly. Oil has been almost phased out.

World electricity production

1974 6 272 TWh



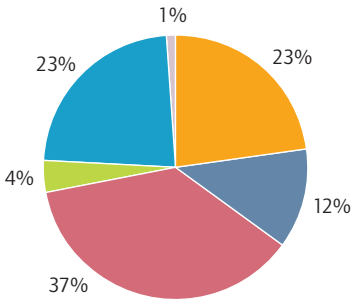
19 771 TWh **2007**

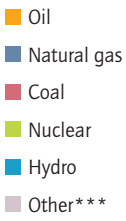


IEA · OECD non-IEA · China · India · Russian Federation* · Non-OECD Europe + FSU* · Middle East · Asia** · Latin America** · Africa

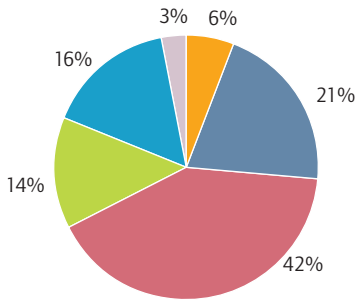
Electricity production by source: world

1974 6 272 TWh



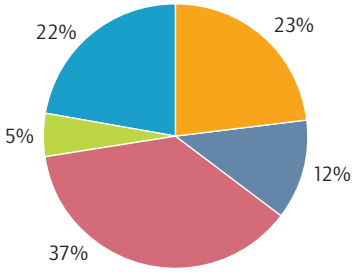


19 771 TWh **2007**

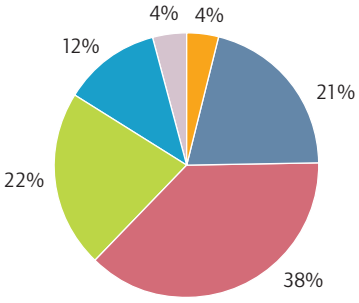


Electricity production by source: IEA member countries

1974 4 460 TWh



10 376 TWh **2007**



** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2007, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*
**** Other includes geothermal, solar, wind, tide/wave/ocean energy, combustible renewables and waste, etc.*

Electricity consumption

▶ Notable shifts have occurred in electricity consumption over the past 35 years. The share consumed by the residential sector has risen from 23% in 1974 to 27% in 2007, largely due to electrification programmes in developing countries and the penetration of more appliances and video/computer equipment in developed countries. Despite a dramatic decrease – from 54% to 42% – industry remains the largest consumer, ahead of the residential and commercial and public services sectors. In fact, the services sector has experienced the fastest growth, rising from 15% to 23%.

▶ The situation is slightly different across IEA member countries, with the industrial, residential and services sectors representing more or less equal shares (one-third) of total electricity consumption. This is a major shift from 1974, when industry accounted for almost half of consumption and services only 20%. The United States remains the dominant electricity consumer, accounting for 42% of IEA consumption; total US consumption is greater than the whole of IEA Europe and around one-quarter of global use.

▶ The four biggest electricity consumers outside the IEA – China, the Russian Federation, India and Brazil – account for almost 60% of IEA non-member electricity consumption. China is by far the largest IEA non-member consumer, accounting for 16% of the world total. This reflects a six-fold absolute growth since 1990 and an average annual increase of almost 17% since 1974.

▶ Analysis of final average **consumption of electricity per capita** by region reveals that even though consumption is increasing for all regions, major differences still exist. Globally, average per capita consumption rose from 1 300 kWh in 1974 to 2 500 kWh in 2007. It should be noted, however, that referring to a "world average" is not always meaningful as a large part of the global population still lacks access to electricity.

▶ In absolute terms, electricity consumption per capita has increased the most in IEA member countries (from 4 400 kWh to 8 400 kWh); somewhat lower increases occurred in the Middle East, China and the Russian Federation.

▶ In relative terms, China (1 200%) and the Middle East (500%) show the fastest growth; both presented very low consumption per capita in 1974 and have since experienced strong increases in GDP. Per capita demand in India, Africa and Asia (excluding China and India) is still three to five times less than the world average.

▶ *Sources*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.
- *World Energy Outlook*, 2009, IEA.

▶ *For further information*

- *Electricity Information, 2009, IEA.*
- *Gadgets and Gigawatts: Policies for Energy Efficient Electronics*, 2009, IEA.

Electricity access and rural electrification

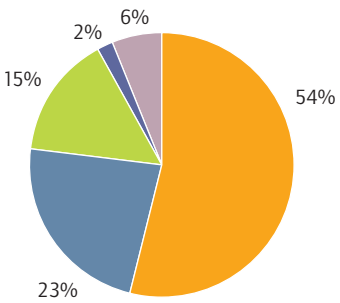
Although electricity access is recognised as an issue of global concern, to date there is no single, internationally accepted definition of the concept. The IEA Secretariat considers electricity access at the household level; i.e. *that people have electricity in their homes. Electricity access comprises electricity sold commercially (both on-grid and off-grid), as well as self-generated electricity. Off-grid data are typically collected through household surveys but such surveys fail to capture unauthorised connections.*

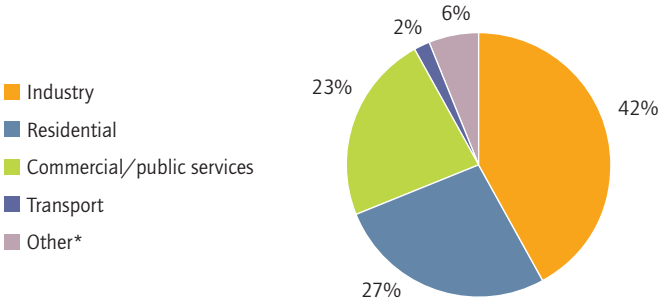
For IEA member countries, the rural electrification rate approaches 100%. The situation is very different for other countries and regions. Rates for North Africa (92%) and China/East Asia (84%) approach those of the IEA member countries; those for Latin America (66%), the Middle East (62%) and South Asia (45%) are much lower. Sub-Saharan Africa lags far behind with a rural electrification rate of only 8%.

Despite massive electrification programmes in many regions and countries, there are still large differences in regional electricity consumption per capita.

Final consumption of electricity: world

1974 5 261 TWh

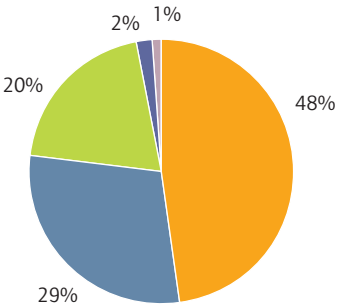


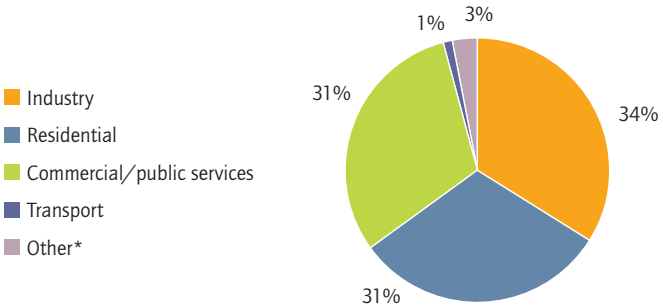


16 446 TWh **2007**

Final consumption of electricity: IEA member countries

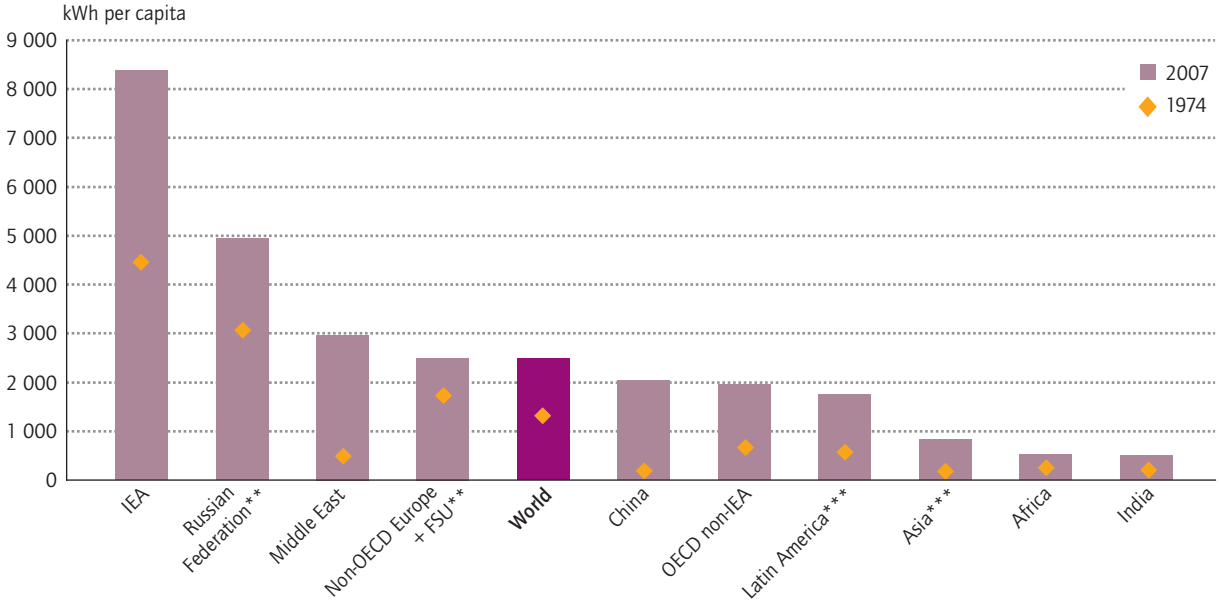
1974 3 792 TWh





9 036 TWh **2007**

Final consumption of electricity per capita by region



** Other includes agriculture/forestry, fishing and other use not specified elsewhere.*
*** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2007, Non-OECD Europe + FSU excludes the Russian Federation.*
**** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

CO_2 emissions from fuel combustion

▶ Carbon dioxide (CO_2) emissions reflect the carbon content of the fuels consumed. Some energy sources, such as coal, oil and gas, emit CO_2; others, including nuclear, hydro, geothermal and solar, produce no CO_2 emissions. Because supply influences emissions in this way, there is no "one-to-one correspondence" between regional shares in global TPES and global CO_2 emissions. Regions that use "cleaner" fuels – even if they use much greater quantities – may have lower emissions than regions that rely on smaller quantities of carbon-based fuels. (It should be noted that CO_2 emissions from biomass combustion are not accounted for in the emissions from fuel combustion).

▶ Global CO_2 emissions from fuel combustion increased by 85% since 1974, a rate that is 11% lower than the increase in world TPES (96%). This gap between emissions and supply results from efforts to: reduce the overall share of fossil fuel in the energy mix through the development of nuclear; and to "decarbonise" the fossil fuel mix by partially substituting natural gas for oil.

▶ IEA member countries are still the main emitters of CO_2, despite a major decrease (from 64% to 43%) of their share in global emissions. China's share jumped from 6% to 21%, making it the second-largest emitter followed by the Russian Federation, Asia, the Middle East and India (each accounting for about 5% of global emissions).

▶ On **a per capita basis**, IEA member countries and the Russian Federation have the highest emissions – more than 11 t CO_2 per capita. India and Africa have the lowest emissions per capita, largely due to low TPES per capita and the large share of renewables in their respective energy mixes. The Middle East has experienced the highest growth in emissions, from 2.3 to 7.2 t CO_2 per capita.

▶ It is noteworthy that IEA member countries have the highest emissions per capita but the lowest **emissions per GDP** measured as CO_2 per USD, using MER. IEA emissions per GDP were almost halved over the last 35 years due to the uncoupling of economic growth and energy consumption.

▶ With 3.9 t CO_2 per 2000 USD, the Russian Federation had the highest emissions per GDP, followed by non-OECD European countries, China and India. In the case of China, CO_2 emissions per GDP decreased dramatically (from 5.8 to 2.3 t CO_2 per 2000 USD) due to a strong increase in the economy. The decrease is even more spectacular in terms of GDP PPP; the emissions decreased by a factor of almost three from 1.7 to 0.6 t CO_2 per 2000 USD.

▶ *Source*

- *CO_2 Emissions from Fuel Combustion*, 2009, IEA.

▶ *For further information*

- Intergovernmental Panel on Climate change National Greenhouse Gas Inventories Programme, *www.ipcc-nggip.iges.or.jp/*.
- *World Energy Outlook*, 2009, IEA.

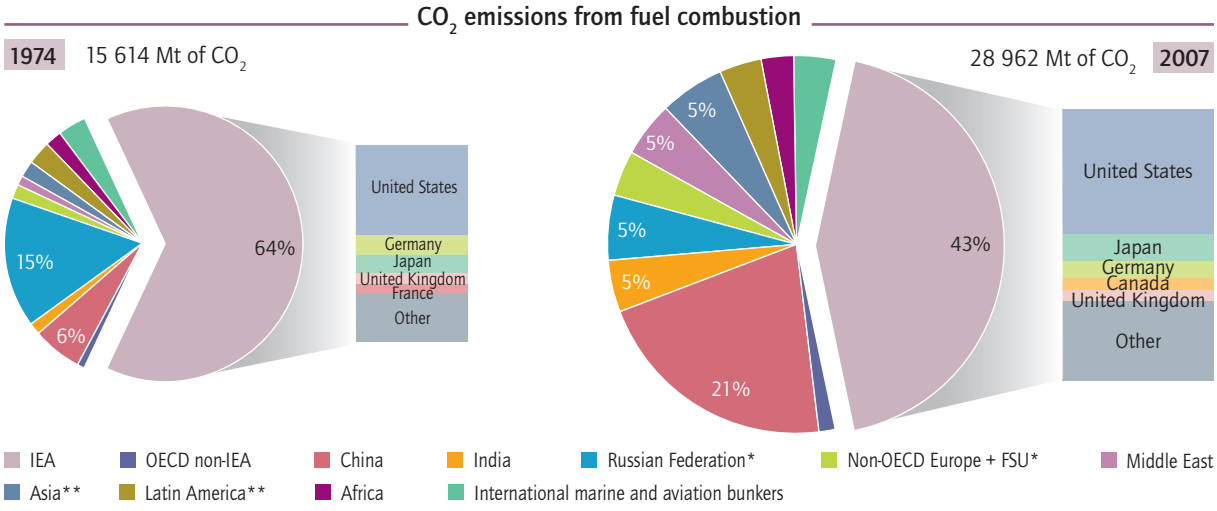
Accounting for emissions from biomass

The IEA Secretariat estimates CO_2 emissions from fuel combustion based on methodologies developed by the Intergovernmental Panel on Climate Change (IPCC). These methodologies estimate and report CO_2 emissions from the combustion of biomass for energy in the context of land-use change rather than with energy consumption. The assumption is that, under balanced conditions, all carbon released during combustion will be reabsorbed by biomass re-growth. If conditions are not balanced, the 2006 IPCC Guidelines *recommend that the resulting net emissions be accounted for in Agriculture, Forestry and Other Land Use (AFOLU).*

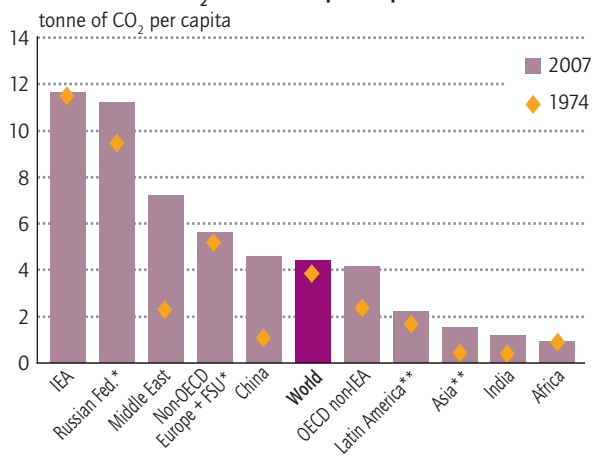
The situation is different for methane and N_2O; these emissions should be accounted for under fuel combustion.

The share of IEA member countries in global CO_2 emissions from fuel combustion dropped from 64% to 44% since 1974. These countries have the highest emissions per capita, but the lowest per GDP.

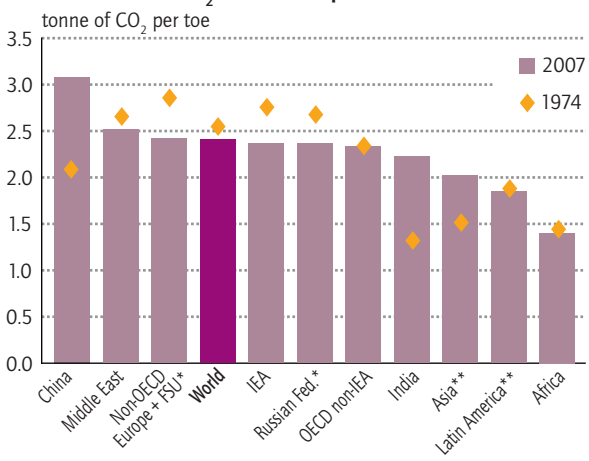
CO_2 emissions from fuel combustion



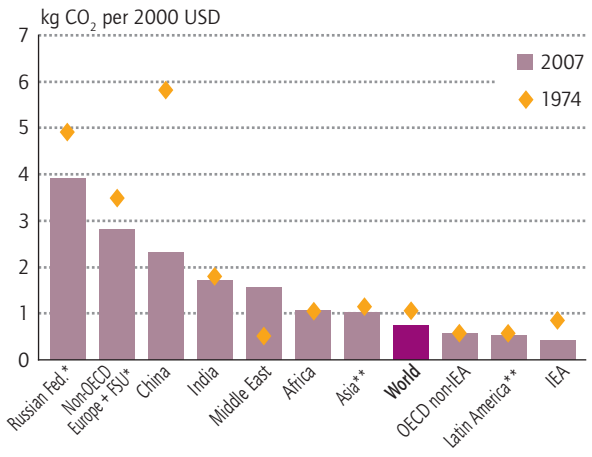
CO_2 emissions per capita



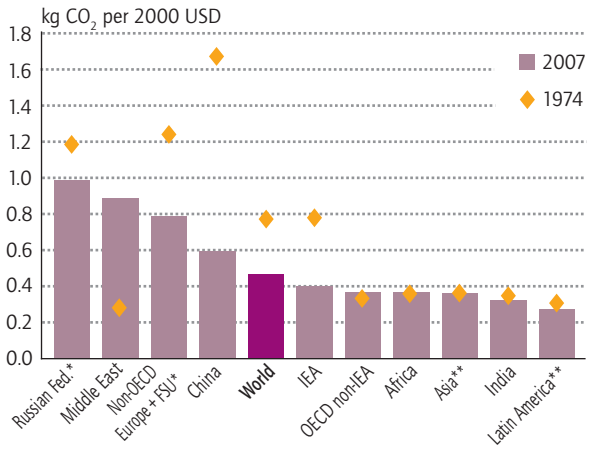
CO_2 emissions per TPES



CO_2 emissions per GDP



CO_2 emissions per GDP PPP



** For 1974, the Russian Federation includes the rest of Former Soviet Union (FSU). For 2007, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

A Diversity within the energy sector

Diversity within the energy sector

A

Diversification in energy production

▶ World energy production increased by 96% from 1974 to 2008. By contrast, overall energy production in IEA member countries increased by only 52%. As a result, the IEA share of global energy production decreased from 38% to 29%.

▶ The United States dominates energy production within IEA member countries, accounting for almost half of all energy produced in the IEA. Despite this high share of production, large demand also makes the United States the largest IEA net importer of energy, especially of oil.

▶ Canada is the second-largest producer of energy in the IEA. After meeting domestic demand, it exports a relatively large portion of this production, mainly to the United States. Oil and natural gas account for three-quarters of its total production (much of which is exported). Both Canada and the United States have quite diversified energy production profiles.

▶ IEA energy resources and production are concentrated in a relatively small number of countries. In fact, three countries combined (the United States, Canada and Australia) produce two-thirds of all energy produced by IEA member countries. By contrast, due to lower domestic resources, the 20 smallest producing countries combined produce only 13% of total IEA energy.

▶ Countries with limited domestic fossil fuel reserves produce a large share of their energy from nuclear and renewables. For example, Korea, France, Belgium and Japan all produce over three-quarters of their energy from nuclear.

▶ In 2008, the IEA produced about 3 600 Mtoe of energy broken down by fuel as follows: coal (28%); natural gas (26%); oil (20%); nuclear (16%); hydro (3%); and biomass, wastes and other renewables (7%).

▶ Most IEA member countries have seen dramatic increases in domestic energy production since 1974, reflecting concerted efforts in exploration, drilling, and mining, and the installation of nuclear and renewable power generation plants. To a large degree, these activities were undertaken to meet growing domestic demand, but they also reduced the need for energy imports, thereby improving the security of energy supply. Despite this increased production, IEA self-sufficiency is not as high as it once was. After peaking in the mid-1980s at more than 76%, self-sufficiency has declined to a current level of 69%, largely because of higher demand and lower production of certain fuels.

▶ Some IEA member countries have seen spectacular increases in energy production. Denmark, which produced almost no energy in 1974, has recorded an almost 60-fold increase. Production has risen by more than 300% in a few countries, especially Australia and Norway. In absolute terms, production has surged in Australia (mostly with coal) and Norway (with oil and natural gas); they now rank third and fourth amongst IEA producers, behind the United States and Canada (which has increased production by 111%).

▶ *Source*

- *Energy Balances of OECD Countries*, 2009, IEA.

▶ *For further information*

- *World Energy Outlook*, 2009, IEA.

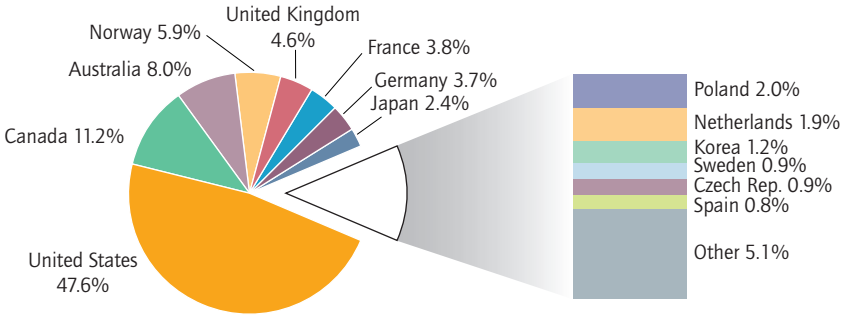
Defossilisation of IEA energy production

Total IEA energy production grew from 2 450 Mtoe in 1974 to 3 610 Mtoe in 2008. Over the same period, there was a significant shift in the shares of energy sources. In 1974, almost 90% of total IEA energy production came from fossil fuels: 33% for coal, 28% for oil and 28% for natural gas. The share of fossil fuels in 2008 was 74% (28% for coal, 20% for oil and 26% for gas) – an overall drop of 15 percentage points.

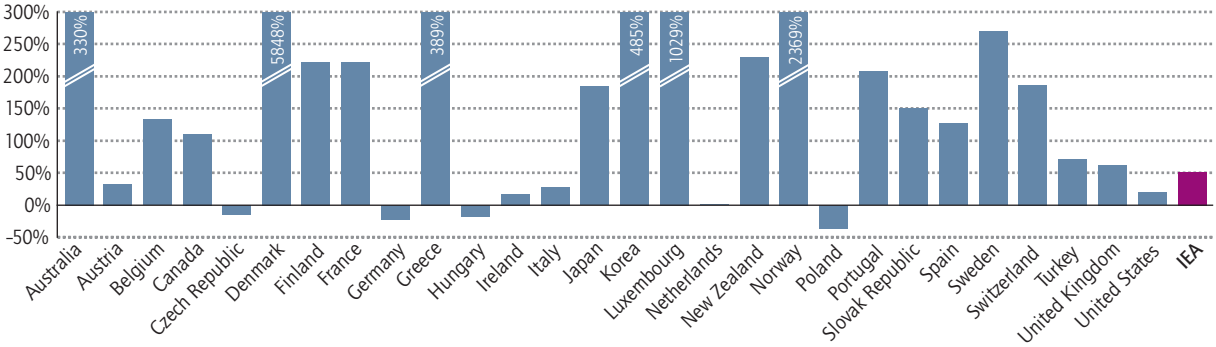
This defossilisation of the energy mix is due primarily to large developments of nuclear and renewables programmes in many IEA member countries. In fact, nuclear and renewables accounted for almost 60% of the growth in total production over the past 35 years. Nuclear is by far the main contributor in the growth: it accounted for 43% of the growth and saw its share in total IEA energy production increase dramatically (from 2% in 1974 to 16% in 2008). Renewables accounted for 15% of the growth and saw their share rise more modestly (from 8% to 10%).

Energy production of IEA member countries has grown by 52% since 1974; nuclear played the largest role in diversifying production.

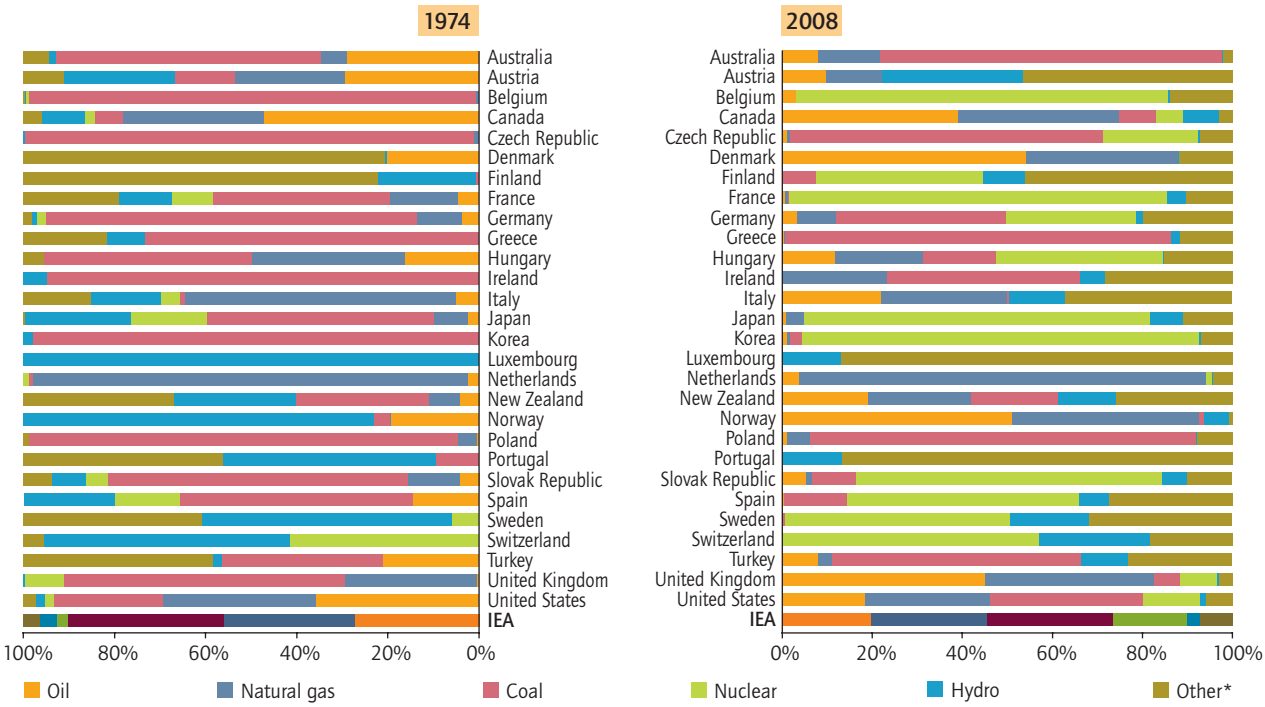
Energy production by country in 2008



Percentage change in energy production between 1974 and 2008



Energy production by fuel and by country



** Other includes geothermal, solar, wind, tide/wave/ocean energy, combustible renewables and waste, etc.*

Diversification in total primary energy supply

▶ To support economic development and population growth, all the IEA member countries (with one exception) have increased their energy supply. The average growth of energy supply for the IEA as a whole was about 45%, compared with GDP growth of 144%. This shows a decoupling of energy demand and economic growth, which can be attributed to a larger share of services in the economy and savings resulting from energy efficiency measures.

▶ Since 1974, the United States has remained, by far, the largest energy consumer amongst IEA member countries. Several factors explain the country's elevated supply and demand: the size of the population (28% of total IEA population); the physical size of the country (second behind Canada); and the fact that the US economy represents more than one-third of total IEA GDP. In absolute terms, the United States has the highest TPES within the IEA. However, when considering TPES per capita it falls to third place (behind Luxembourg and Canada); in terms of TPES per GDP, it ranks in 13th position.

▶ Japan and Germany (the second- and third-largest IEA member countries in terms of population and economy) follow the United States in size of energy supply. Luxembourg (the smallest country in terms of both population and GDP) accounts for the lowest demand.

▶ In reality, the overall IEA 45% average growth masks large differences in the respective growth rates of energy supply in IEA member countries. Korea's energy demand multiplied by almost ten (starting from a much lower level than most other IEA member countries). Several Mediterranean countries (including Turkey, Portugal, Greece and Spain) that also started from a low supply have experienced two- to four-fold increases in their supplies.

▶ Luxembourg is the only IEA member country that experienced a decrease in supply. This reflects a shift to more services and less industry, as well as a switch from coal and oil to natural gas for electricity production. Poland, the Czech Republic and the Slovak Republic have seen very little increase in their supply due to economic restructuring. The very small increase in Germany can be explained, at least in part, by the reunification of the country.

▶ Analysis of the overall IEA supply mix shows that the share of coal stayed more or less stable at about 22%. Natural gas increased from 19% to 24%, but nuclear experienced by far the strongest growth in relative terms. In 1974, nuclear accounted for less than 2% of IEA TPES. Major nuclear development programmes (primarily in the 1970s and 1980s) in several IEA member countries pushed the share of nuclear to 11% of IEA TPES in 2008. In recent years, development of wind and solar energy has contributed to a slight increase in the share of renewables.

▶ Almost all countries show a slight "defossilisation" of the energy mix with the combined share of oil, coal and natural gas dropping from 93% to 82% for the IEA as a whole. However, major differences between countries are apparent. In 2008, Sweden had only 34% of its supply coming from fossil fuels; by contrast, Australia, Greece, Ireland and Luxembourg derived 5% or less of their supply from non-fossil fuels.

▶ *Source*

- *Energy Balances of OECD Countries*, 2009, IEA.

▶ *For further information*

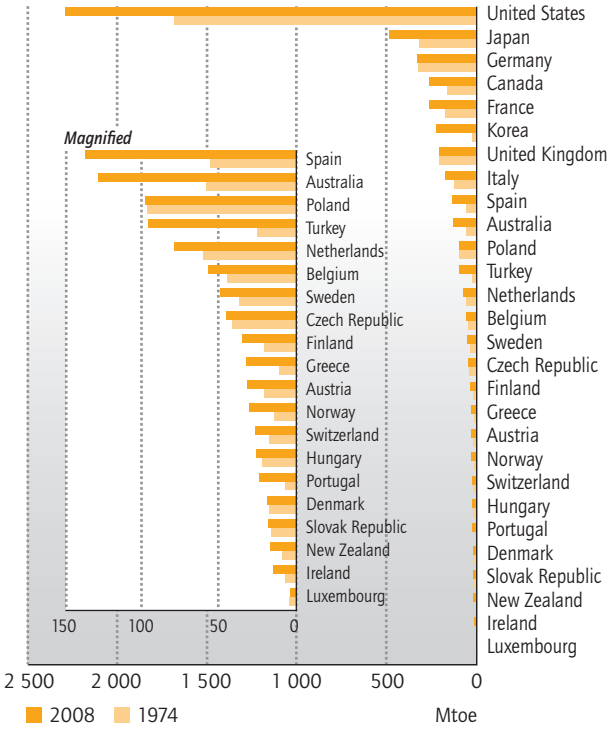
- *World Energy Outlook*, 2009, IEA.

The importance of diversification in the Shared Goals

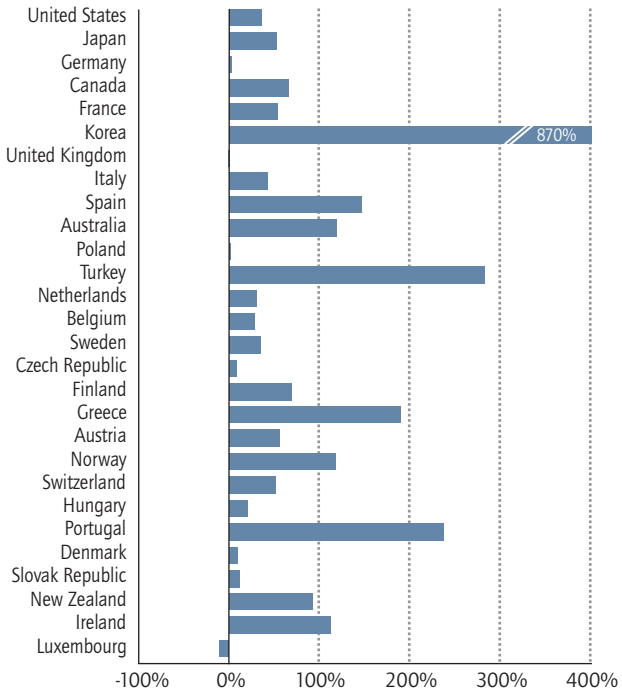
*According to the IEA Shared Goals (see Annex 1), member countries should take steps to ensure that the fuels used within and across sectors, as well as the sources of these fuels, are as diverse as practicable. Thus, diversification of energy supply should be a key goal in the policy framework of all IEA member countries and this overriding aim should be considered in terms of: energy production and total primary energy supply; the origins of the imports and the destinations of the exports; and the energy mix in each consumption sector (*e.g. *electricity generation, industry or residential).*

TPES in the IEA grew by "only" 45% since 1974, compared to GDP growth of 146%. A drop (11 percentage points) in the combined share of coal, oil and natural gas reflects a slight "defossilisation" of the energy mix.

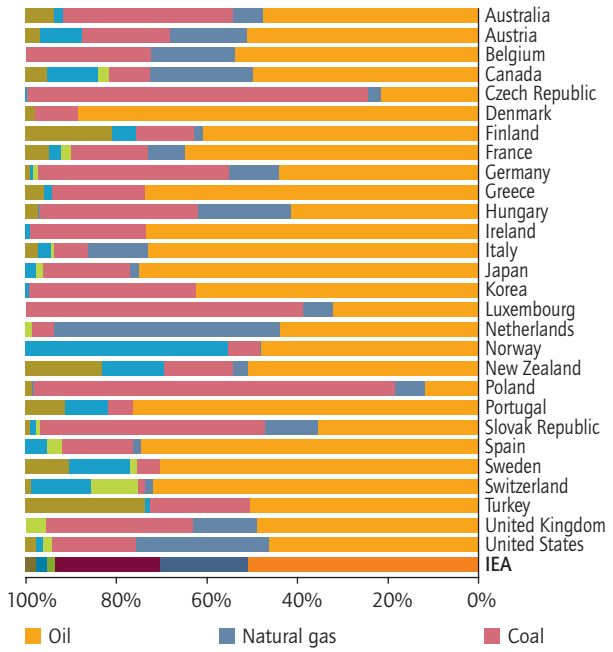
Total primary energy supply



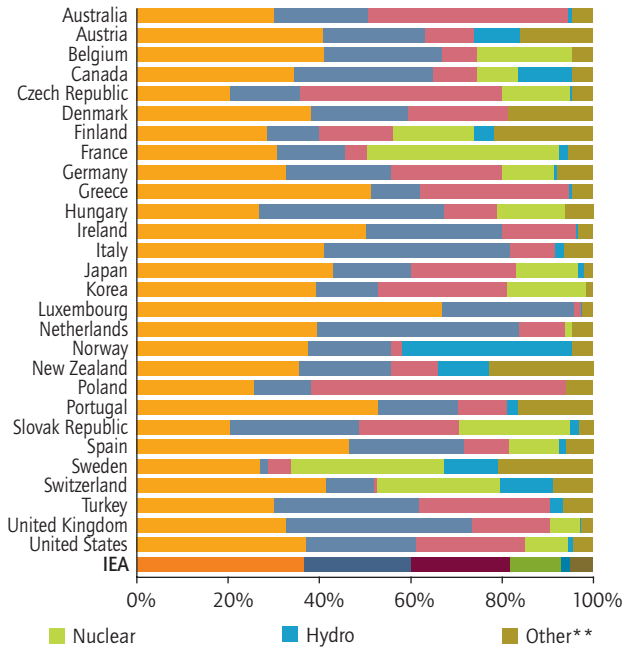
Percentage change of TPES between 1974 and 2008



TPES* by fuel in 1974



TPES* by fuel in 2008



** Excludes electricity and heat trade.*

*** Other includes geothermal, solar, wind, tide/wave/ocean energy, combustible renewables and waste, etc.*

Diversification in oil supply and consumption

▶ Over the past 35 years, oil has remained a key energy source in all IEA member countries. Although its share has gradually fallen in all IEA member countries bar two, on average it still accounts for almost 37% of TPES. The decreased share of oil is linked to improved efficiency and sectoral interfuel substitution in favour of other energy sources.

▶ Luxembourg and Poland are the exceptions to the trend of decreasing oil shares, each due to unique features of their economies. Domestic consumption of gasoline and diesel of Luxembourg is artificially high due to "fuel tourism". Relatively lower end-user taxes in the country result in lower fuel prices; this prompts motorists from neighbouring countries (Belgium, France and Germany) to cross the border to fill their tanks. Increased oil shares in Poland reflect the fact that the country is catching up quickly in terms of oil use per capita – the country's vehicle fleet, in particular, has expanded significantly.

▶ Perhaps the most striking change in oil consumption since 1974 is the sectoral shift to transportation usage (including passenger travel and freight by both road and air). In the early 1970s, the transportation sector accounted for slightly over one-third of total IEA oil demand; today, it represents 57% on average – almost twice as much. This average, however, masks significant variations among IEA members. In some European countries, the share of transportation doubled or even tripled – and in Luxembourg, it quadrupled.

▶ By contrast, the use of oil for industry and power generation has diminished sharply due to greater efficiency, the delocalisation of heavy industries to IEA non-member countries, and the greater penetration of natural gas and other sources. In many industries, these developments have been driven by a growing environmental awareness, coupled with the internationalisation of supply chains.

▶ Oil consumption in the residential and the commercial and public services sectors has also declined; many households and buildings are moving away from heating oil and turning to natural gas or electricity.

▶ To date, no viable alternative to oil has been developed in the transport sector. Thus, despite government efforts to promote fuel efficiency initiatives, the relative size of this sector in overall oil demand is bound to continue expanding over the next decades.

▶ Source

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ For further information

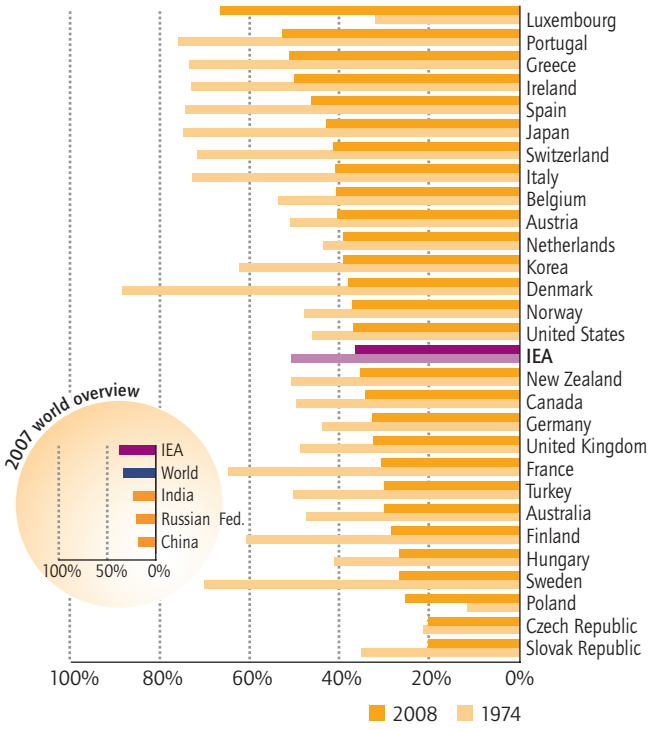
- *IEA Monthly Oil Data Service*, *www.iea.org/Textbase/stats/mods.asp.*
- *Medium-Term Oil Market Report*, *www.oilmarketreport.org.*
- *Oil Information*, 2009, IEA.
- *Oil Market Report*, *www.oilmarketreport.org.*

Refineries

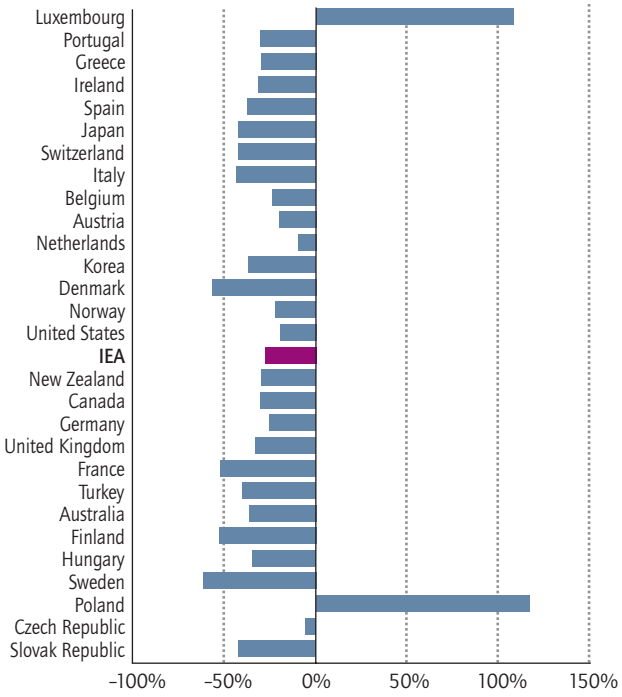
Refineries are an important element of the oil production-consumption chain. IEA member countries have always been major players in the world refining sector; in 1974, IEA refinery output accounted for two-thirds of the world refinery output. The IEA share has since decreased due to expansion of the refining sector at both ends; that is, closer to oil production (as in the Middle East) or to oil consumption (as in China and India). In 2008, IEA member countries represented about half of the global refinery output, which more or less covers IEA demand for petroleum products.

Efforts to diversify energy supply have reduced the share of oil in the energy mix of almost all IEA member countries. Almost 60% of oil is now consumed in transport.

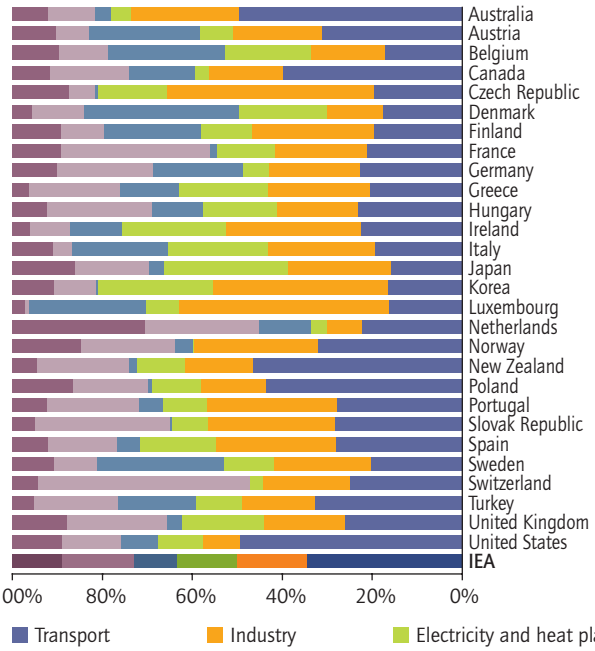
Share of oil in TPES*



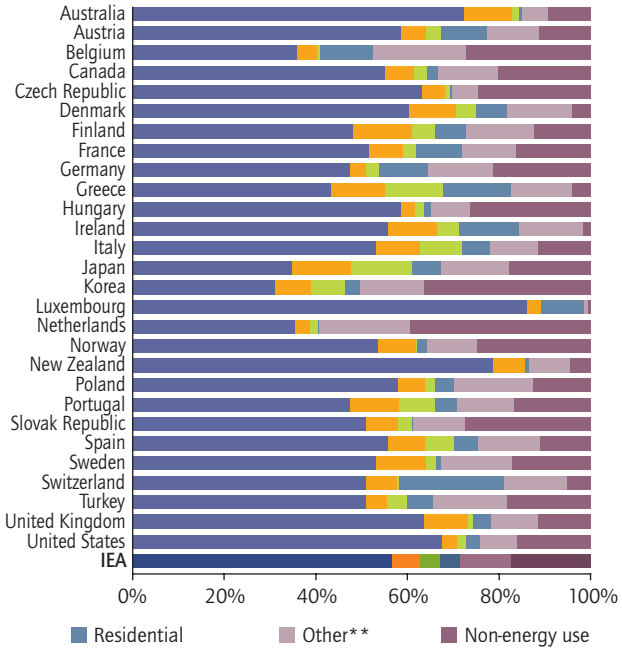
Percentage change of share of oil in TPES* between 1974 and 2008



Oil consumption by sector in 1974



Oil consumption by sector in 2007



Transport | Industry | Electricity and heat plants | Residential | Other** | Non-energy use

** TPES excludes electricity trade.*

*** Other includes commercial/public services, agriculture/forestry, fishing and other use not specified elsewhere.*

Diversification in coal supply and consumption

▶ Some IEA member countries are significant coal producers. The United States ranks second in the world. Australia is also a significant producer and the world's largest exporter. Germany is the world's largest producer of brown coal; Turkey, Greece, Poland and the Czech Republic are also major players in this market. Access to indigenous coal is reflected in the share of coal in the TPES of these countries. Poland relied on coal for 56% of its TPES in 2008, more than any other IEA member country.

▶ Many other IEA member countries rely on imported coal. Japan, Denmark, Ireland and Austria are entirely reliant on imports. Japan is the world's largest coal importer; Korea is the second-largest; and a number of IEA member countries in Europe are also significant importers.

▶ On average, the share of coal in the TPES of IEA member countries has declined slightly, from 23% in 1974 to 22% in 2008. But, in fact, this decline masks an absolute one-third increase in coal use by IEA member countries.

▶ Sixteen IEA member countries (mainly those having higher shares in 1974, *e.g.* Poland) have seen the share of coal in TPES decreasing, while coal shares are increasing in 12 others (mainly those having lower shares in 1974, *e.g.* Denmark).

▶ The way coal is used in IEA member countries has changed significantly since 1974. Industrial use of coal has dropped by more than one-third, its share in total coal consumption falling from 20% to 10% in 2007. Other uses of coal, mainly in the commercial and public services sector, have declined by one-half, with their share falling to 7%.

▶ Coal was once an important transport fuel for railways and shipping. By 1974, it had been replaced by oil and electricity, and its use had dwindled to the last remaining steam locomotives in just a few countries. Residential use of coal has declined markedly – by 81% – across IEA member countries with its share falling from 8% to 1%. For the most part, residential use of coal is now a life-style choice, not a necessity. The non-energy uses of coal are insignificant.

▶ Always important, the generation of electricity has become the dominant use of coal in IEA member countries, rising from 53% in 1974 to 82% in 2007. Some IEA member countries rely heavily on coal for power generation: in 2008, 92% of electricity in Poland was generated from coal, 76% in Australia, 60% in the Czech Republic, 57% in Greece and 51% in Denmark. In the United States, 49% of electricity was generated by coal, which represented 93% of coal use within the country.

▶ Denmark, Portugal and the Netherlands are now much more reliant on coal in their TPES than in 1974 because of strong growth in coal-fired power generation, mainly from very efficient plants. Coal demand in Luxembourg has collapsed across all sectors, but most notably for iron and steel production.

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *Cleaner Coal in China, 2009, IEA.*
- *Coal Information, 2009, IEA.*
- *International Coal Market and Policy Developments*, IEA Coal Industry Advisory Board, *www.iea.org/ciab/ciabmark_2008.pdf.*

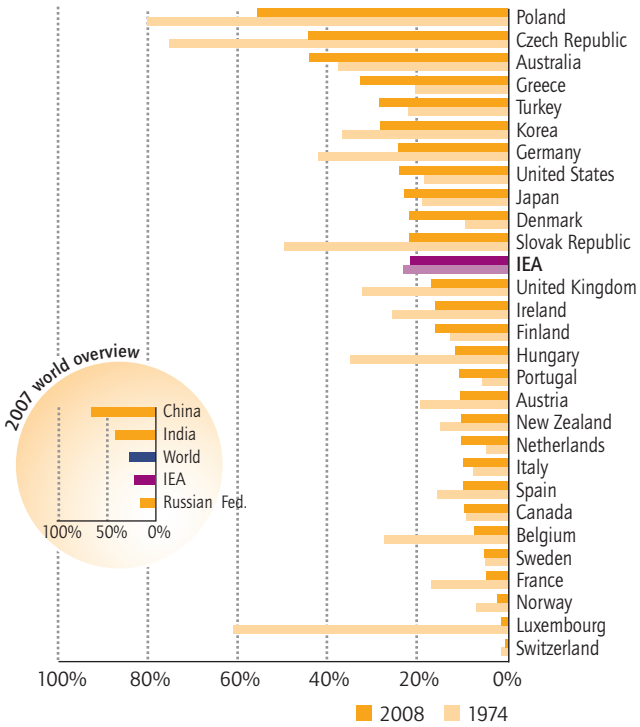
Principles for IEA action on coal

An IEA policy on coal, known as the Principles for IEA Action on Coal, was adopted in May 1979 with the aim of expanding the use, production and trade of coal as an alternative to crude oil. At that time, the IEA Governing Board created the Coal Industry Advisory Board to provide independent advice and suggestions to assist in the practical implementation of the Principles. To the extent that there is now an efficient global market in coal, this policy has been successful.

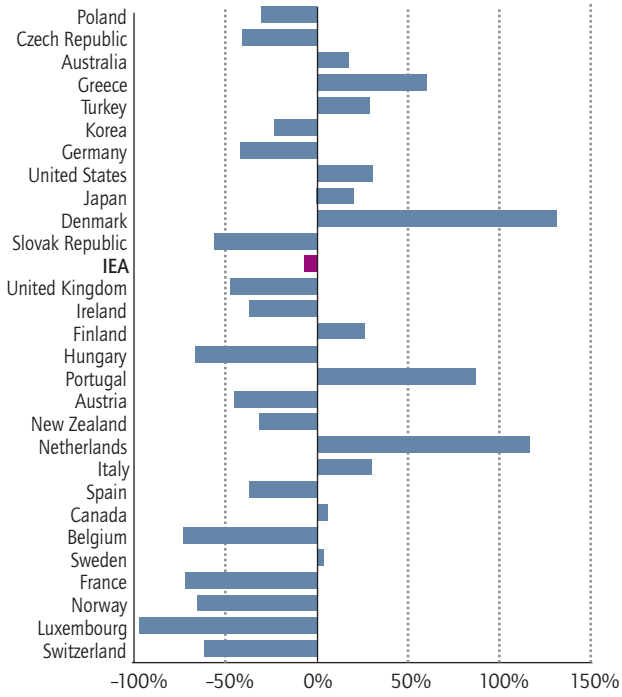
However, while coal continues to offer a secure and low-cost source of energy in IEA member countries, the policy focus has shifted to measures that mitigate the environmental impacts of its use.

The share of coal in TPES has decreased in 16 IEA member countries and increased in 12. More than 80% of coal consumption goes to electricity production; only 1% is used in residential.

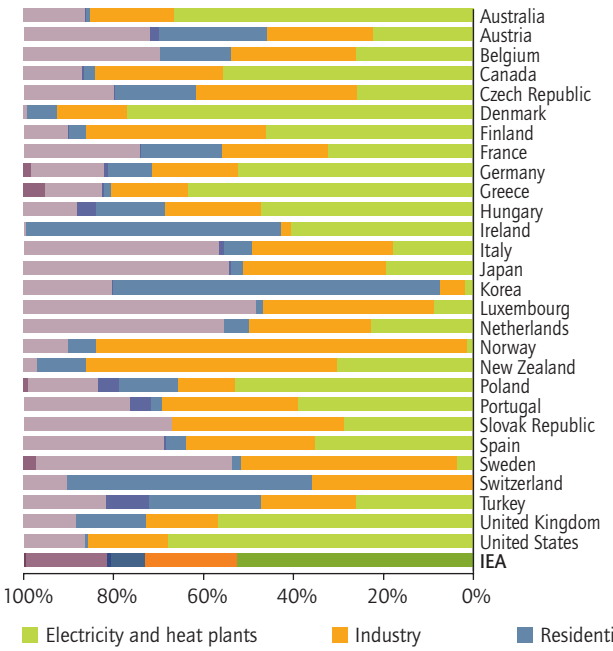
Share of coal in TPES*



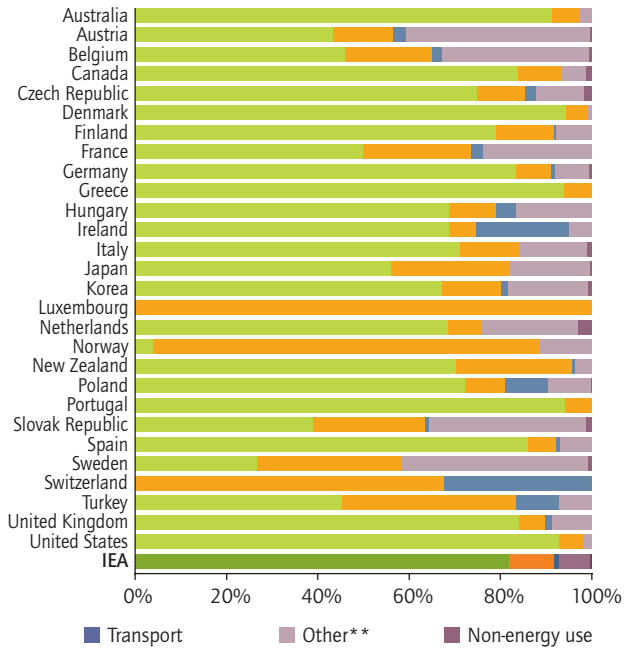
Percentage change of share of coal in TPES* between 1974 and 2008



Coal consumption by sector in 1974



Coal consumption by sector in 2007



Electricity and heat plants | Industry | Residential | Transport | Other** | Non-energy use

** TPES excludes electricity trade.*

*** Other includes commercial/public services, agriculture/forestry, fishing and other use not specified elsewhere.*

Diversification in gas supply and consumption

▶ Historically, natural gas was considered to be a clean, cheap and safe alternative to oil and, thus, a means to reduce the high oil dependence of IEA member countries. In 1974, 12 current IEA member countries had no or very little gas consumption. By 2008, all IEA member countries had become gas consumers and the overall IEA gas supply had increased by 75%. The United States is currently by far the largest consumer, followed by Japan, the United Kingdom, Canada and Germany. Norway, one of the 12 with no or very little consumption in 1974, is now a major gas exporter.

▶ The share of gas in TPES has increased in all IEA member countries but two, the Netherlands and the United States. In 1974, these two countries already had significant shares of almost 50% and 30%, respectively, far more than any other IEA member country. The subsequent reduction in share of gas in the US TPES (from 29% to 24%), coupled with the weight of the country in the total IEA gas energy supply (44% in 2008), dramatically reduced the observed growth in the overall IEA gas share. The share of gas in IEA TPES increased by only 4 percentage points, from 19% to 23%.

▶ This modest overall growth tends to mask considerable increases in the share of gas in TPES in almost all the other IEA member countries. In many member countries, the gas share multiplied by two, three or even more. For example, in Japan, the second-largest IEA gas consumer, the share of gas surged from 2% to 17%. In general, increases have been much higher for countries that had no or very little consumption in 1974.

▶ Three sectors dominate the consumption of natural gas in IEA member countries: the production of electricity and heat, residential consumption and industry use. Steep growth in gas consumption for electricity and heat led to an associated increase in the sector's share (from 18% to 34%), while the share for industry shrank (from 35% to 20%) and that of the residential sector remained stable (just over 20%). It is interesting to note that the combined share of these three sectors still accounts for three-quarters of the gas supply of the IEA member countries.

▶ Norway's situation is particularly interesting. Although it is the largest gas exporter among IEA member countries, Norway consumes very little gas (7% of its production). Virtually none of the gas is consumed for electricity production (98% generated from hydro) or in the residential sector (heating derives mainly from hydroelectricity and wood). Most of the country's gas consumption is used for oil and gas extraction.

▶ Source

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ For further information

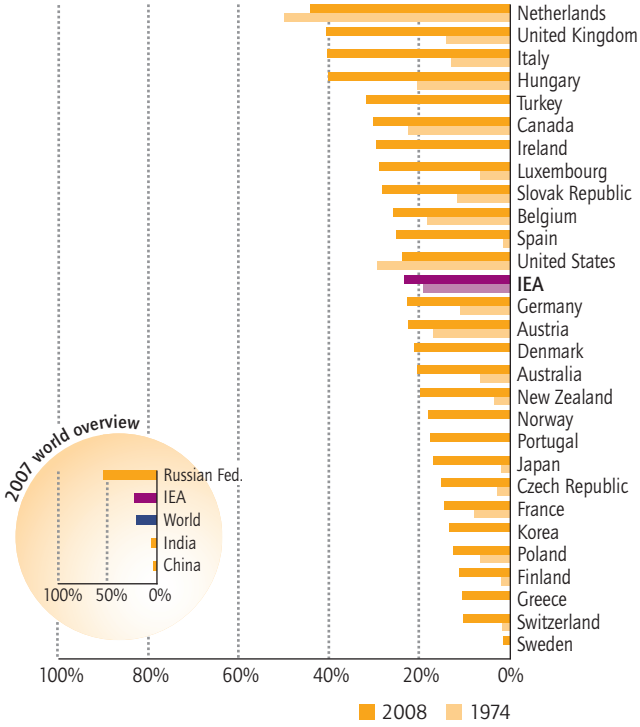
- *Development of Competitive Gas Trading in Continental Europe, www.iea.org/Textbase/Papers/2008/gas_trading.pdf.*
- *Natural Gas Information*, 2009, IEA.
- *IEA Monthly Gas Data Service, www.iea.org/Textbase/stats/mods.asp.*
- *Natural Gas Market Review 2008: Optimising Investments and Ensuring Security in a High-priced Environment*, 2008, IEA.

The development of natural gas in the electricity and heat sector

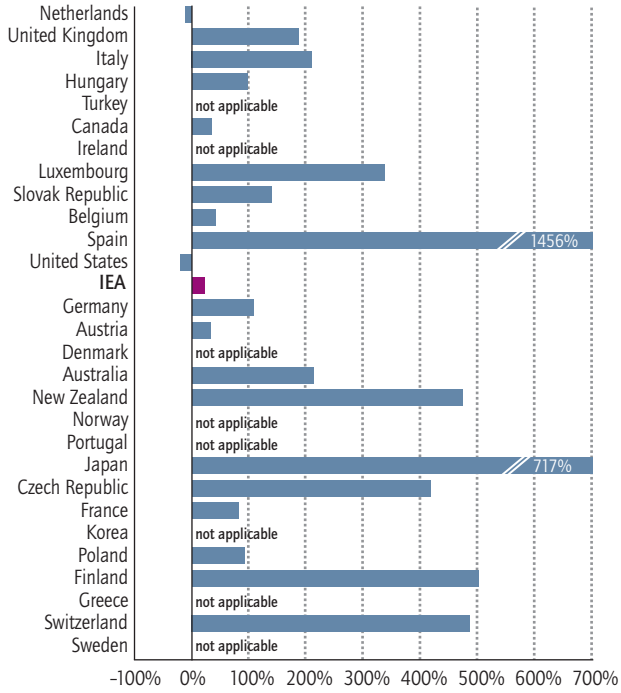
Natural gas is increasingly used for power and heat generation, with gas-fired power dominating supply growth in IEA member countries over the last decade. At present, high-efficiency combined cycle gas turbines are attractive competitors to coal-fired power plants, particularly as they are less capital intensive and require less time to bring on stream. Gas-fired power plants also emit less CO_2, an important feature from an environmental perspective. Several IEA member countries, particularly in Europe, need to take decisions in relation to the future of ageing coal and nuclear power plants. Their choices in replacing such infrastructure may have significant impacts on the demand for gas-fired heat and power, and on the overall gas supply.

The share of natural gas in TPES has risen in almost all IEA member countries; the exceptions are two countries in which natural gas already had a share of 30% or more in 1974.

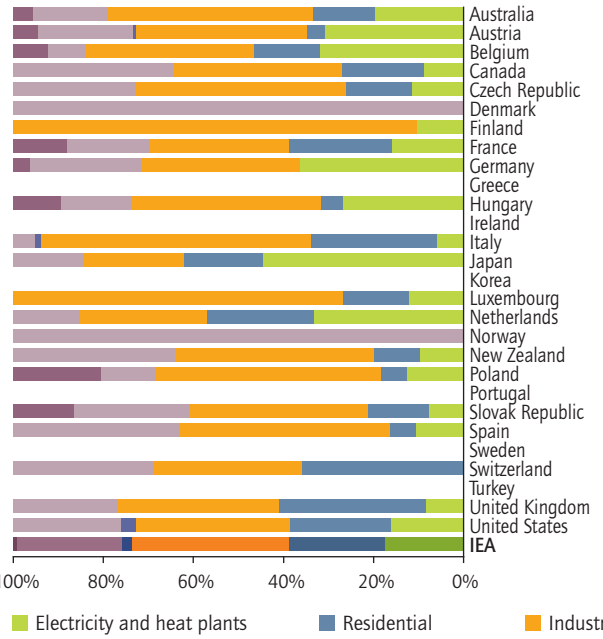
Share of natural gas in TPES*



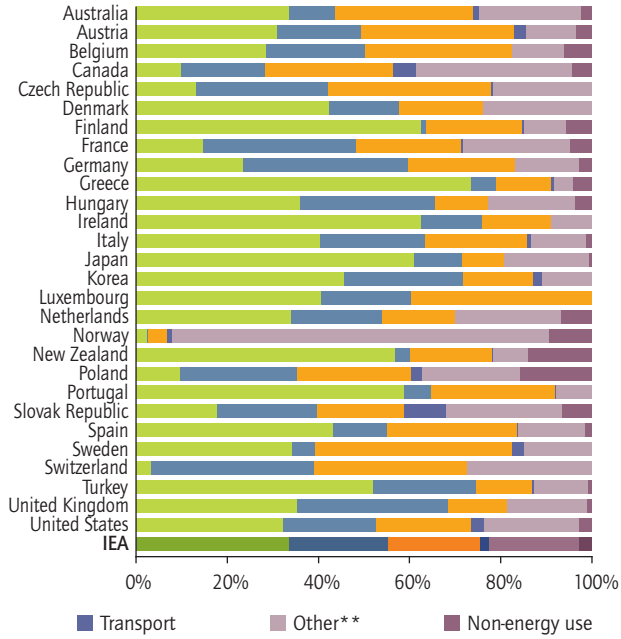
Percentage change of share of natural gas in TPES* between 1974 and 2008



Natural gas consumption by sector in 1974



Natural gas consumption by sector in 2007



Electricity and heat plants | Residential | Industry | Transport | Other** | Non-energy use

** TPES excludes electricity trade.*

*** Other includes commercial/public services, agriculture/forestry, fishing and other use not specified elsewhere.*

Diversification in industry consumption

▶ Historically, the bulk of energy consumption in IEA member countries has been in four main sectors: industry, transport, residential, and commercial and public services. Over the past 35 years, industry is the only sector that experienced a drop – of almost 9% – in its energy consumption. With 840 Mtoe (excluding non-energy use), industry has fallen to second place – far behind transport with 1 190 Mtoe.

▶ Several factors explain this decline, the main one being the delocalisation of energy-intensive sectors such as iron and steel. It should be noted, however, that other sectors such as chemical, petrochemical, and pulp and paper experienced increases in their activities and, thus, in their energy consumption.

▶ The United States still represents more than one-third of the total IEA industry consumption, although its share decreased from 41% in 1974 to 35% in 2007. Japan, Germany, Canada and Korea follow as the next largest industry consumers.

▶ Oil consumption in industry decreased dramatically, in both absolute and relative terms. It accounted for 32% of industry consumption in 1974, but only 15% in 2007. The share of coal also dropped, from 19% to 13%. Electricity consumption rose from 17% to 31%, largely displacing both oil and coal to become the main source of energy in industry.

▶ The evolution of natural gas consumption by industry is quite unusual. The gas share in industry in IEA as a whole increased only marginally (from 27% to 29%). Yet the share of gas increased quite significantly in many individual IEA member countries. In fact, gas is now the main energy of the industry sector in 11 countries, but takes second place (behind electricity) in total IEA industry consumption. This situation is partially explained by the decrease of gas in the United States and the weight of the US share in the IEA total.

▶ Most IEA member countries increased the use of combustible renewables and waste in industry. Their combined share rose from 4% to 8%. Two examples include the extensive use of biomass (wood wastes and residues) in the pulp and paper industry and increased use of waste in other sectors (*e.g.* used tyres in the cement industry).

▶ IEA member countries accounted for 37% of global industry consumption in 2007, ahead of China (which alone represented 26%). As coal accounted for 56% of the energy mix of China's industry sector, the share of coal in world industry demand (26%) is double that for IEA member countries (13%). World industry demand is somewhat lower for gas (20%) and oil (14%).

▶ Source

- *Energy Balances of OECD Countries*, 2009, IEA.

▶ For further information

- *Energy Use in the New Millennium*, 2007, IEA.
- *Tracking Industrial Energy Efficiency and CO_2 Emissions*, 2007, IEA.

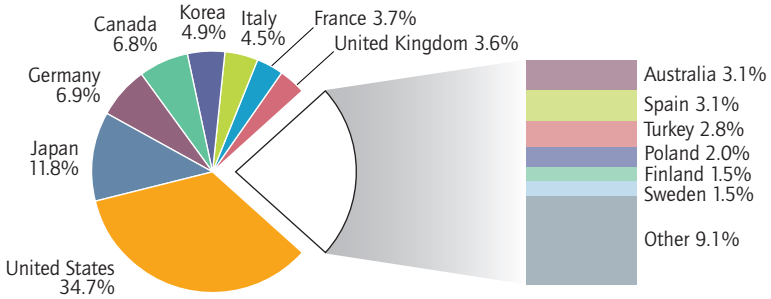
Delocalisation of energy-intensive industries

Delocalisation refers to the transfer of economic activities from one region to another to benefit from a competitive advantage such as lower wages, better access to markets and/or natural resources, lower carbon prices, or other factors.

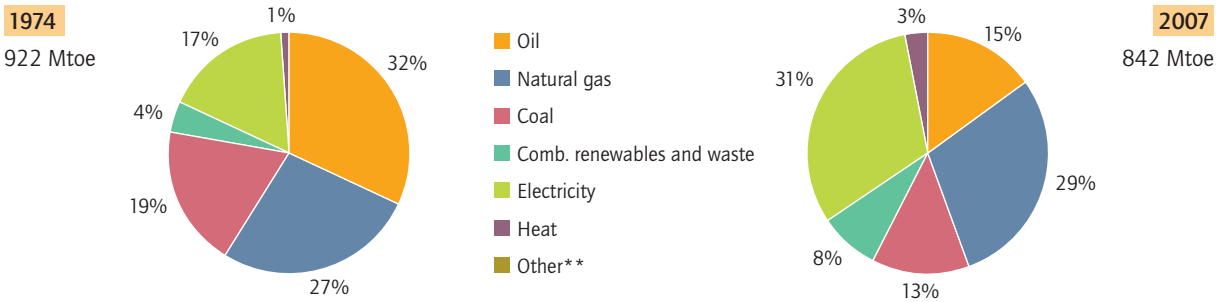
*Concerns over delocalisation of energy-intensive industries (*e.g. *iron and steel, and chemical) are increasingly part of the energy policy debate in IEA member countries. One of the concerns deals with competitiveness because of the introduction of policies related to CO_2 mitigation costs in some parts of the world but not in others. However, delocalisation policies are rarely based solely on mitigation costs: other factors include prices, political stability, availability of work force and synergy.*

Industry is the only sector that experienced an overall drop in energy consumption; electricity has replaced a large share of oil and coal to become the main fuel consumed in the sector.

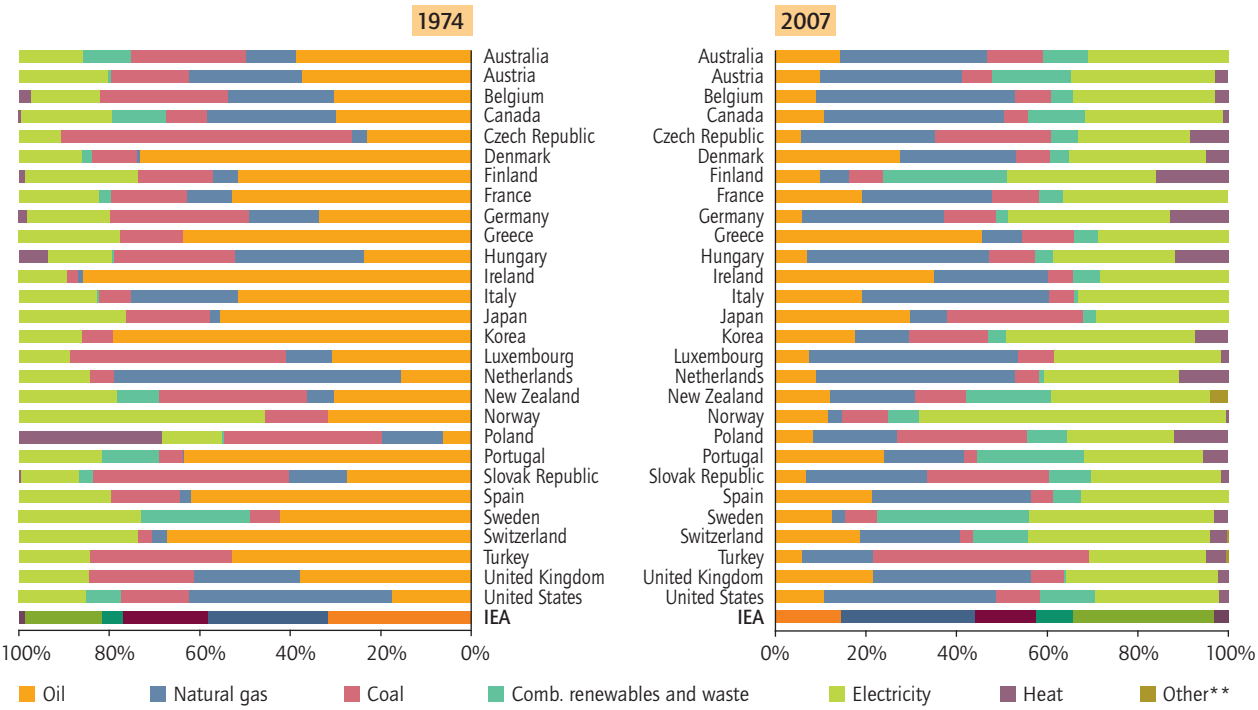
Industry consumption* by country in 2007



Industry consumption* by fuel



Industry consumption* by fuel and by country



** Industry consumption excludes non-energy use.*

*** Other includes direct use of geothermal and solar thermal heat (which represents less than 0.05% of IEA industry consumption in 2007).*

Diversification in transport consumption

▶ Transport has become the largest of the four main energy-consuming sectors, partly due to decreased demand in industry. Transport now accounts for 32% of total IEA final energy consumption (up from 25% in 1974). In absolute terms, transport consumption (excluding international marine and aviation bunkers) increased from 670 Mtoe in 1974 to 1 190 Mtoe in 2007.

▶ Several factors drive the demand for transport and, thus, consumption of the sector. The main drivers include population, number of cars per household, GDP per capita and the size of the country. Not surprisingly, the United States is by far the largest IEA consumer for transport, even though its share dropped from over 60% in 1974 to 54% in 2007. Japan, with the second-largest population, ranks as the second-largest transport consumer, followed by Canada, with its large physical size.

▶ Road transport (passengers and freight) represents 89% of the sector consumption (excluding bunkers) followed by domestic aviation. Rail represents only 2%. Consequently, transport is still heavily dominated by oil and is the only sector in which displacement of oil has not been achieved. In fact, the share of oil in transport is virtually unchanged: it accounted for 96% of consumption in 1974 and 95% in 2007.

▶ The petroleum products mix of the transport sector has seen more significant changes: in some IEA member countries, favourable taxation regimes and energy-saving initiatives have led to higher demand of gas/diesel oil compared to gasoline. As a result, the share of gasoline shrank from two-thirds in 1974 to one-half in 2007 while the share of gas/diesel oil almost doubled (from 19% to 35%). The share of jet fuel (for domestic aviation) was stable at 7% to 8%.

▶ Analysis of the transport energy mix by country reveals large variations. In fact, a fundamental shift is evident: the number of IEA member countries with a larger share of gas/diesel oil (such as Belgium, France, Luxembourg, Portugal, Spain and Turkey) now exceeds that of countries with a higher share of gasoline (such as Australia, Canada, Greece, Japan, Switzerland and the United States).

▶ In 2007, international marine and aviation bunkers accounted for slightly more than 14% of global transport consumption and 13% for IEA member countries. It should be noted, however, that they are not usually included in the final consumption of a given country as they are not considered as domestic consumption. Such bunkers are also unique in that they are often subject to different taxation regimes and their emissions are not allocated to the GHG inventories of the countries that delivered the fuel.

▶ As a result of rapid development of transport in many countries around the world, the IEA share in global transport consumption dropped substantially over the last 35 years, from 62% to 52%.

▶ *Source*

- *Energy Balances of OECD Countries*, 2009, IEA.

▶ *For further information*

- *Energy Use in the New Millennium*, 2007, IEA.

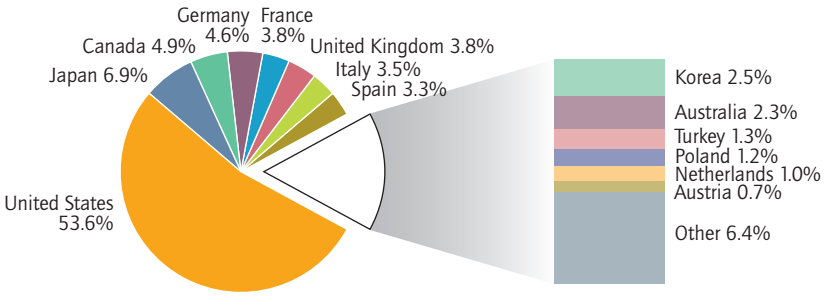
What is included under transport?

For the purposes of IEA energy balances, transport includes all transport activity regardless of the economic sector to which it contributes. Under this definition, transport includes the following: domestic aviation; domestic navigation; road; rail; pipeline transport (energy used in the support and operation of pipelines transporting gases, liquids, slurries and other commodities, including the energy used for pump stations and maintenance of the pipeline); and other non-specified transport.

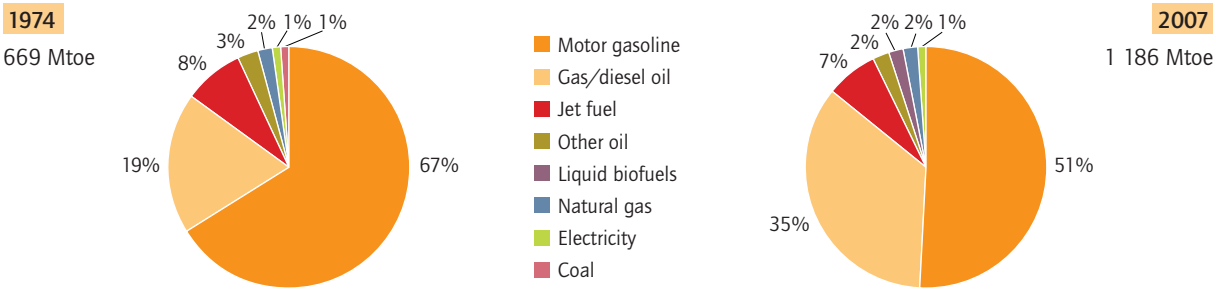
At the country level, international marine and aviation bunkers are not considered part of the transport sector. Energy consumed by such bunkers is subtracted from supply.

Transport has become the largest consuming sector. Due to high growth in gas/diesel oil demand, the share of gasoline in transport sector consumption has fallen from two-thirds in 1974 to about one-half.

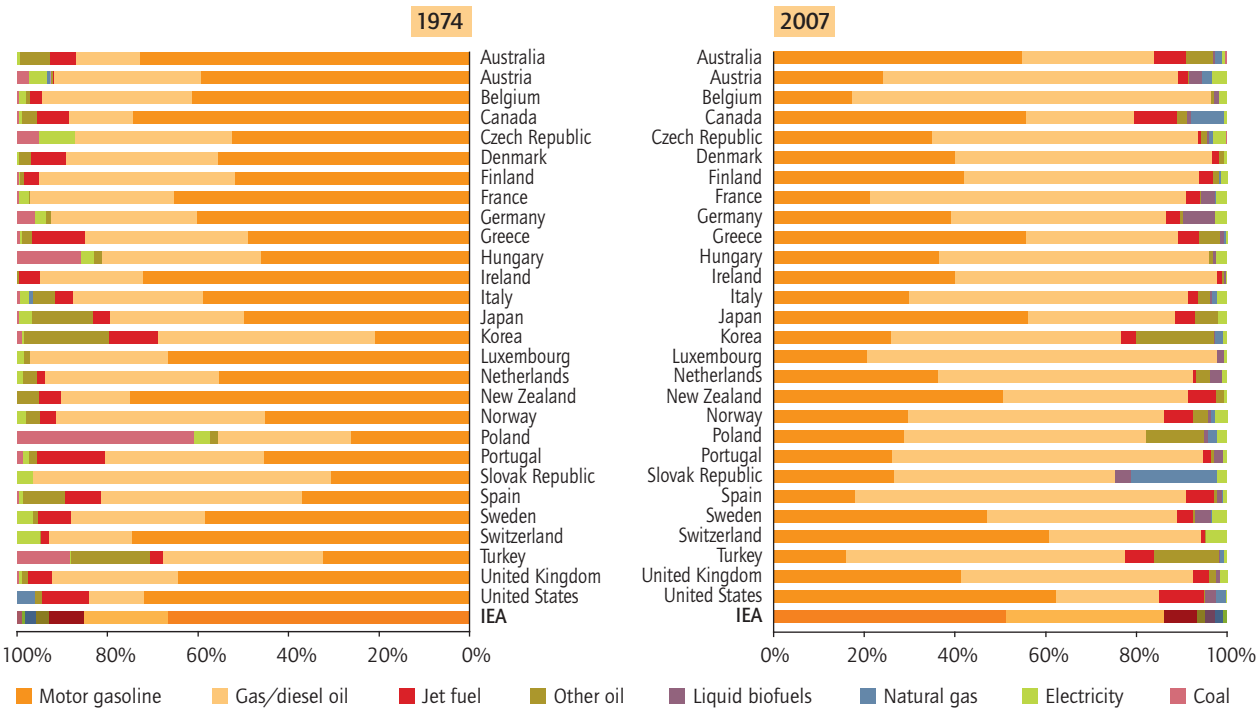
Transport consumption* by country in 2007



Transport consumption* by fuel



Transport consumption* by fuel and by country



** Transport consumption excludes international marine and aviation bunkers. This convention reduces the shares of jet fuel, gas/diesel oil and other oil.*

Diversification in residential consumption

▶ Energy consumption of the residential sector is usually a function of two main factors, the size of a country's population and number of its heating and cooling degree-days (due to the weight of heating and cooling in consumption). With 28% of the IEA population, the United States has the largest consumption, although its share has decreased slightly from 44% in 1974 to 40% in 2007. Other highly populated countries such as Germany, Japan, France and the United Kingdom follow. The share of Turkey (the fourth-largest population) is less than the countries above, due in part to lower heating degree-days and therefore lower consumption for heating.

▶ The residential sector has experienced a relatively lower growth in energy consumption as compared to the transport and the commercial and public services sectors. The sector's consumption rose by 30% (from 520 Mtoe to 675 Mtoe) and accounts for 18% of IEA total final energy consumption. The faster increase of electricity in the demand of the sector - and the fact that the fuel input for electricity generation is not accounted for in final consumption – explains in part this relatively lower growth.

▶ Electricity and natural gas have displaced, to a large degree, oil for heating. Together, natural gas and electricity accounted for three-quarters of the consumption in 2007 (up from 48% in 1974). The share of oil fell dramatically (from 34% to 13%), as did that of coal (from 13% to 2%).

▶ Based on 2006 data for 19 IEA member countries, 53% of the consumption goes to heating, followed by appliances (18%), water heating (16%), lighting (5%), cooking (5%), and space cooling (3%). Since 1990, one of the first years for which the breakdown of end uses is available, the share of appliances has slightly increased (+4 percentage points), compensating a small decrease in the share of heating. This trend reflects more efficient boilers (*e.g.* condensation boilers) and the development of electrical heating in several countries. The development of air conditioning, computers, televisions and appliances explains the faster growth in the share of electricity.

▶ The breakdown of residential consumption by fuel varies widely from country to country, depending on historical tradition, climate (due to the weight of heating and cooling) and energy resources. For example, electricity represents 78% of residential demand in Norway, a country with a large hydro production. By contrast, in the Netherlands, where hydro is limited but natural gas is more abundant, electricity represents only 23% of demand while natural gas accounts for 72%. In 1974, oil represented more than 40% of demand for almost half of IEA member countries; in 2007, it accounted for 40% in only three countries.

▶ Sources

- *Energy Balances of OECD Countries*, 2009, IEA.
- IEA Indicators Database, 2009, IEA.

▶ For further information

- *Energy Use in the New Millennium*, 2007, IEA.
- *Gadgets and Gigawatts: Policies for Energy Efficient Electronics*, 2009, IEA.
- *Promoting Energy Efficiency Investments: Case Studies in the Residential Sector*, 2008, IEA.

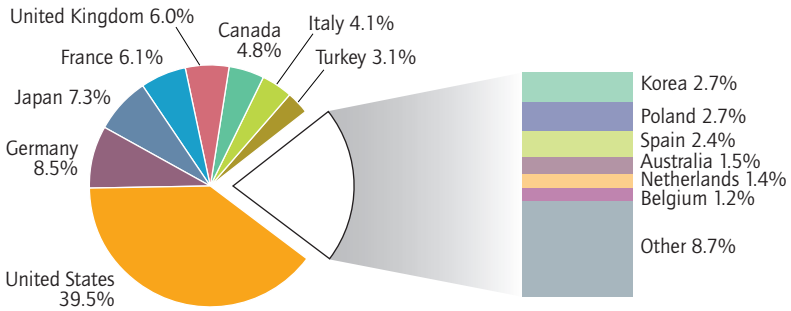
Small appliances driving growth in energy consumption

Traditionally, energy consumption of appliances in the residential sector was driven by large appliances. Five appliances (freezers, refrigerators, washing machines, dishwashers and televisions) still account for around 40% of household electricity consumption by appliances in IEA member countries.

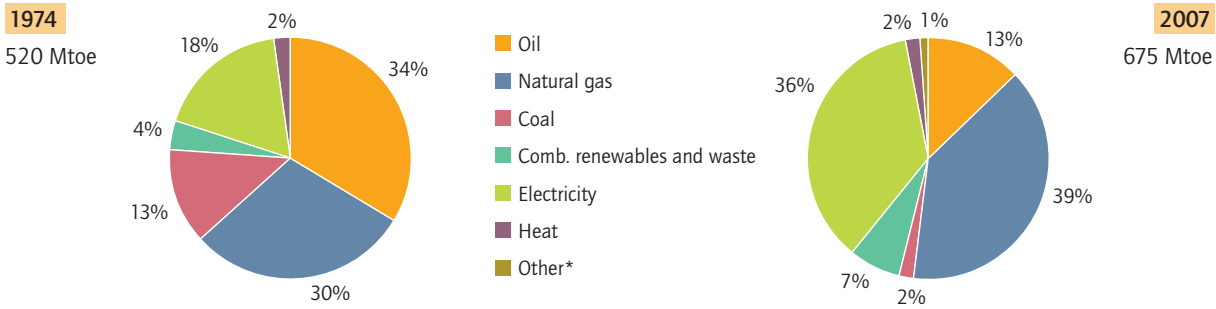
This share is declining, however, as the most rapid increases in appliance energy consumption now derives from increasing ownership of a wide range of mostly small, miscellaneous appliances such as personal computers, mobile phones, personal audio equipment and other home electronics.

Energy supply to households has changed dramatically. Coal has been gradually phased out; natural gas is the main fuel, followed closely by electricity (the share of which doubled since 1974).

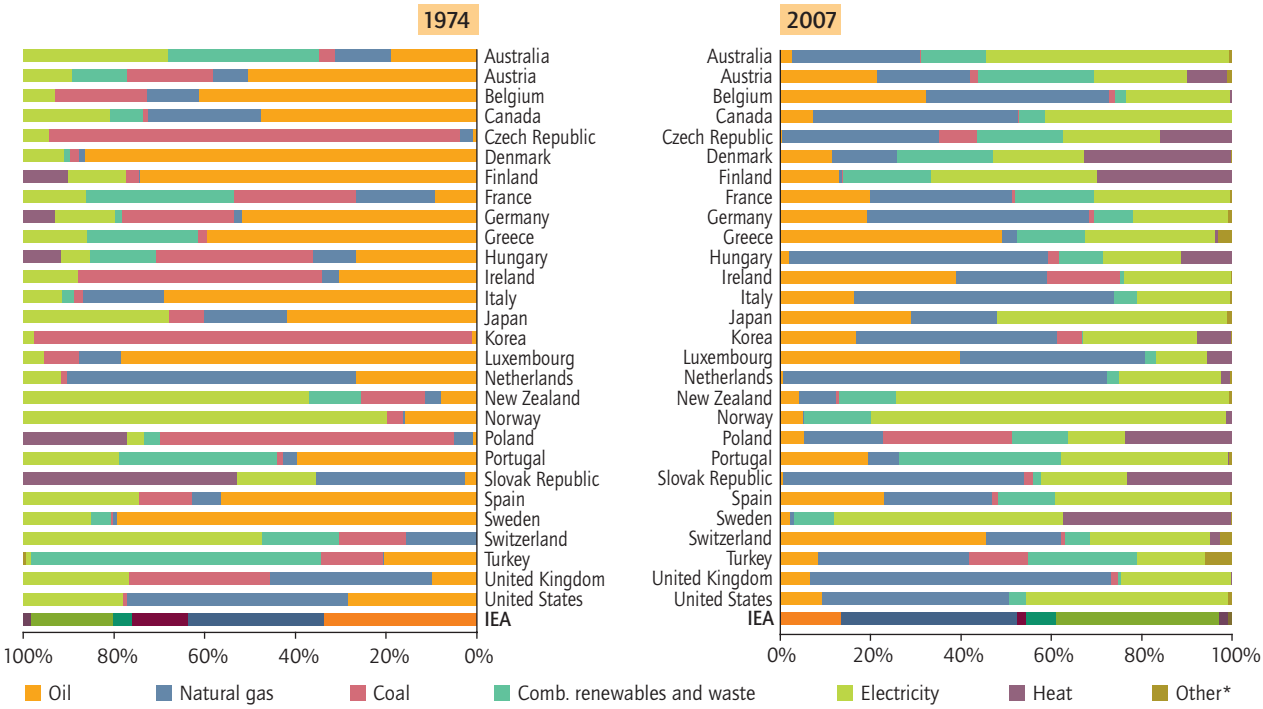
Residential consumption by country in 2007



Residential consumption by fuel



Residential consumption by fuel and by country



** Other includes direct use of geothermal and solar thermal heat.*

Diversification in commercial and public services consumption

▶ The commercial and public services sector encompasses a wide variety of activities such as administration, shops, schools and hotels. As it is often difficult to collect detailed energy consumption data on each of these activities, they are often aggregated in one common sector. The aggregation is useful, but makes the analysis less meaningful.

▶ A shift of the economy away from industry to services in many IEA member countries has led to a 69% growth of energy consumption of the commercial and public services sector, from 270 Mtoe in 1974 to 460 Mtoe in 2007. As more than half of the consumption comes from electricity, the growth would have been even higher if the fuel inputs to electricity production were taken into account.

▶ The United States represents 44% of the overall IEA sectoral consumption followed by Japan (14%), Canada (7%), Germany (5%) and France (5%). In 1974, these five countries represented 87% of IEA total consumption in this sector; because of widespread sectoral development in other IEA member countries, their share has fallen to only 74%.

▶ As in the industry and residential sectors, oil has been massively displaced from a 42% share in 1974 to 13% in 2007. Electricity has dramatically contributed to the diversification in the energy mix with its share more than doubling over the period. Electricity (*e.g.* for air conditioning and office equipment) now represents more than half of the sector's consumption; natural gas follows with 31% (up from 27%).

▶ Electricity became a more important part of the energy mix in almost all IEA member countries while oil's importance decreased. There are, however, some exceptions. In Austria, Denmark and Sweden, development of district heating now accounts for one-quarter to one-third of the energy mix, and has contributed to a reduction of the share of electricity.

▶ Due to the wide variety of activities covered under commercial and public services, and the lack of detailed data, it is sometimes difficult to compare consumption amongst countries. However, a study of 11 IEA member countries shows major differences in both energy use per unit of floor area and energy use per value added. For both, the energy use varies significantly depending on the country.

▶ Source

- *Energy Balances of OECD Countries*, 2009, IEA.

▶ For further information

- *Worldwide Trends in Energy Use and Efficiency* (Brochure), 2008, IEA.

An urgent need for more detailed activity statistics

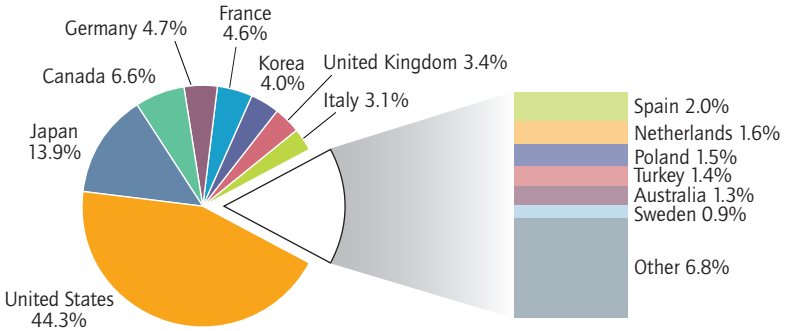
The consumption patterns of a school cannot be compared to those of a hospital or a swimming pool. Thus, in order to fully analyse the commercial and public services sector there is an obvious need for detailed energy consumption data (as well as other information such as floor area, occupancy, etc.) broken down by sub-sector.

Currently, these data are not readily available in many countries. The growing importance of the commercial and public services sector calls for a special effort to collect additional information in order to conduct more meaningful assessments, for example on the impact of energy-saving policies within a given country or cross-country comparisons.

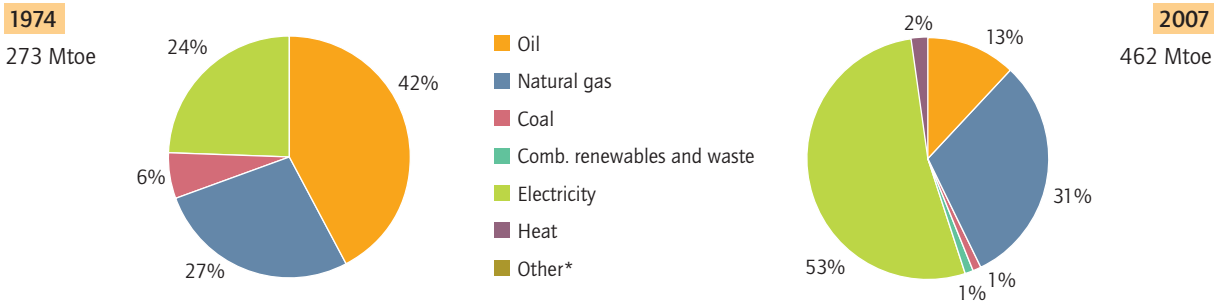
The IEA Secretariat, in close co-operation with the Mure-ODYSSEE project of the European Commission and with the Asia-Pacific Economic Cooperation (APEC), has launched an "energy-efficiency indicators" template to promote regular collection of basic information on the commercial and public services sector. The template also covers data on industry, transport and households.

Energy supply to the commercial/public services sector has experienced major changes: the share of oil dropped by a factor of three between 1974 and 2007 while that of electricity more than doubled.

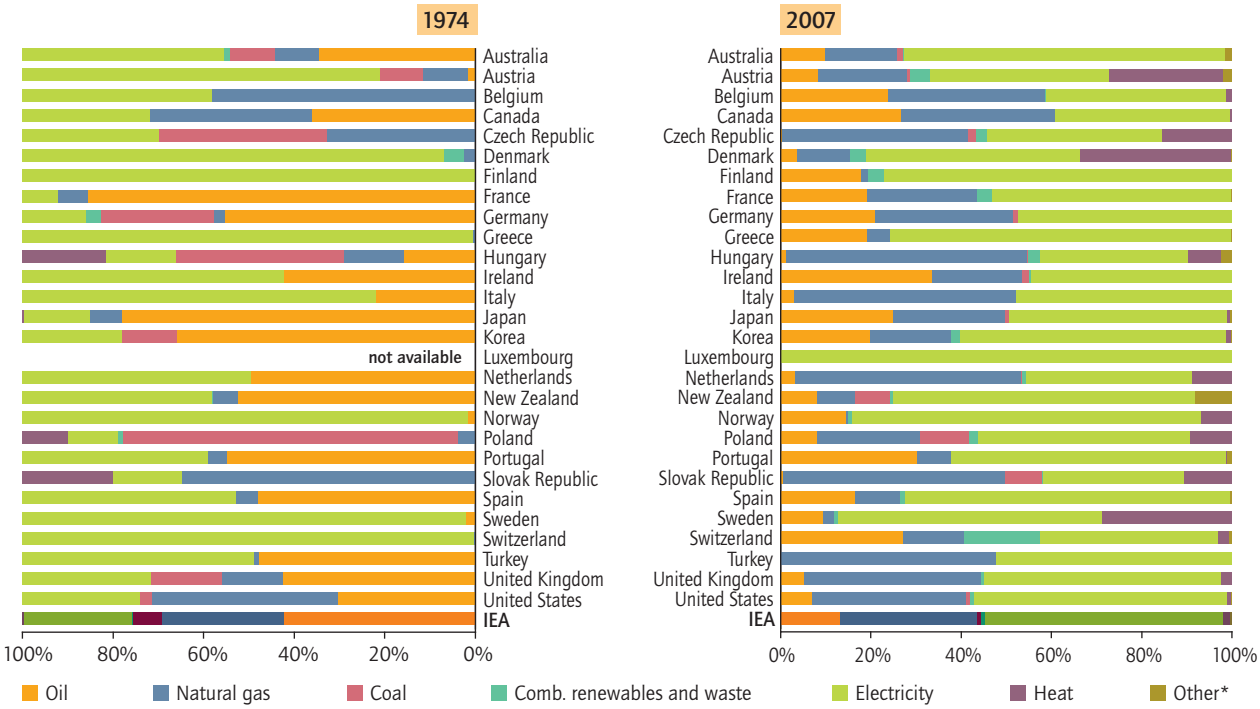
Commercial/public services consumption by country in 2007



Commercial/public services consumption by fuel



Commercial/public services consumption by fuel and by country



** Other includes direct use of geothermal and solar thermal heat.*

Diversification in electricity production

▶ The generation mix of electricity in IEA member countries has changed significantly over the last 35 years. Fossil fuels continued to dominate, although their share fell from 72% in 1974 to about 62% in 2008. The success of policies to lower oil use in stationary applications is evident in the steep decline in consumption by oil-fired power plants, from 23% to 3%. In many countries, oil use in the power sector has been significantly reduced, if not eliminated.

▶ **Coal** remains the predominant fuel for power generation; its relatively constant share of around 37% obscures the fact that in absolute terms, coal-fired power has grown by almost 140%. Several countries, including Poland, Australia, Greece and the Czech Republic, still depend on coal for a large part of their electricity production.

▶ **Gas** currently ranks third in the electricity production mix (almost on par with nuclear, the second-largest source). Its share has dramatically increased from 12% to 21% due to the installation of new high-efficiency generators, mainly since 1990. In some countries (the Netherlands, Ireland and Italy), natural gas contributes more than one-half of the total electricity production. In Luxembourg, a newly installed large CHP plant has raised the share of gas to about 90%.

▶ Since 1974, a large majority of IEA member countries (19 out of 28) have reduced the share of fossil fuels by developing ambitious nuclear and renewable programmes. Some countries (including France, Sweden, Switzerland, the Slovak Republic and Belgium) have cut the share of fossil fuels by more than 50%.

▶ Large-scale development of nuclear power in several countries (the United States, France, Japan, Korea and Canada), particularly during the 1970s and 1980s, helped to boost the share of nuclear to 22% in 2008, compared to 5% in 1974.

▶ In 1974, **hydro** was virtually the only renewable source contributing to electricity production in IEA member countries. Growth of output from hydro has stalled since 1996, although it contributes to almost 100% of the electricity production in Norway and to more than 50% in Canada, Austria, Switzerland and New Zealand. By contrast, the share of **non-hydro renewables** – particularly of wind – has been increasing, especially since 2000. Much wind development has been supported by strong incentive programmes such as mandates and feed-in-tariffs. Overall, renewables maintained a stable share since 1990 and continues to represent 16% of electricity production in 2008.

▶ *Sources*

- *Energy Statistics of OECD Countries*, 2009, IEA.
- *Energy Balances of OECD Countries*, 2009, IEA.

▶ *For further information*

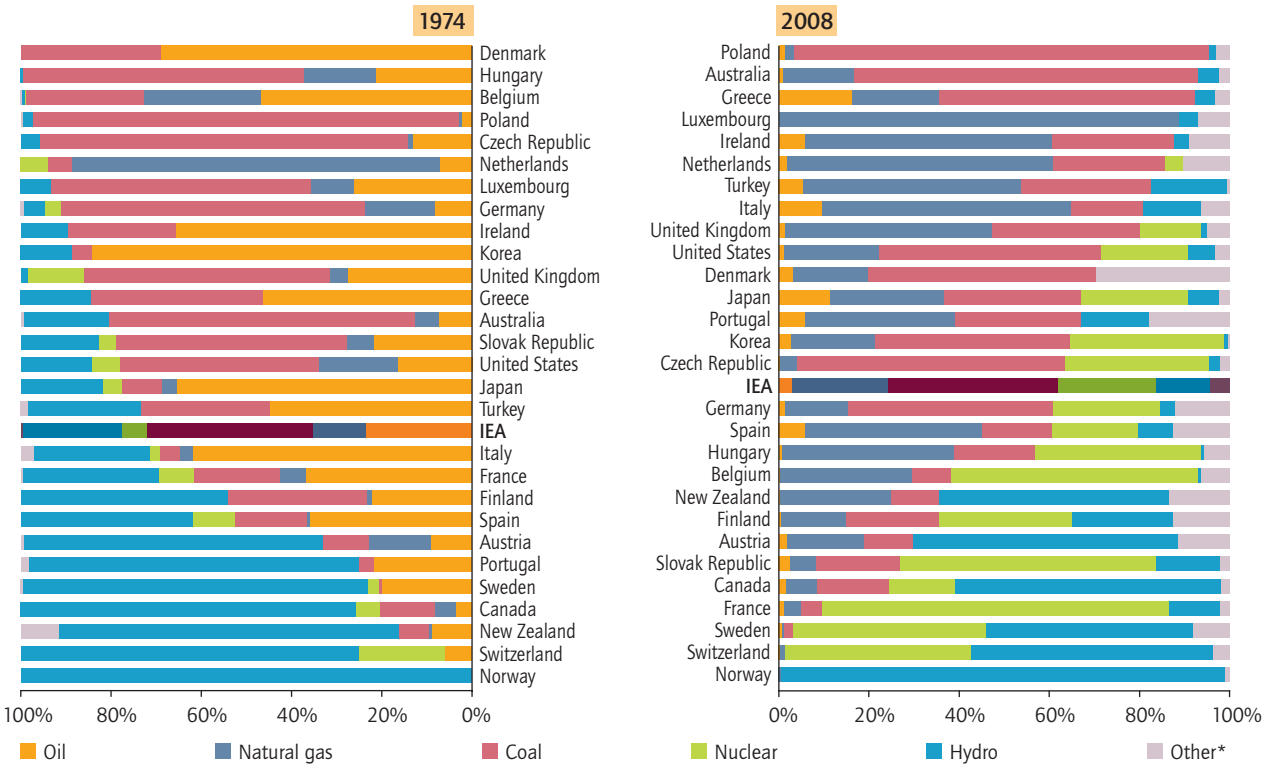
- *Electricity Information*, 2009, IEA.
- *Electricity Transmission: Getting the Best Investments*, 2009, IEA.

Cleaner electricity generation

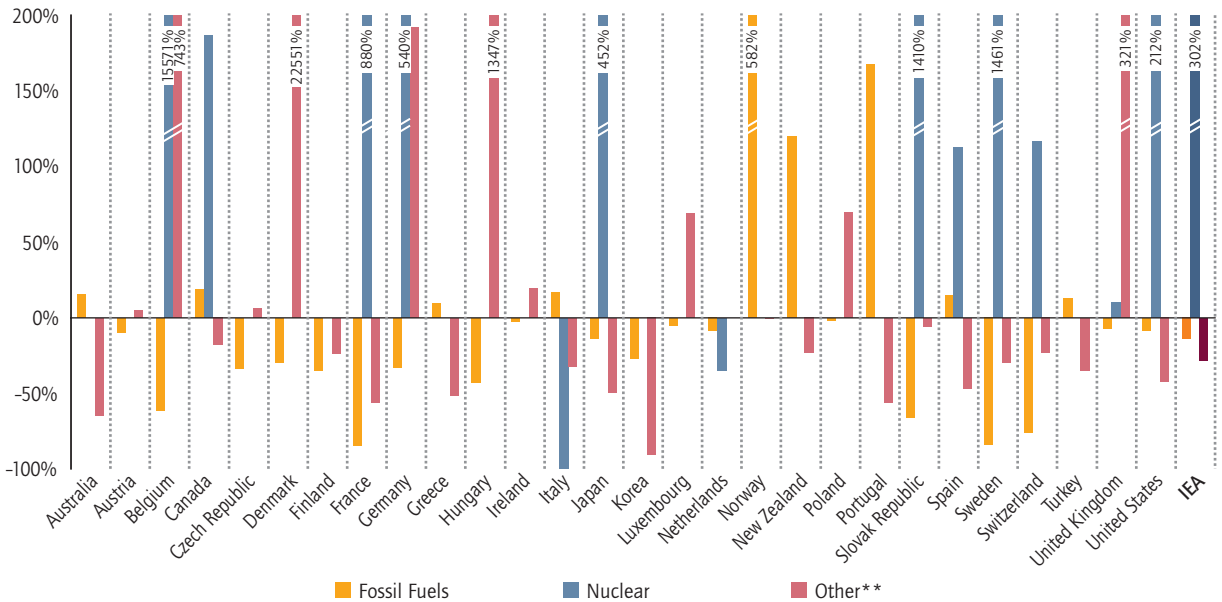
Adequate generation and transmission are essential elements of secure and reliable electricity supply. While it is strategically important to ensure that investments are sufficient and timely, IEA member countries are increasingly focusing on energy diversification as a means to address the twin challenges of supply security and climate challenge. Diversification in the latter context implies shifts in the generation mix towards low- or zero-carbon generation technologies such as renewables, nuclear and those fitted with carbon capture and storage (CCS). Already since 1990, development of renewables in IEA member countries and more use of natural gas have complemented nuclear to reduce CO_2 emissions from 486 to 446 g CO_2 per kWh (in 2007).

The share of fossil fuels in electricity production decreased from more than three-quarters in 1974 to less than two-thirds in 2008: oil has been almost phased out. The share of nuclear grew from 5% to 22%.

Percentage share of electricity generation by fuel ranked by fossil-fuel share



Percentage change in electricity generation share between 1974 and 2008



** Other includes geothermal, solar, wind, tide/wave/ocean energy, combustible renewables and waste, etc.*

*** Other includes hydro, geothermal, solar, wind, tide/wave/ocean energy, combustible renewables and waste, etc.*

Diversification in sectoral electricity consumption

▶ Total electricity consumption in IEA member countries increased by 2.4 times from 1974 to 2007, somewhat below world consumption which saw a three-fold increase. The United States, which accounted for 44% of total IEA consumption in 1974, is still the major consumer with 42%. The next four countries together (Japan, Germany, Canada and France) represent around 30%. Thus, the top five IEA electricity consumers account for nearly 70% of total IEA consumption.

▶ A number of variables affect electricity consumption in each of the three main end-use sectors (residential, commercial and public services, and industry). For example, while levels of economic activity are the main driver of industrial electricity consumption, significant variations in heating and cooling degree-days can cause major fluctuations in demand in both the residential and commercial and public services sectors.

▶ Overall, IEA member countries have experienced faster growth in the residential and the commercial and public services sectors compared to industry. This can be attributed to factors such as the delocalisation of energy-intensive industries, the development of the commercial and public services sector, and more appliances and electronic equipment in houses. As a result, the share of industry declined (from 49% in 1974 to 33% in 2007), while that of the commercial and public services sector increased (from 20% to over 31%). The share of residential has also increased, but more modestly (from 29% to 31%).

▶ For most IEA member countries, industry remains the largest consuming sector for electricity. This is not readily apparent in the IEA average – only 33% – because of the relatively low share of industry in US electricity consumption (24%), the lowest of all IEA member countries. The share of industry has decreased in all countries but two: Denmark and New Zealand had the lowest shares in 1974 and subsequent growth has been relatively limited. However, for some countries such as Luxembourg, Finland and Korea, industry still accounts for more than half of electricity consumption.

▶ The combined share of the residential and the commercial and public services sectors has risen in all countries, with the latter experiencing the largest increase. The growth – over 100% – in the combined share has been particularly spectacular in a few countries, either due to huge development of the commercial and public services sector (Luxembourg, for instance) and/or stronger use of electricity in households (Czech Republic, Hungary, Japan and Poland). Some countries (*e.g.* Canada and Spain) have experienced rapid growth in demand for cooling and their residential electricity consumption is shifting towards higher summer peaks.

▶ Source

- *Energy Balances of OECD Countries*, 2009, IEA.

▶ For further information

- *Electricity Information*, 2009, IEA.
- *Electricity Transmission: Getting the Best Investments*, 2009, IEA.
- *Gadgets and Gigawatts: Policies for Energy Efficient Electronics*, 2009, IEA.

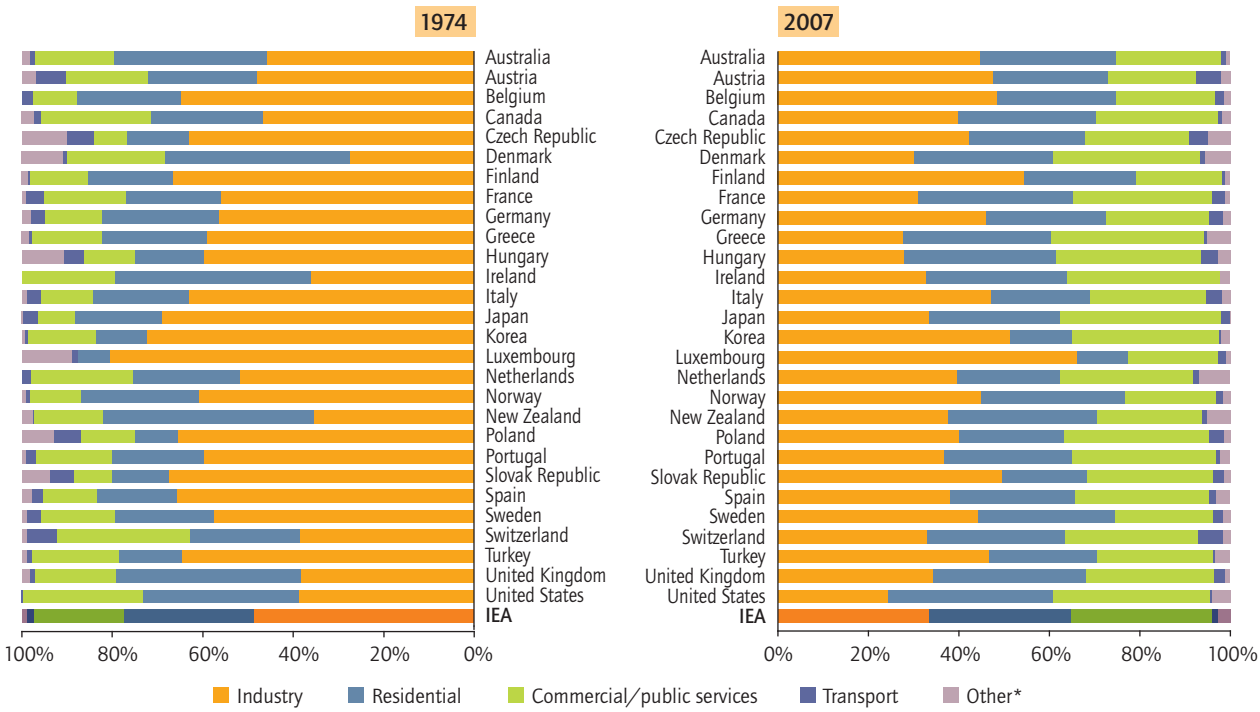
Standby power

Standby power is the electricity consumed by devices while switched off or not performing their primary functions. It is responsible for 5% to 10% of total electricity use in most homes and an unknown amount in commercial buildings and factories.

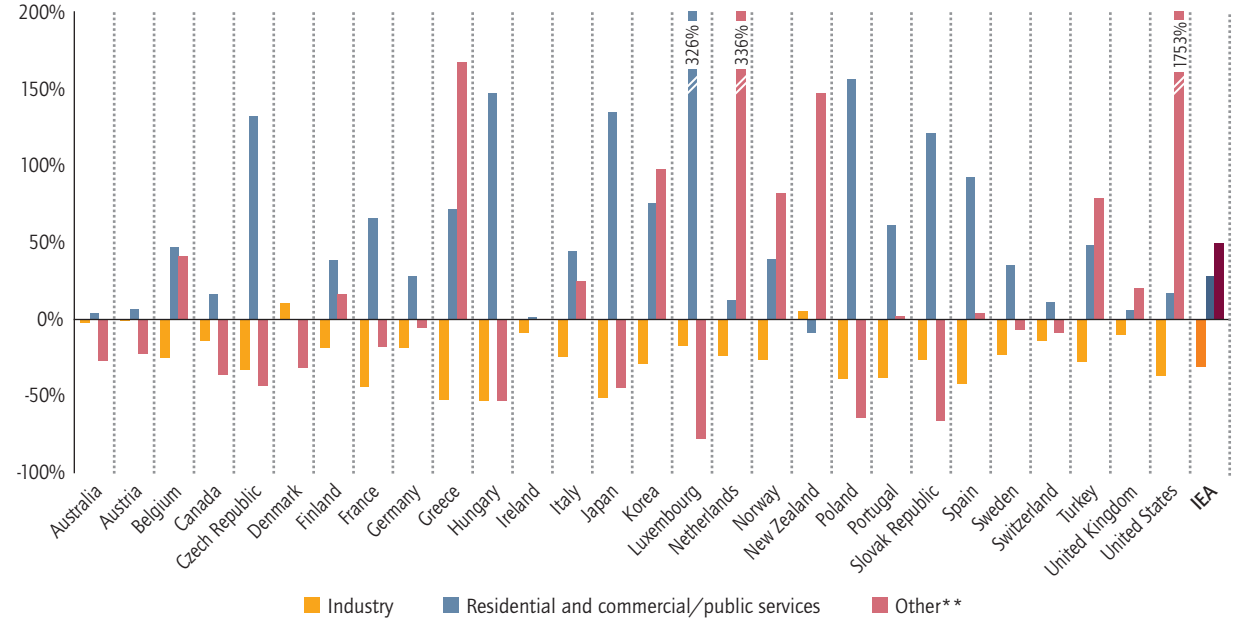
As part of the package of recommendations on energy efficiency policies made to the last four G8 Summits, the IEA Secretariat highlighted several policies relevant to standby power. One measure is to apply a one-watt limit to all products. Another is to require electronic devices not in use to enter automatically into a low-power mode. The IEA Secretariat also suggested that governments should work co-operatively to develop a horizontal approach covering all major functions and low-power modes. These measures could be implemented either as voluntary or mandatory policy measures.

Electricity consumption in IEA member countries is divided in roughly equal shares across industry, households and commercial/public services, reflecting a decline in the share of industrial consumption.

Percentage share of final consumption of electricity by sector



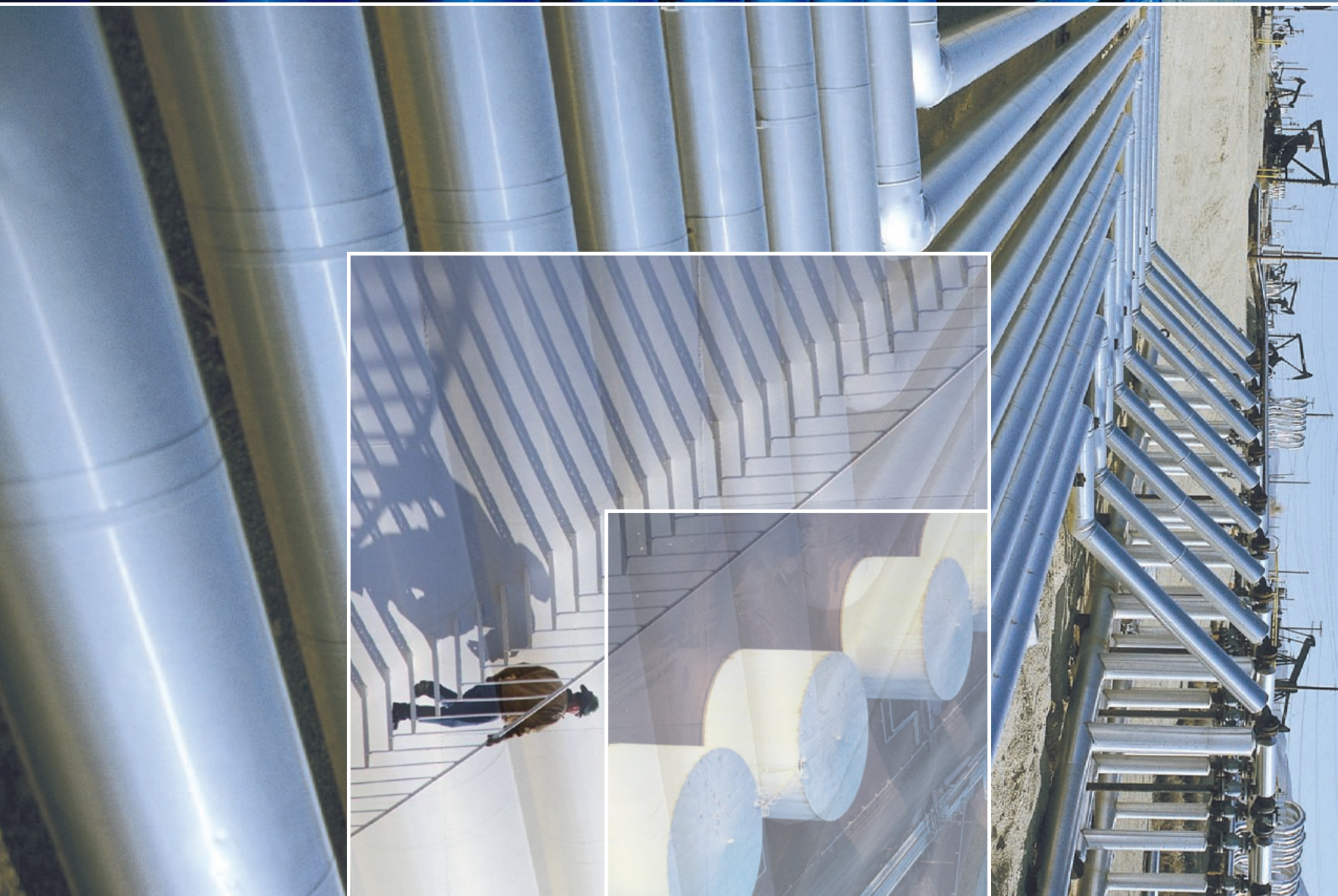
Percentage change in electricity consumption share by sector between 1974 and 2007



** Other includes agriculture/forestry, fishing and other use not specified elsewhere.*

*** Other includes transport, agriculture/forestry, fishing and other use not specified elsewhere.*

Ability to respond promptly to energy emergencies



Ability to respond promptly to energy emergencies

B

▶ Total IEA demand has grown by 1 600 Mtoe while total net imports have increased by only 450 Mtoe. In an effort to limit growth in imports, several IEA member countries have increased domestic production and diversified towards nuclear and renewables. However, the IEA as a whole remains highly dependent on imported energy.

▶ In 1974, there were three net IEA exporting countries: Australia (coal), Canada (oil and gas), and Poland (coal). Since then, larger oil imports have made Poland a net energy importer, while oil and gas exploitation has transformed Norway into the largest IEA energy exporter. Today, there are four IEA net energy exporters: Australia, Canada, Norway and Denmark (only marginal net energy exports from oil and gas). Net energy imports of the United States are by far the highest among all IEA member countries, followed by Japan.

▶ **Oil** imports still dominate, making up three-quarters of total energy imports. Imported oil remains an important component to satisfying domestic consumption needs for IEA member countries, especially for transport. In absolute terms, IEA member countries as a whole tallied net oil imports of more than 1 400 Mtoe for 2008, about the same amount as in 1974.

▶ In 2008, only three IEA member countries (Norway, Canada, the United Kingdom and Denmark) fell under the category of "net oil exporter". Most IEA net import flows are concentrated among a few countries. Among net importers, the United States accounts for 38% and Japan accounts for about 15%. Germany, Korea, France, Spain and Italy combined account for slightly less than 30% of the total.

▶ **Gas** imports provided a much smaller proportion of net energy imports, less than one-fifth of total imports. Norway, Canada, the Netherlands and Australia are all major gas exporters; Denmark exports much smaller volumes. Norway, Canada and the Netherlands were pipeline gas exporters; Australia exported only LNG. Norway recently also became an LNG exporter.

▶ Net **coal** imports of IEA member countries were 116 Mtoe in 2008, representing one-twelfth of oil imports and one-quarter of gas imports. Most coal used in IEA member countries is for power generation. Japan is by far the largest IEA coal importer, followed by Korea and Germany. Together, these three countries account for 64% of IEA coal imports. The United Kingdom, Italy, France, Turkey and Spain combined account for another 25% of IEA coal imports.

▶ Seven IEA member countries are net coal exporters. Australia is by far the largest, accounting for 63% of IEA coal exports. Others include the United States, Canada, Poland, the Czech Republic, New Zealand and Norway.

▶ In absolute terms, net imports of electricity and combustible renewables is very limited. Most of the imports and exports that do occur are within IEA member countries. France and Canada are the main net exporters of electricity; Italy and the United States are the main net importers.

▶ *Source*

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *Coal Information*, 2009, IEA.
- *Natural Gas Information*, 2009, IEA.
- *Oil Information*, 2009, IEA.

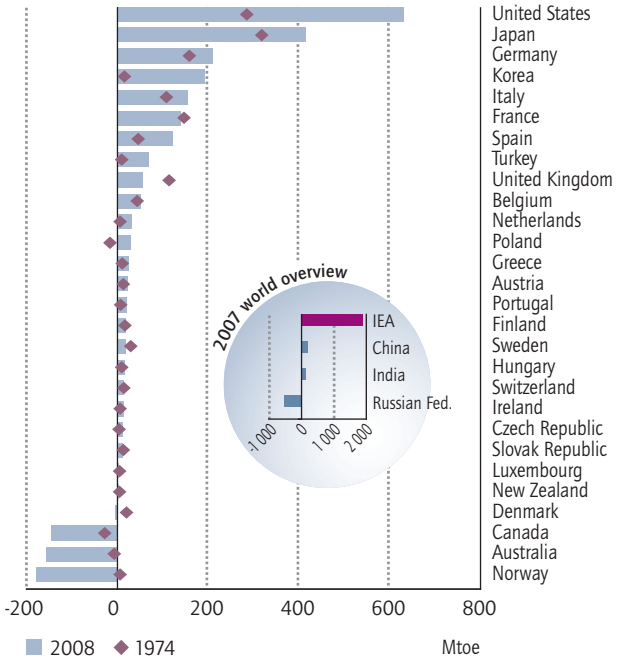
Transit trade of natural gas

Knowing the origin of gas that is imported is a key element in gas supply security. Transit trade already represents somewhere between 25% and 40% of consumed gas volumes in Europe. With increasing gas demand, the need for gas imports and transit across third countries will inevitably increase, making it more difficult to identify the first origin and the ultimate destination of the gas. Information on origins and destinations of gas is typically held by transmission grid operators in transit and dispatching; thus, their co-operation will become an increasingly important component of transparency in the gas market.

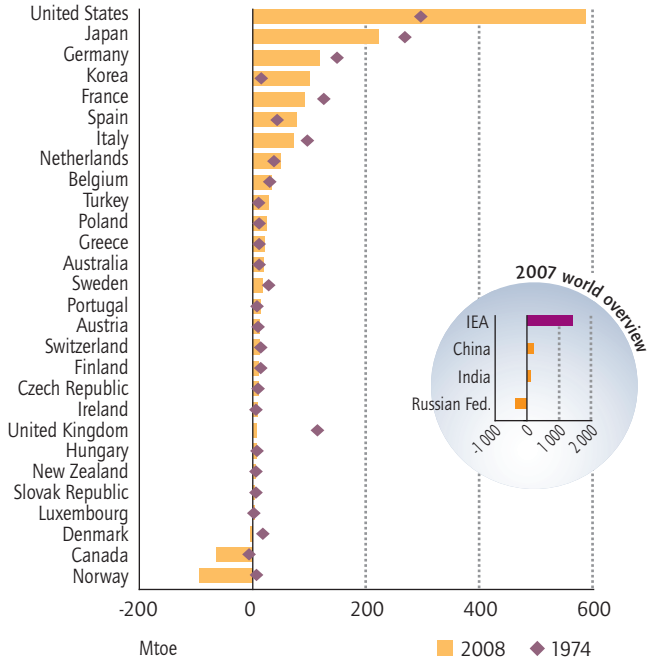
All IEA member countries but four are net energy importers.
In 2008, oil accounted for 76% of IEA net imports.

Net energy imports in 2008

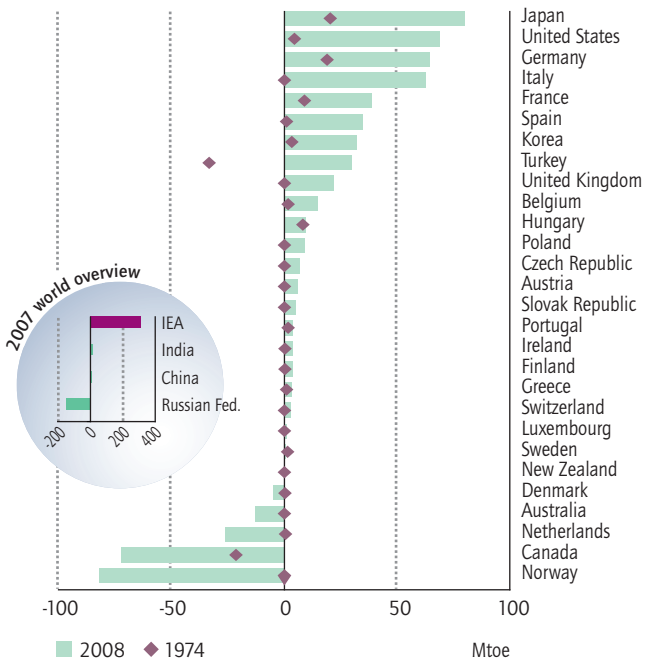
Total



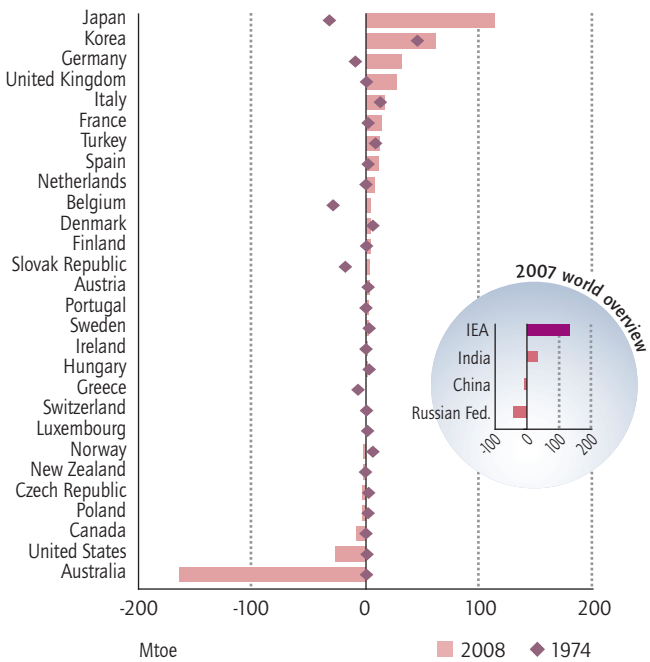
Oil



Natural gas



Coal



▶ Self-sufficiency of supply should not necessarily be seen as a priority objective for energy policy; yet it is interesting to compare the situation over the years and across countries. In 1974, energy self-sufficiency in the IEA as a whole was 66%. After a slight dip, it rose to 76% in 1984, largely due to the development of nuclear and of oil fields in the North Sea. Since then, a decline in the production of oil and an increase in overall energy demand have caused IEA self-sufficiency to fall back to approximately the same level as in 1974.

▶ At present, the overall IEA ratio for self-sufficiency is 69%; 18 of the 28 member countries fall below that level and ten are above. While the overall IEA self-sufficiency ratio remained stable compared to 1974, some countries have experienced significant shifts – either favourable (*e.g.* Denmark) or unfavourable (*e.g.* Poland).

▶ Australia, Canada, Denmark and Norway are fully energy self-sufficient; in fact, all four improved their self-sufficiency ratios between 1974 and 2008. Sweden, France, Switzerland and Finland have become significantly more self-sufficient due to large nuclear programmes. Self-sufficiency decreased in particular in the Netherlands, Poland, the Czech Republic, the United States, Turkey, Korea and Germany.

▶ At 37% in 2008, the overall self-sufficiency ratio for oil is quite low for IEA member countries. In 21 countries, oil self-sufficiency is 20% or less. The ratios for the two largest IEA net oil importers stand at 37% for the United States (down from 65% in 1974) and at 0% for Japan. Only four countries, Norway, Denmark, Canada and the United Kingdom, are self-sufficient in oil.

▶ IEA member countries recorded a 74% self-sufficiency ratio in natural gas in 2008, much lower than 98% in 1974. This reflects, in part, rapid growth in gas demand in power generation and increased reliance on imports to satisfy domestic requirements. Six IEA member countries (including Norway, Denmark, the Netherlands and Canada) are self-sufficient in natural gas. At the other end of the scale, nine IEA member countries (including Belgium, Finland, Greece and Portugal) rely totally or almost totally on imports to satisfy their domestic gas use. Most of the other IEA member countries have seen their gas self-sufficiency reduced significantly (*e.g.* Poland, Hungary and Italy).

▶ IEA member countries as a whole are close to being self-sufficient in coal, with a ratio of 90% in 2008 (a slight decline from 96% in 1974). However, large production in Australia, which is subsequently exported, masks the fact that many IEA member countries have registered significantly lower self-sufficiency ratios, including Germany, Turkey, Spain, the United Kingdom, Ireland, Korea and France. Self-sufficiency in coal is achieved in seven countries, with Greece being very close to joining their ranks. Being a large exporter, Australia holds the highest self-sufficiency ratio at almost 400%.

▶ Source

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ For further information

- *Coal Information*, 2009, IEA.
- *Natural Gas Information*, 2009, IEA.
- *Oil Information*, 2009, IEA.

Self-sufficiency

The measure of self-sufficiency reflects what percent of a country's energy demand can be met by its domestic production. It is calculated as production divided by supply. If a country is less than 100% self-sufficient in any or all energy forms, it must rely on imports and/or stock changes to meet the remaining demand.

As a consequence of the definition, international marine and aviation bunkers are not accounted for in calculating self-sufficiency ratios.

The overall IEA energy self-sufficiency was 66% in 1974, peaked at 76% in 1984 and decreased to 69% in 2008. It varies by fuel: currently, self-sufficiency is 90% for coal, 74% for natural gas and 37% for oil.

Self-sufficiency* in 2008

** Countries that are fully self-sufficient or are net exporters are shown as 100%.*

14 Emergency oil stockholding

▶ All net importing IEA member countries are required to maintain total oil stock levels equivalent to at least 90 days of net imports of the previous calendar year. Countries may guarantee meeting their obligation by holding stocks as government emergency reserves, through specialised stockholding agencies, or by placing minimum stockholding obligations on companies operating in domestic oil markets.

▶ Stocks held by agencies or owned directly by member country governments are referred to as **public stocks**. These are held exclusively for emergency purposes.

▶ **Industry stocks** include stocks held for commercial purposes as well as stocks held by industry to fulfil domestically imposed stockholding obligations. During an oil supply disruption, governments typically reduce temporarily the industry stockholding obligations, thereby making a portion of the held stocks available for consumption.

▶ As the IEA stockholding obligation is based on net imports, net exporting countries (currently Canada, Denmark and Norway) do not have an IEA stockholding obligation. Marginal net importers, such as the United Kingdom, hold significantly high levels of stocks when measured in days of net imports.

▶ Countries have a degree of flexibility in meeting their obligation by holding stocks as both crude oil and refined products. The mix of stocks will depend on specific circumstances within each country, such as the relative size of its refining industry. In countries where the refining industry is small compared to domestic oil consumption (such as Ireland and Switzerland), stocks are held primarily as products. Luxembourg has no refining capacity and thus holds all oil stocks as products.

▶ IEA member countries in the European Union typically hold a larger portion of their total oil stocks in the form of refined products, reflecting the requirements of EU regulations. In Japan and the United States, significant volumes of public stocks are held almost entirely in the form of crude oil.

▶ At the end of March 2009, total oil stocks in IEA member countries were the equivalent of 162 days of the previous year's net imports. In 1985, these same countries had total stocks of more than 180 days of 1984 net imports.

▶ The recent decline in number of days of stocks in many IEA member countries reflects several interrelated trends. Rising oil demand, coupled with declining domestic oil production, has resulted in growing net imports. At the same time, more efficient, "just-in-time" stockholding practices in industry have led to lower commercial stockholding levels.

▶ Public stocks of IEA member countries have grown, both in terms of volume and as a share of the total stocks in IEA member countries. Today, about 36% of the total IEA stocks are held as public stocks, compared to 23% in 1985.

▶ *Source*

- *IEA Monthly Oil Data Service*, *www.iea.org/Textbase/stats/mods.asp.*

▶ *For further information*

- *IEA Response System for Oil Supply Emergencies*, 2008, IEA.
- *Oil Supply Security: Emergency Response of IEA Countries*, 2007, IEA.
- Stock Levels of IEA member Countries in Days of Net Imports, *www.iea.org/netimports.asp.*

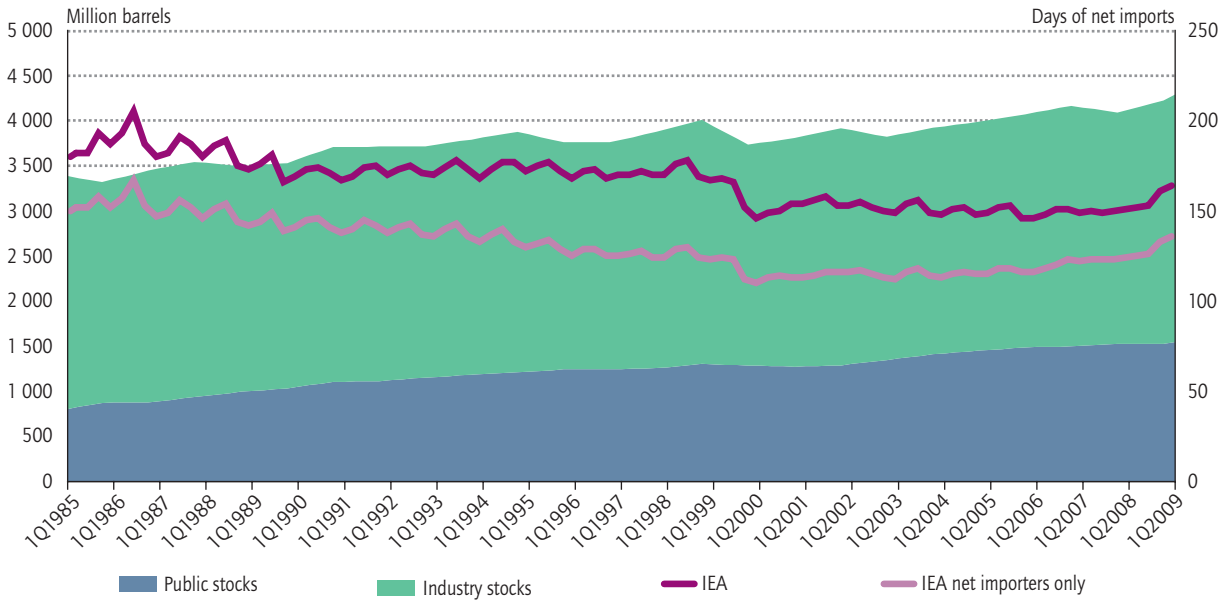
IEA response to an oil supply disruption

Emergency response to oil supply disruptions is one of the main pillars of the IEA. In fact, IEA membership is contingent on a country's ability to meet two key obligations: holding oil stocks equivalent to at least 90 days of net oil imports; and being prepared to implement other emergency response measures that can contribute to an IEA collective action in response to a severe oil supply disruption.

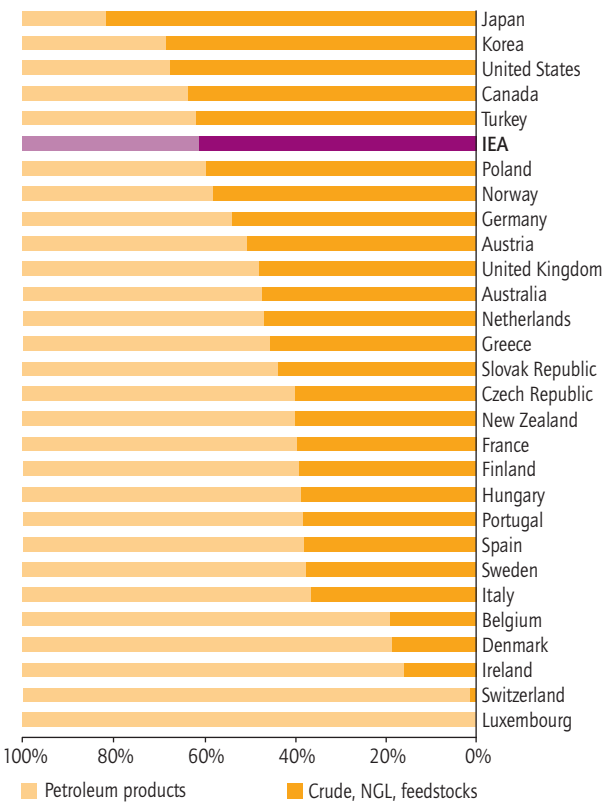
IEA collective response actions typically involve a combination of several measures – including stockdraw, demand restraint, fuel switching and surge oil production – all of which are designed to mitigate the negative economic and social impacts of sudden oil supply shortages. Stockdraw and surge production effectively increase the supply of oil available; demand restraint and switching to other fuels aim to curb consumption of oil.

Total crude oil and petroleum product stocks in IEA member countries at the end of March 2009 were the equivalent of 162 days of the previous year's net imports, well over the 90-day requirement.

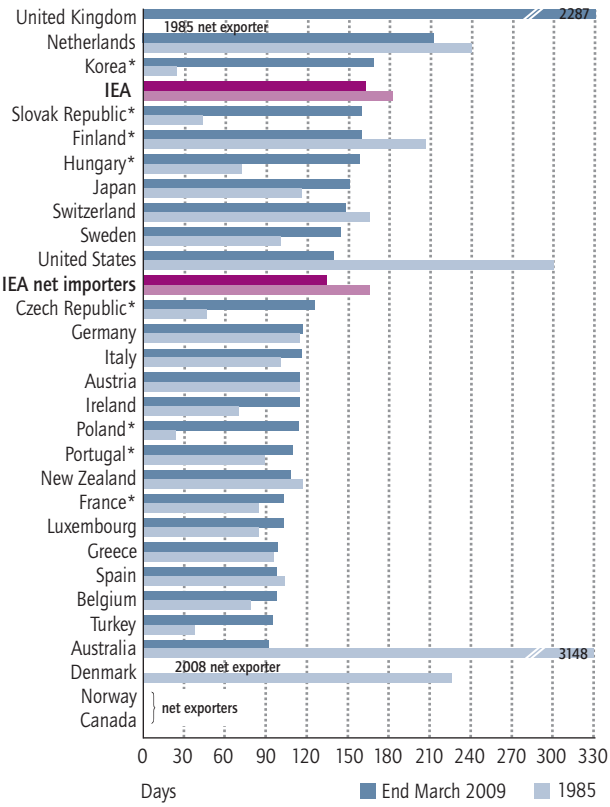
Total IEA oil stocks in million barrels and days of net imports



Total oil stocks by type at end March 2009

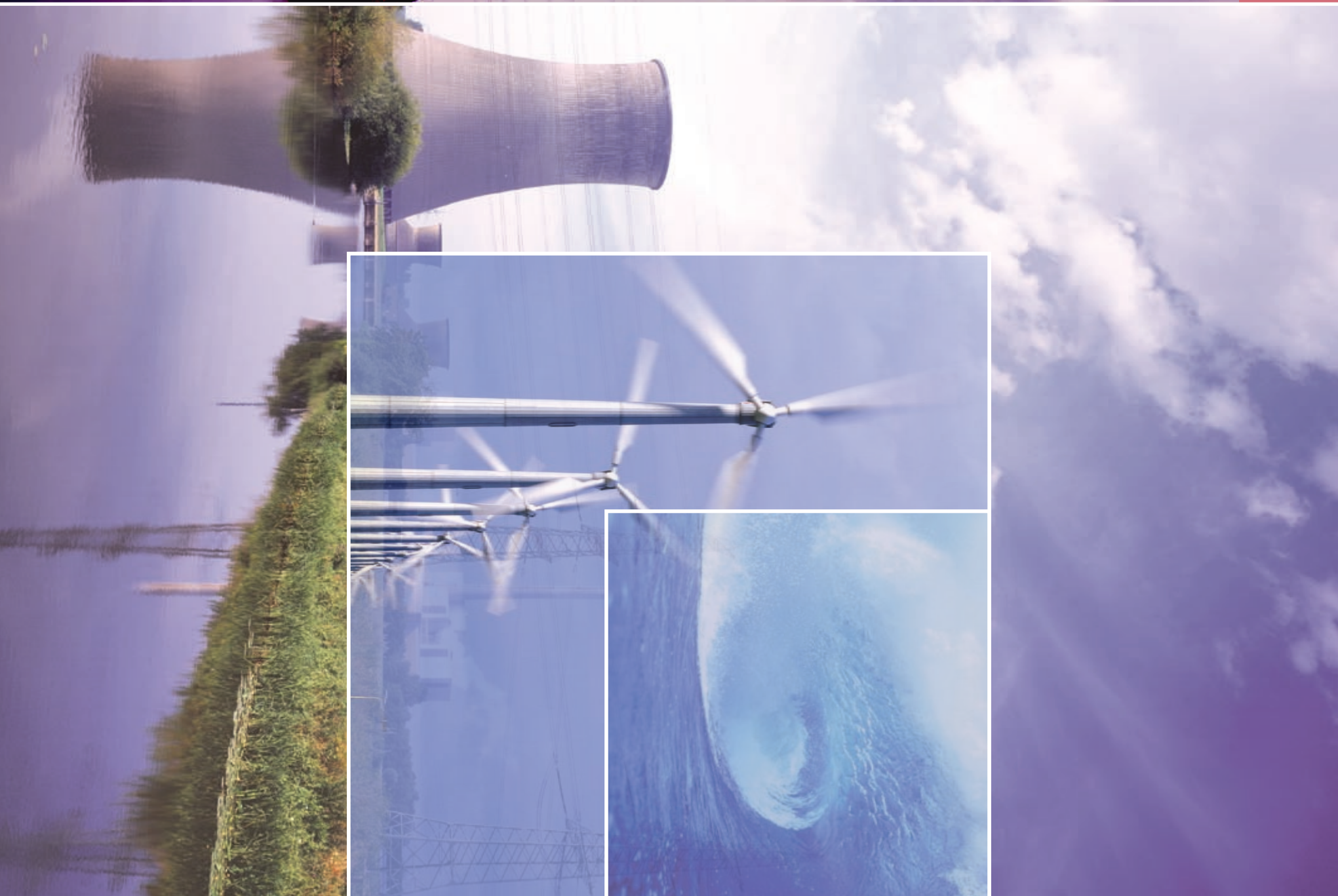


Days of net imports



** Countries that were not members of the IEA in 1985.*

Development of economic non-fossil fuels



Development of economic non-fossil fuels: nuclear and renewables

C

Share of nuclear in TPES and electricity production

▶ The development of nuclear energy for commercial purposes in IEA member countries accelerated after the first oil crisis in the early 1970s, largely in an effort to diversify the energy supply mix and reduce dependence on fossil fuels. To meet growing demand, nuclear generation rose most rapidly in the 1980s, then more steadily in the early 1990s. Very little growth occurred in the 2000s. Nuclear is mainly used to produce base-load electricity.

▶ National policies regarding nuclear development vary significantly among IEA member countries, ranging from being active in nuclear development (*e.g.* France, Finland, Japan, Korea and the United States) to phasing out nuclear generation (*e.g.* Germany). Twelve IEA member countries do not currently have commercial nuclear generating capacity.

▶ The United States has by far the world's largest nuclear production, followed by France and Japan. Together, these three countries account for 68% of total IEA nuclear generation. Over the last ten years, the United States, France, Korea and Canada have registered increased (although limited) generation, reflecting improved capacity factors. Japan, the United Kingdom, Germany, Sweden and Belgium recorded some declines in nuclear generation.

▶ The share of nuclear in total IEA TPES has increased from less than 2% in 1974 to 11% in 2008. France has achieved the most spectacular increase, with its nuclear share in TPES rising from 2% to 42%, the highest among all IEA member countries. Second-place Sweden also experienced impressive growth with its nuclear share rising from less than 2% to 33%. Switzerland is third with a share of 27%.

▶ The nuclear share in IEA electricity generation reached 22% in 2008, up from 5% in 1974. With a 77% share in 2008, France has the highest proportion of nuclear in electricity generation among IEA member countries (however, its absolute production is only slightly more than half that of the United States). The Slovak Republic ranks second (57%) and Belgium third (55%).

▶ In recent years, there has been a renewed interest in nuclear power in both IEA member and non-member countries, reflecting rising concerns about security of supply and climate change. The production of nuclear electricity is practically CO_2-free; however, the long-term disposal of spent fuels remains a key challenge. Moreover, expansion of nuclear capacity is constrained by safety concerns, as well as siting and permitting issues.

▶ Most reactor units currently under construction are located in IEA non-member countries, mostly in China, India and the Russian Federation. IEA member countries with units under construction include Finland, France, Korea and Japan. Canada has plants under refurbishment.

▶ Source

- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ For further information

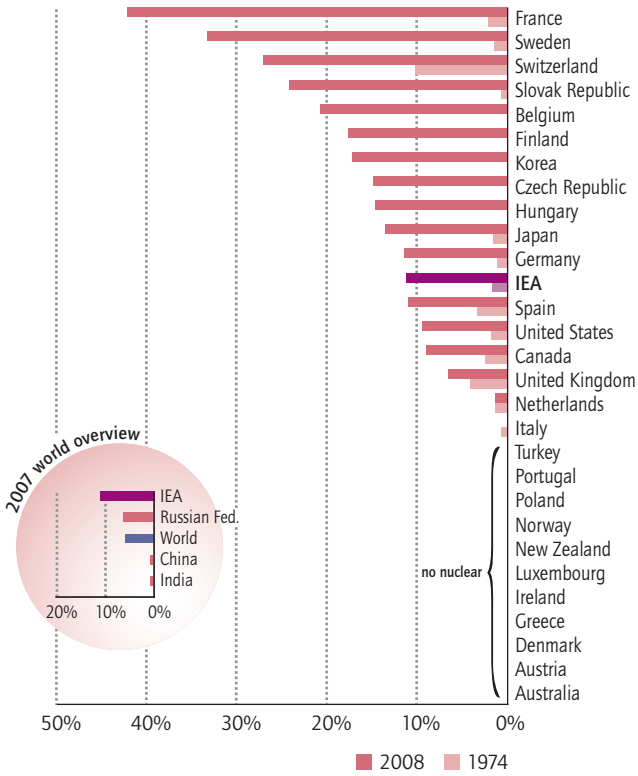
- *Electricity Information*, 2009, IEA.
- *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*, 2008, IEA.
- *Nuclear Energy Outlook*, 2008, NEA.
- *Tackling Investment Challenges in Power Generation*, 2007, IEA.
- *World Energy Outlook*, 2009, IEA.

The evolution of nuclear technologies

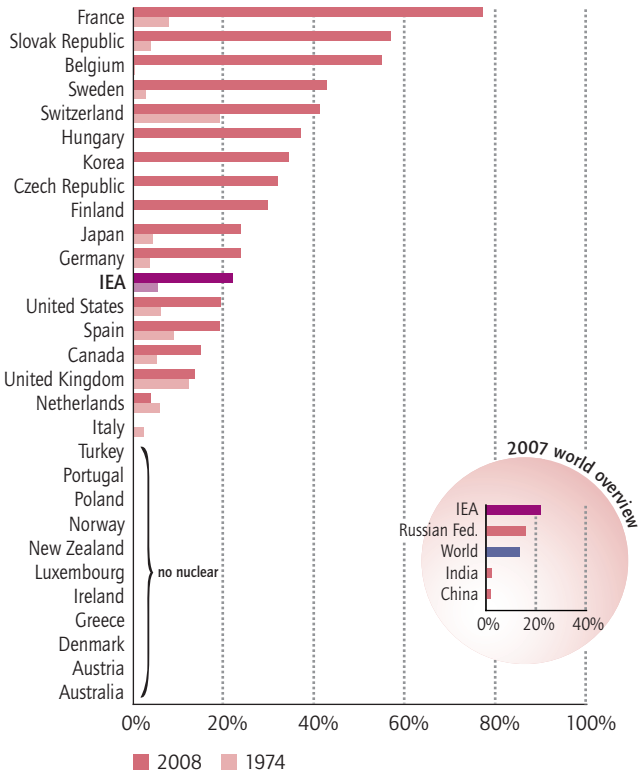
Nuclear fission technologies are classified into four generations. The first generation includes early prototypes, most of which have been decommissioned or are coming to the end of their lives. The majority of reactors currently operating belong to Generation II, while those under construction are predominantly of Generation III and III+. Generation III includes three main technology types: the advanced boiling water reactor (ABWR); the advanced pressurised water reactor (APWR); and the European pressurised water reactor (EPR). Generation III+ includes the pebble bed modular reactor (PBMR) and the AP1000, an advanced Westinghouse design. Generation IV is expected to be commercial by 2030.

Nuclear contributes, to varying degrees, to energy supply in 16 IEA member countries. Overall, its share of electricity production increased from 5% in 1974 to 22% in 2008.

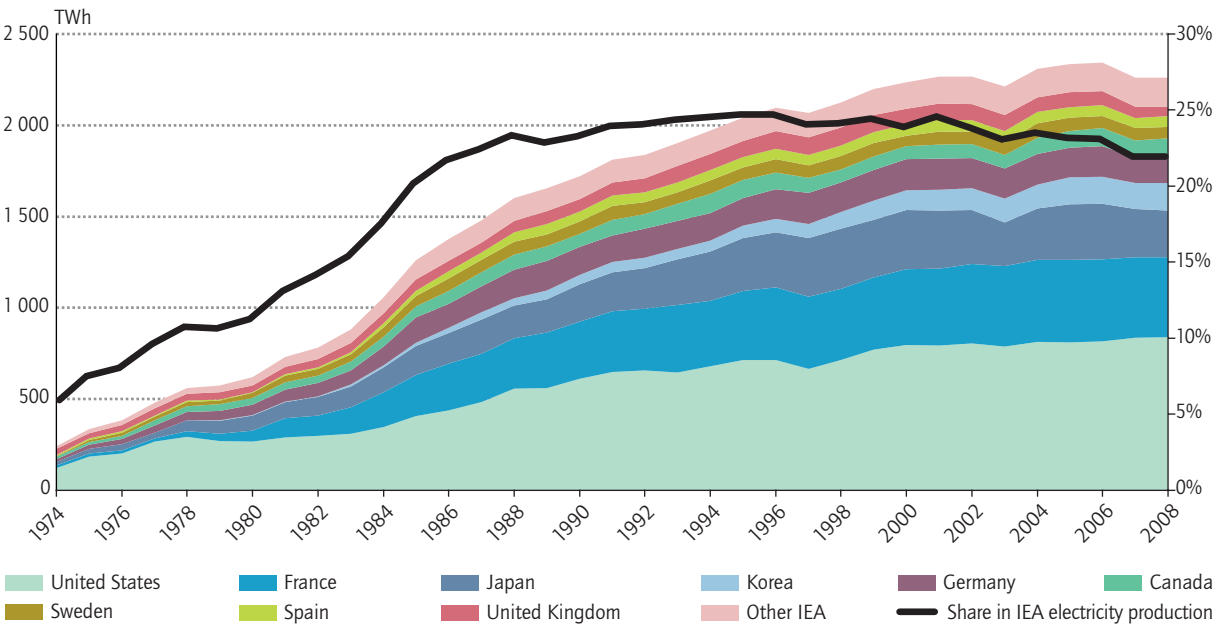
Share of nuclear in TPES*



Share of nuclear in electricity generation



IEA nuclear electricity production by country



** TPES excludes electricity trade.*

16 Share of renewables in TPES

▶ Renewable energy sources and technologies can play an important role in addressing emerging major global energy challenges including climate change, energy security, access to energy and supply of affordable energy to enable economic growth. Several IEA member countries have made progress in promoting renewables in their energy mixes. Many obstacles remain, however, and greater efforts are needed in terms of implementation of effective policies and technology improvement.

▶ The share of renewable energy sources in IEA total primary energy supply (TPES) has remained relatively stable since 1974. A slightly increasing trend is evident over the last few years, reflecting the increasing role of bioenergy, liquid biofuels and wind in some IEA member countries. The share of renewables was 5% in 1974, 6% in 1990 and 7% in 2008.

▶ Norway, the largest IEA oil exporter and the largest IEA gas exporter, has by far the greatest share (42%) of renewable energy in TPES, mainly due to its large hydro capacity. New Zealand (34%) ranks second with a mix of hydro and geothermal, followed by Sweden (32%) with a mix of wood and hydro.

▶ The shares of renewables in TPES of Norway and New Zealand have decreased over time. By contrast, shares of renewables have increased in Sweden, Austria, Finland and Switzerland, all countries with a significant share of combustible renewables in their TPES.

▶ **Combustible renewables** (mainly wood) are the main contributor to the overall supply of renewables in many IEA member countries. They represent about 60% of the share of renewables in total IEA TPES, approximately twice as much as hydro. The relatively higher share of combustible renewables and waste also reflects the fact that biomass is often burnt with low efficiency, which leads to a high primary energy consumption per unit of final energy service delivered.

▶ **Hydro** is the second-largest contributor to TPES among renewables. Its share in TPES is particularly high in Norway, Canada and Switzerland.

▶ **Geothermal** contributes around 40% of total renewable energy supply in New Zealand and Italy, followed by Japan (16%) and Turkey (11%).

▶ Despite impressive growth of the "new" renewables (*i.e.* **wind and solar**) over the last few years, their contributions in overall IEA TPES remain limited. The growth in the share of wind in TPES has been significant in Denmark, Germany, Ireland and Spain. Solar water heaters represented a noteworthy fraction of TPES from renewables in Greece (9.7%) and Turkey (4.6%).

▶ *Sources*

- *Renewables Information*, 2009, IEA.
- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

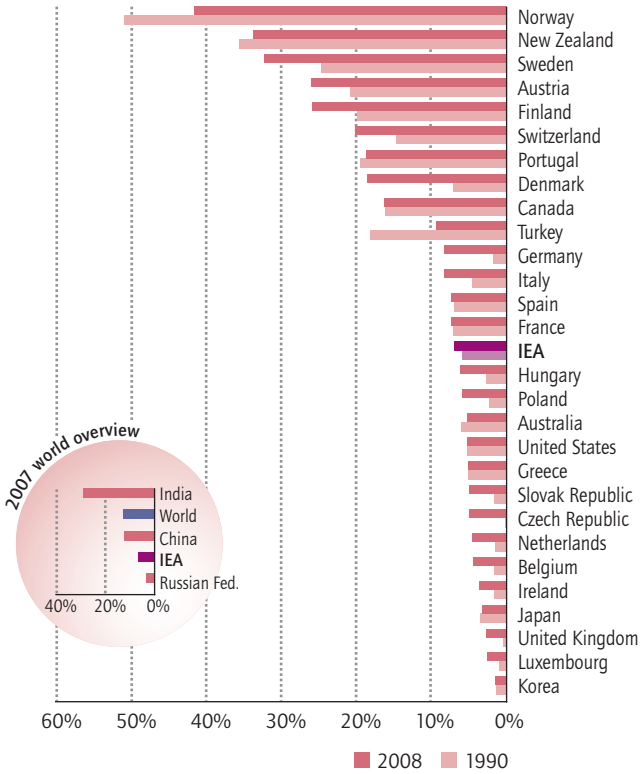
- *Deploying Renewables: Principles for Effective Policies*, 2008, IEA.
- *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*, 2008, IEA.
- *Renewables for Heating and Cooling*, 2007, IEA.

Calculation of TPES for renewable sources

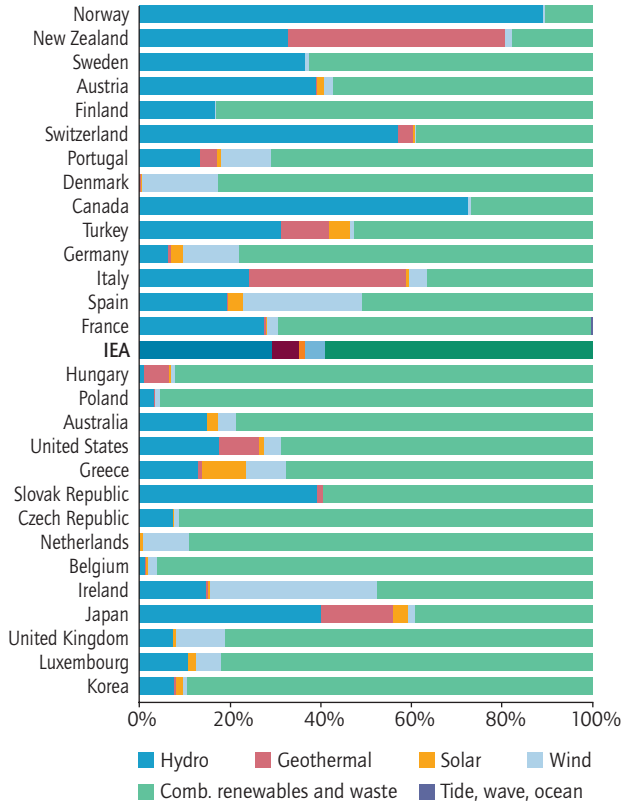
The choice of methodology to calculate the total primary energy supply (TPES) correspondent to a given amount of final energy has important implications on the respective share of each contributing energy source. This is particularly true for calculation of the shares of renewable energy sources. The IEA Secretariat uses the "physical energy content" methodology to calculate TPES. For combustibles, TPES is based on the calorific value of the fuels. For other sources, the IEA assumes an efficiency of 10% for geothermal electricity, 33% for nuclear, 50% for geothermal heat and 100% for hydro, wind and solar PV. As a result, for the same amount of electricity produced, the TPES calculated for combustible renewables will be several times higher than the TPES for hydro, wind or solar PV.

Despite some growth since 2000, renewables accounted for only 7% of TPES in IEA member countries in 2008. Biomass and hydro still represent the largest shares.

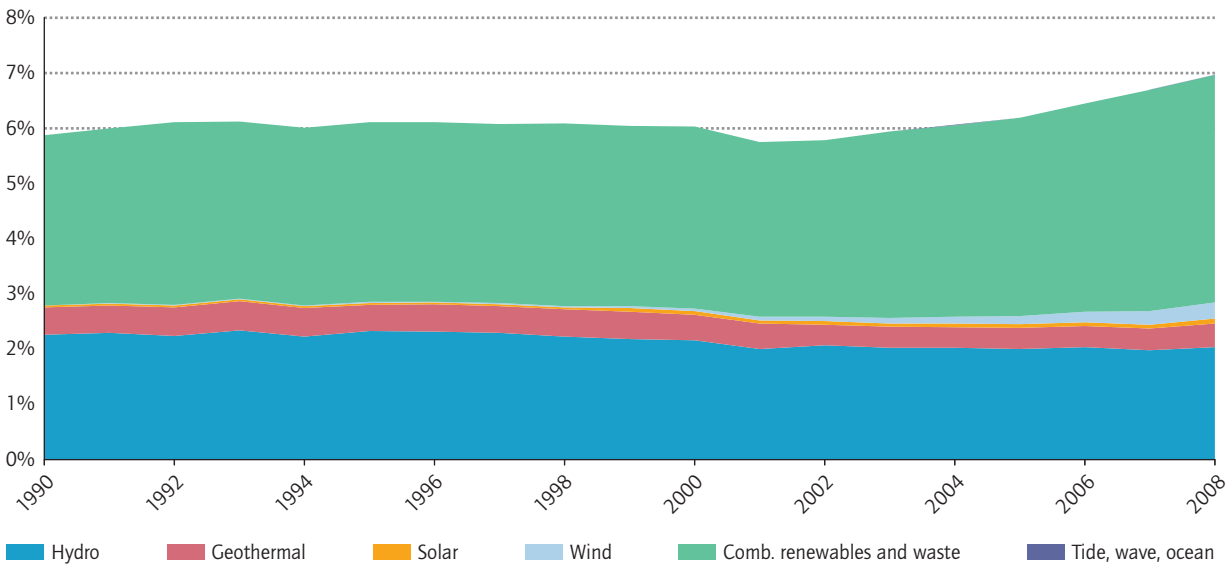
Share of renewables in TPES*



Renewables by share in 2008



Share of renewables in IEA TPES* from 1990 to 2008



** TPES excludes electricity trade.*

Share of renewables in electricity production

▶ Despite a 25% increase in hydro production and rising production from combustible renewables, geothermal, wind and solar, the overall share of renewable sources in total IEA electricity production has not kept pace with the growth of electricity generation from fossil fuels and nuclear. The share of renewables fell from 23% in 1974 to 15% in 2001. However, government policies supporting the deployment of wind, bioenergy and solar projects have helped to reverse this trend, and the share of renewables rose to 16% in 2008.

▶ At present, six IEA member countries obtain more than 50% of their electricity production from renewable sources: Norway (99%), Austria (70%), New Zealand (64%), Canada (61%), Switzerland (57%) and Sweden (54%). Hydro accounts for 80% or more of the total electricity generation from renewables in these countries.

▶ **Hydropower** has always played the most important role in electricity generation from renewable sources. In 1974, hydro accounted for 22% of total IEA electricity production and 98% of production from renewables. Although hydro production increased over time in absolute terms, its share in total renewables decreased to 88% in 1990, then fell even further to 74% in 2008. The decline is largely due to higher growth from other renewables sources, mainly wind and solar, both of which exhibited double-digit growth over the last decade.

▶ Generation from **combustible renewables** (especially solid biomass) is significant in absolute terms in regions with abundant primary resources such as the Nordic countries, Austria and Switzerland. The use of biogas is starting to gain visibility in Germany, the Netherlands, the United Kingdom and Italy.

▶ **Wind** electricity generation expanded considerably in the last decade and now represents a significant portion (between one-third and two-thirds) of electricity generation from renewables in Denmark, Germany, Spain, the Netherlands, Portugal and Ireland.

▶ **Solar** energy has also experienced high growth over the last several years. It is starting to play a significant role in Spain, where both solar PV and concentrating solar power (CSP) capacities are expanding very rapidly. The United States, Japan and Germany are other countries with important generation from solar PV.

▶ Electricity production from **geothermal** sources has not evolved much since 1990, although it remains traditionally important in New Zealand, Italy, the United States and Japan.

▶ *Sources*

- *Renewables Information*, 2009, IEA.
- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

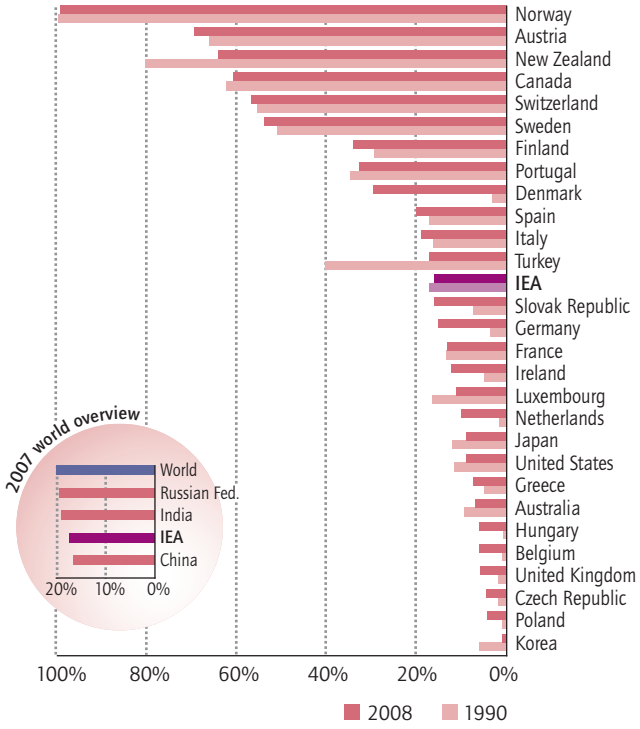
- *Deploying Renewables: Principles for Effective Policies*, 2008, IEA.
- *Empowering Variable Renewables: Options for Flexible Electricity Systems*, 2008, IEA.
- *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*, 2008, IEA.
- *Renewable Energy Essentials*, 2009, IEA.

Share of renewables in IEA electricity generation

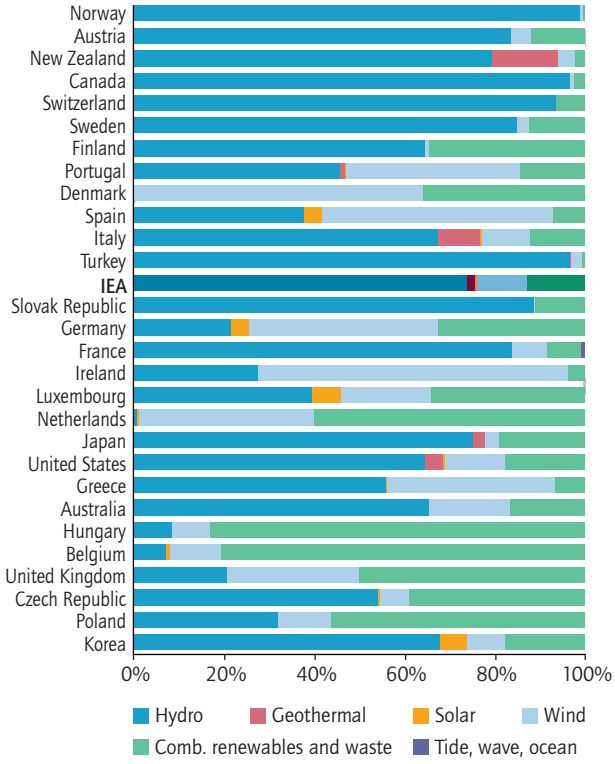
Despite the growth of electricity generation from renewable sources in absolute terms since 1990, its share in total electricity generation decreased for the IEA as a whole until 2001. During this period growth of renewables did not keep pace with growth of fossil-fuel generation. More recent data show that the trend is reversing: since 2001, renewable electricity shares have been slightly increasing, mainly thanks to the accelerated deployment of wind – and, to lesser extent, of biomass and solar.

The share of renewables in total electricity production varies widely amongst IEA member countries – ranging from 1% to 99%, with the average in 2008 being 16%.

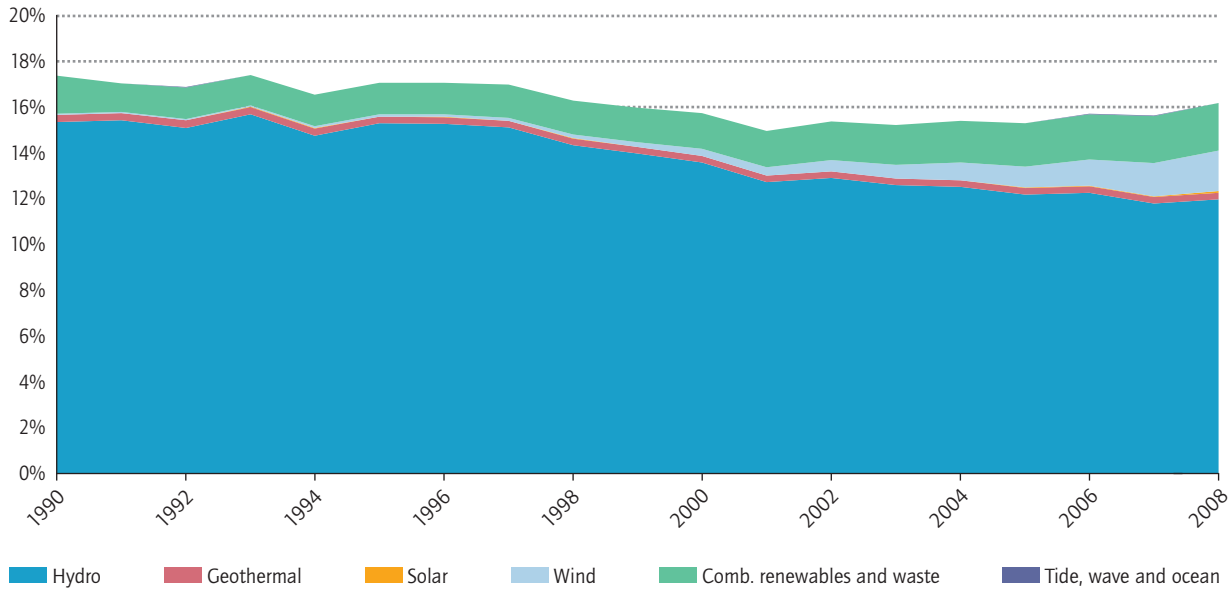
Share of renewables in electricity production



Share of electricity production by renewable energy source in 2008



Share of renewables in IEA electricity production from 1990 to 2008



▶ Hydropower remains a major contributor of renewables energy to the energy mix, and in particular the power mix, of IEA member countries. In 2008, with 1 200 TWh, hydro accounted for 12% of total IEA electricity production.

▶ Over the last 35 years, two distinct trends are evident in electricity production from hydro. From 1974 to 1997, the addition of new dams increased production, with hydro electricity peaking in 1996 97 at 1 300 TWh (up from 990 TWh in 1974). Since then, production has declined by 5%.

▶ Two countries, Canada (30%) and the United States (20%), account for half of total IEA hydro production, followed by Norway (11%) and Japan (6%). In 1974, the United States was the largest producer; in subsequent years, Canada considerably developed its hydro production (from 210 TWh in 1974 to 370 TWh in 2008) to move into first place.

▶ With an additional 160 TWh, Canada experienced by far the highest growth in hydro production since 1974, followed by Norway (63 TWh) and Turkey (30 TWh.) However, the share of hydro in total electricity production has decreased in all three countries. Several other countries (such as Sweden, France, Austria, Turkey, Switzerland New Zealand and Germany) also managed to increase their absolute production of hydroelectricity, but not their shares in total electricity generation.

▶ Although total IEA generation from hydro increased by about 25% since 1974, its share in IEA electricity production decreased, from about 22% to roughly 12%. This is due to higher growth in the production from other energy sources.

▶ Norway generates almost all its electricity from hydro and, not surprisingly, has the highest hydro share (98%) amongst IEA member countries. In 2008, four other countries produced more than half of their electricity from hydro: Canada (59%), Austria (59%), Switzerland (54%) and New Zealand (51%).

▶ Some countries witnessed an absolute decrease in hydroelectricity from 1974 to 2008, notably the United States, Japan, Italy and Spain. This does not necessarily indicate a long-term declining trend, but rather an extended stagnation with a short-term decline due to yearly resource variability.

▶ Hydropower is linked to water availability, and production can change dramatically from year to year. In the United States, for example, hydroelectricity dropped by 14% in 2007 as a result of reduced precipitation in several regions (notably California). A similar drop occurred in 2001.

▶ Sources

- *Renewables Information*, 2009, IEA.
- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ For further information

- *Deploying Renewables: Principles for Effective Policies*, 2008, IEA.
- *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*, 2008, IEA.
- *Hydropower Essentials*, forthcoming, IEA.

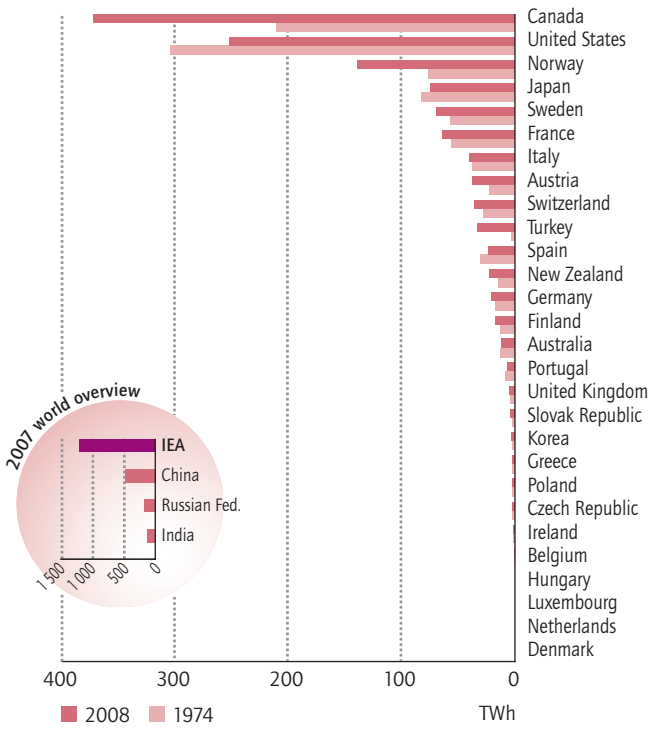
Potential for hydro

Hydropower is the most mature renewable energy technology, and is often seen as having achieved its full potential in industrialised countries. However, this is not the case: recent studies investigating technical potential of hydro suggest that only a few countries (Switzerland, Japan, Sweden, France, Mexico and Norway) have realised 60% or more of their potential.

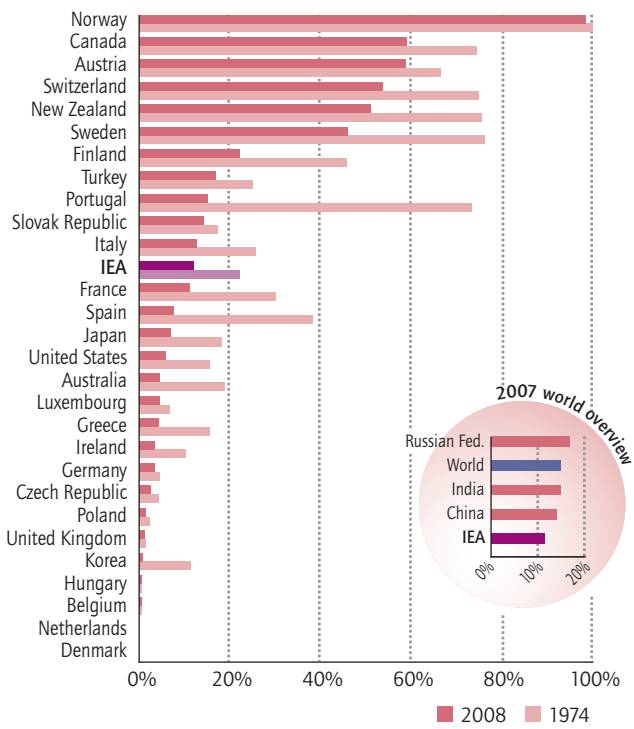
To exploit the significant remaining potential of hydropower it will be important to fully address possible environmental and social impact issues associated with hydropower projects, also duly taking into account the multipurpose use of water resources for non-energy applications. The IEA Implementing Agreement for Hydropower Technologies and Programmes, Annex VIII, has produced a report on Hydropower Good Practices: Environmental Mitigation Measures and Benefits, with 60 Good Practice cases from 20 countries worldwide.

Despite a 25% increase in absolute terms, the share of hydro in electricity production has been almost halved since 1974.

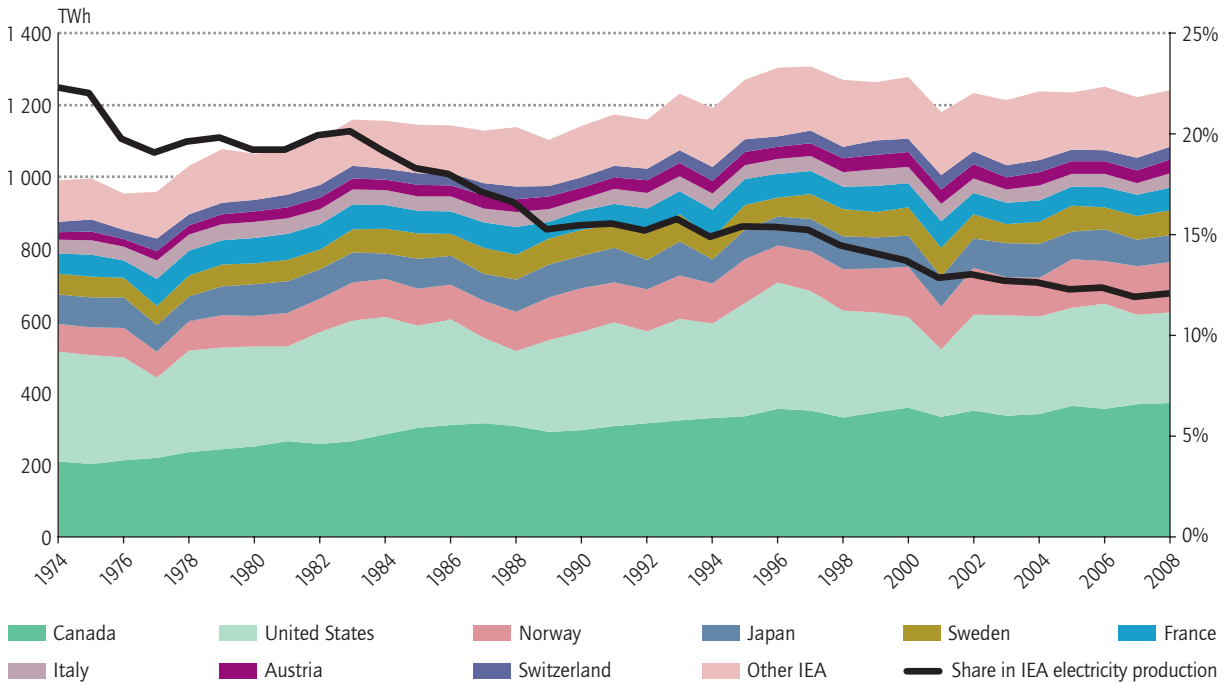
Hydroelectricity production



Share of hydro in total electricity production



IEA hydroelectricity production by country



▶ Wind power and solar electricity are the leading "new" renewable energy technologies. Both have significant potential to reduce emissions of CO_2 and pollutants, while contributing also to energy security and economic growth. They are now beginning to play a role in the global and IEA member country energy mixes, thanks in part to public sector incentives that have facilitated market development (particularly in a number of IEA member countries). In 2008, global new investment in wind electricity reached USD 52 billion; it was somewhat lower for solar electricity, reaching USD 33.5 billion.

▶ In 2008, **wind** turbines produced 11% of total IEA renewable electricity, 66% of which was in Europe. Between 1990 and 2008, wind electricity production increased by 48 times (from 3.8 TWh to 183 TWh) according to IEA statistics. The wind industry reported somewhat higher global production (260 TWh) in 2008.

▶ Installed wind capacity (mainly onshore) has been growing at a rate of 20% to 30% per year since 2000, and reached 121 GW at the end of 2008. Installed capacity was greatest in the United States (25 GW), Germany (24 GW), Spain (17 GW) and China (12 GW). The top two markets in 2008, by a large margin, were the Unites States (8.4 GW) and China (6.3 GW), with India in third place (1.8 GW). Offshore installed capacity topped 1.1 GW, mainly located in Denmark (420 MW), the United Kingdom (300 MW), Sweden (135 MW), the Netherlands (130 MW), Ireland (25 MW) and Germany (8 MW).

▶ Although its contribution to IEA electricity production is still limited (1.8%), wind power has reached significant penetration in a number of IEA member countries. In 2008, wind provided 19% of electricity consumption in Denmark, 13% in Portugal, 10% in Spain, 8% in Ireland and 7% in Germany.

▶ Penetration of **photovoltaic** (PV) power is still very limited, and difficult to assess due to widespread off-grid use. PV capacity has been growing at an average rate of 41% per year since 2000. In 2007, cumulative installed capacity in IEA member countries belonging to the IEA PV Power Systems Programme surpassed 7.8 GW – 11 times that in 2000 (0.7 GW) – with 2.3 GW installed in 2007 alone. Germany (3.8 GW) leads by a significant margin, followed by Japan (1.9 GW), the United States (1.0 GW) and Spain (0.6 GW) where capacity in 2007 increased four-fold.

▶ Worldwide installed capacity of **concentrated solar thermal** electricity reached around 500 MW by the end of 2008. Additional projects were recently completed in Spain and the United States. Several other projects are in construction or in consideration in these two countries, suggesting a new phase in technology deployment.

▶ Installed capacity of **barrage-based tidal** power was 300 MW in 2007. For the first time, commercial-scale tidal stream prototypes in the 1 MW range are undergoing tests. The first-ever commercial scale, floating, wave power plant, of 2.25 MW (3*0.75 MW units), was installed off the Portuguese coast in 2008.

▶ *Sources*

- *Renewables Information*, 2009, IEA.
- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ *For further information*

- *Deploying Renewables: Principles for Effective Policies*, 2008, IEA.
- *Empowering Variable Renewables - Options for Flexible Electricity Systems*, 2008, IEA.
- *Renewable Energy Essentials: PV*, 2009, IEA.
- *Renewable Energy Essentials: Wind*, 2008, IEA.
- IEA Photovoltaic Power Systems Programme, *www.iea-pvps.org.*

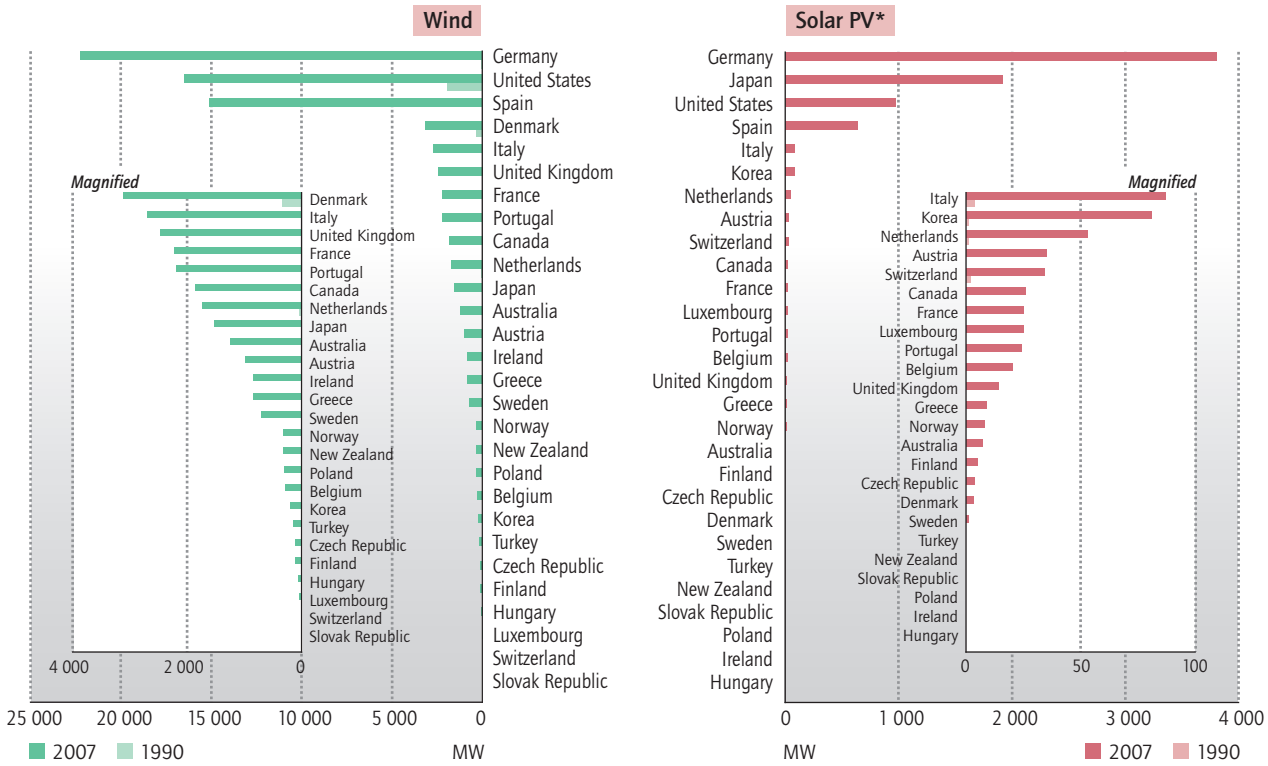
Recent developments in new renewables

Effective deployment policies have helped to boost electricity generation from renewable sources in several IEA member countries. This is especially true for wind and solar PV generation, which have been experiencing double-digit growth rates and are the fastest-growing energy technologies.

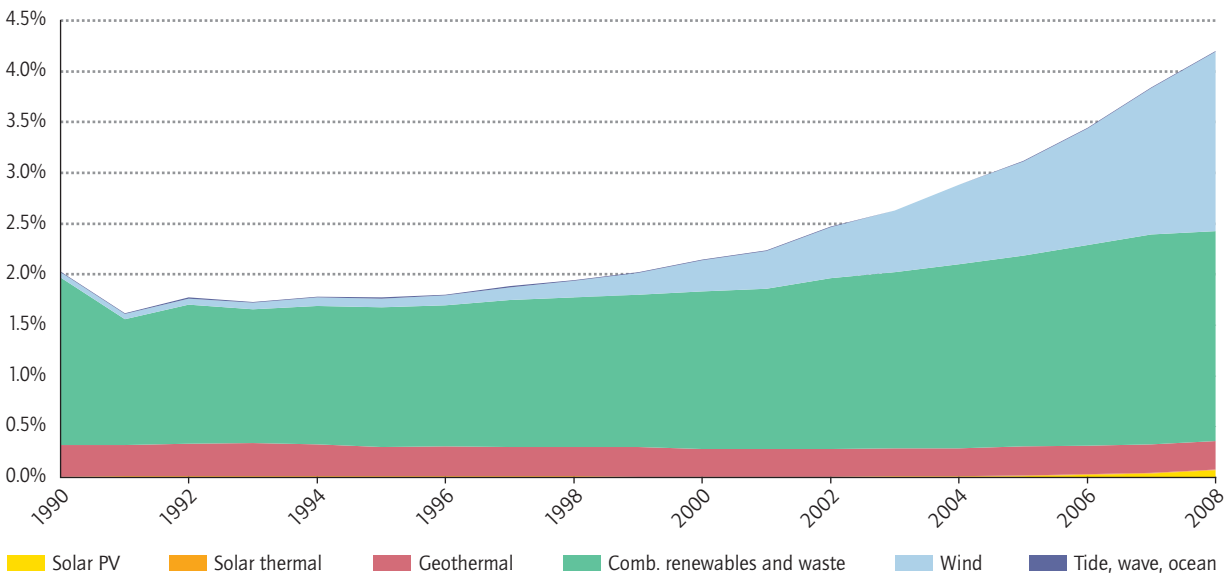
From 2000 to 2007, wind installed capacities in IEA member countries increased at an average yearly growth rate of 26%; the average yearly growth rate of solar PV was 41%.

Between 1990 and 2008, total electricity production from wind increased by almost 50 times, reaching a 2% generation share in 2008.

New renewables installed capacity



Share of non-hydro renewables in IEA electricity production from 1990 to 2008



** Installed capacities come from the annual questionnaires received by the IEA Secretariat from its member countries. However, other sources show large variations in the installed capacity for some countries.*

▶ Liquid biofuels production, mainly for transport applications, has experienced considerable growth in the past few years. The political drivers vary by country but commonly include security of energy supply, greenhouse gas (GHG) emission reductions and support for the agricultural sector.

▶ The total share of biofuels for road transport fuels rose to over 2% of IEA demand in 2007. Since then, there have been signs of slower growth, with several producers significantly reducing production and others declaring bankruptcy.

▶ Bio-ethanol has only about two-thirds of the energy content of gasoline, and biodiesel about 90% to 95% the energy content of mineral diesel. The distance travelled by a vehicle using a litre of biofuels is, therefore, correspondingly less than if burning a litre of petroleum fuels.

▶ Biodiesel growth using mainly locally grown oilseed rape has been particularly high in Germany since 2000 due to strong government incentives, but these have recently been reviewed. As a result, biodiesel blending has been scaled back and the fuel tax increased, with the effect that demand has begun to decline significantly. Biodiesel production in the United States, based largely on soya bean, has grown significantly.

▶ Ethanol production from corn (maize) in the United States also grew rapidly since 2000, and has now surpassed ethanol fuel production from sugarcane in Brazil, the long-time leader. Profitability depends on the relationship between the corn price and the oil price. The high oil prices in 2007-08 offset the high corn prices, so profitability remained. Since then, the oil price has dropped further than the corn feedstock price paid to farmers. As a result, several processing plants have been closed.

▶ Following the United States and Germany, the largest producers of bio-ethanol are Canada, France, Sweden and Spain. The largest producers of biodiesel are France, the United Kingdom, Italy and Poland. Some countries, including the United Kingdom, Italy, Spain, Sweden and Poland have developed a biofuels industry since 2000, usually in response to mandated targets for blending a portion of biofuels with gasoline and diesel.

▶ Many IEA member countries now import biofuels for local blending and consumption. Import duty barriers and blending policies have caused international debate, as have the sustainability of biofuels production and the perceived impacts of competing feedstocks and land use on food prices. Some governments have accordingly revised their biofuel targets downward.

▶ Second-generation biofuels produced from non-food feedstocks (*e.g.* cereal straw and wood residues) remain at the demonstration phase and provide less than 1% of total biofuels.

▶ Sources

- *Renewables Information*, 2009, IEA.
- *Oil Market Report*, 10 April 2009, IEA.

▶ For further information

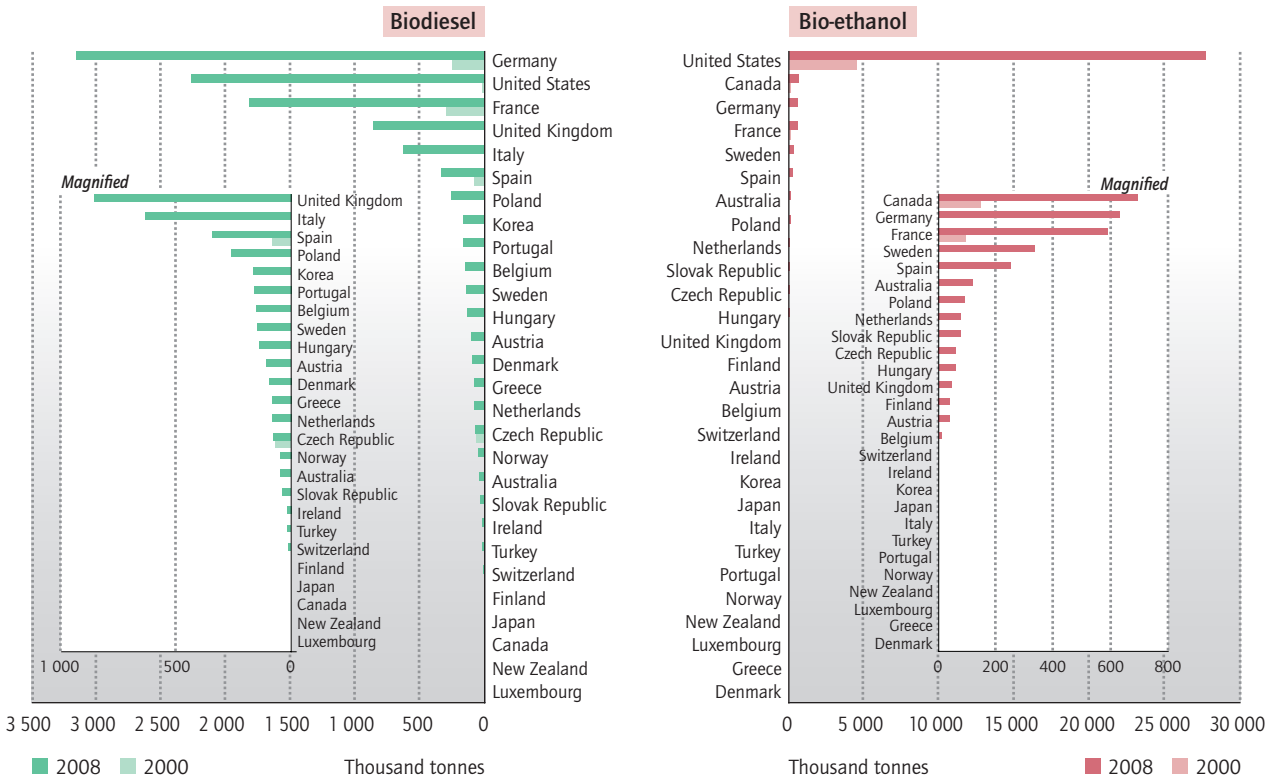
- *Bioenergy Project Development and Biomass Supply: Good Practice Guidelines*, 2007, IEA.
- *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*, 2008, IEA.
- *Economic Assessment of Biofuel Support Policies*, 2008, OECD.
- *From 1st- to 2nd- Generation Biofuel Technologies*, 2008, IEA.

Biofuels and potential greenhouse gas emission reductions

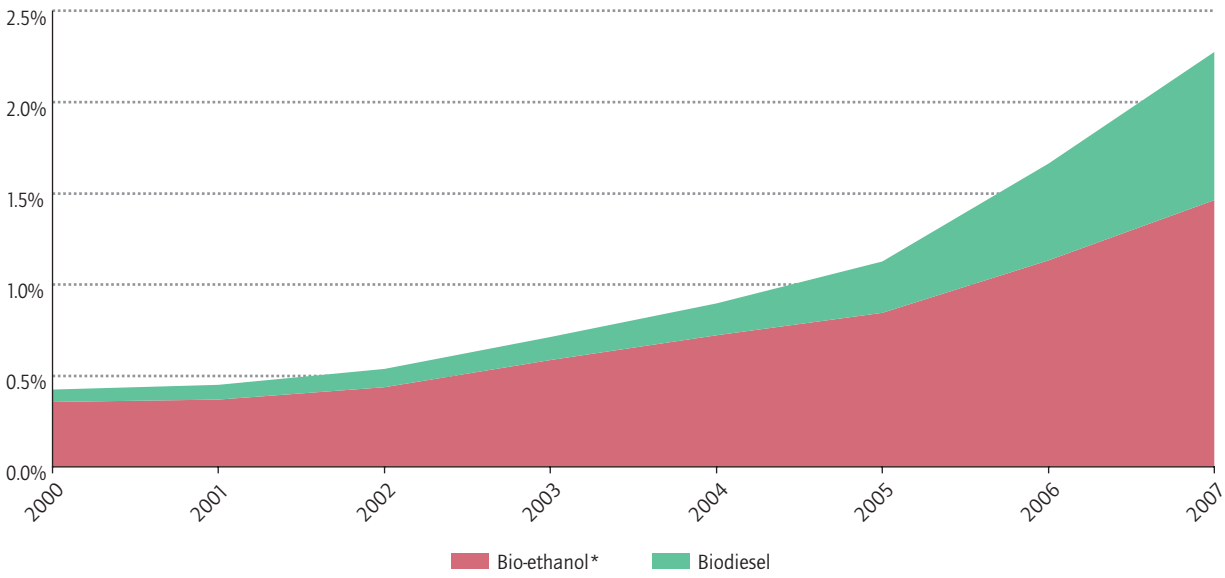
*The potential of various biofuels to reduce greenhouse gas (GHG) emissions has been the subject of many detailed life-cycle analyses. Reductions (excluding land-use change), when compared with emissions from gasoline consumption, vary from as high as 90% of total GHG for some biofuels (*e.g. *sugarcane ethanol) to below 20% (*e.g. *corn ethanol). Key variables include: crop yields, co-products, process energy inputs, fuel types and production, and transport and storage methods. However, direct and indirect land-use change can have a far greater impact on GHG emissions, and requires full evaluation.*

The share of biofuels in road transport increased from less than 0.5% in 2000 to more than 2% in 2007, with a sharp rise in biodiesel since 2005.

Production of biofuels for transport



Share of biofuels in IEA road transport from 2000 to 2007



** Bio-ethanol includes other biofuels that are blended with gasoline.*

Improved energy efficiency

Improved energy efficiency

D

TPES per capita

▶ With about 5 toe per capita, IEA member countries have the highest energy consumption per capita, almost three times more than the world average. IEA consumption per capita is just ahead of the Russian Federation, but more than nine times that of India. However, in relative terms, IEA consumption per capita has increased moderately (14%) over the last 35 years, much less than many regions (the Middle East and Asia, for instance) and emerging countries (China in particular).

▶ Several factors explain the gap in absolute terms between the IEA and other regions/countries: a much higher starting point in 1974 (4.2 toe per capita); the structure of the respective economies; a higher GDP per capita; the level of development; climate; and the energy mix.

▶ A wide range of consumption per capita is evident within IEA member countries, from 8.5 toe per capita in Luxembourg to 1.3 toe per capita in Turkey. Except for Luxembourg where fuel tourism (due to lower taxation of gasoline and diesel oil) artificially increases the consumption per capita, the other five countries in the top six IEA consumers are either large countries in terms of area or colder countries (Nordic countries, for instance) or both as in the case of Canada.

▶ As for the lower IEA consumers, five out the top seven are Mediterranean countries that have lower demand for heating. It should be noted that Portugal experienced the second-highest growth (+185%) in consumption per capita since 1974, followed by Greece, Turkey and Spain. Consumption in all these countries is approaching levels seen in other IEA member countries.

▶ Korea experienced by far the largest increase (+593%). Several factors explain this dramatic rise: low consumption in 1974 compared to other IEA member countries; impressive development of its industry and commercial and public services sectors; and a major jump of its GDP per capita.

▶ Almost all IEA member countries experienced an increase of consumption per capita. Decreases noted in six countries can be explained on a case-by-case basis, taking account of factors such as higher starting points in 1974, changes in economic structure, changes in energy mix, or gains in energy efficiency.

▶ Sources

- *National Accounts of OECD Countries*, Volume 1, 2009, OECD.
- *World Development Indicators*, 2009, the World Bank.
- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ For further information

- *World Energy Outlook*, 2009, IEA.

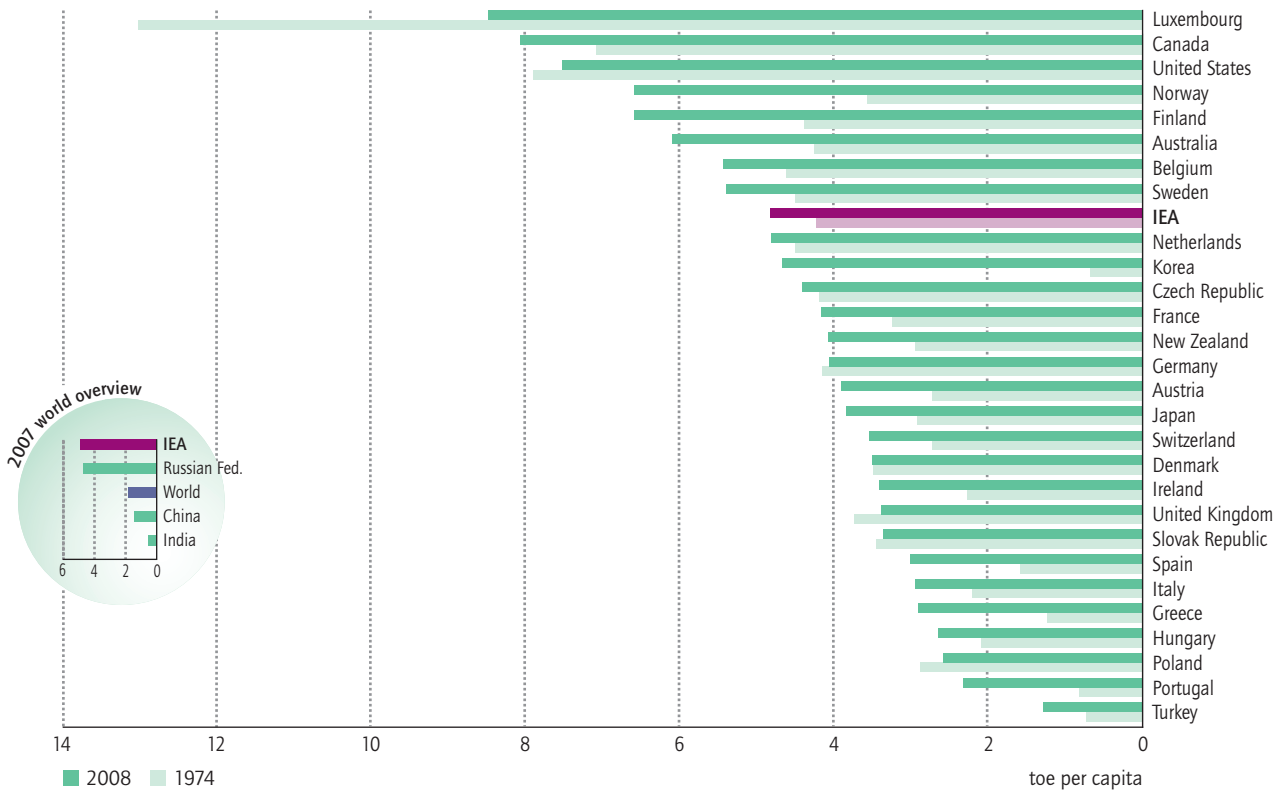
Fuel tourism

Gasoline and diesel price differentials between neighbouring countries have encouraged a phenomenon known as "fuel tourism". People living in border regions of countries with relatively high fuel taxes have an incentive to drive across the border to buy cheaper fuel with lower taxes.

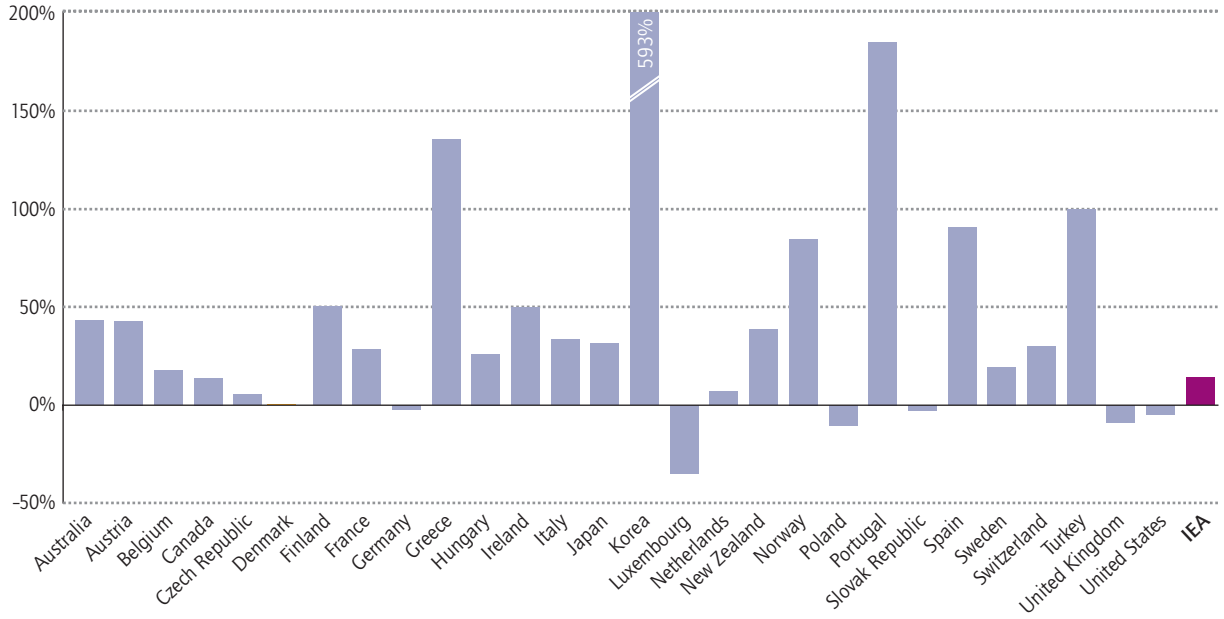
In IEA Europe, the European Commission has been working to harmonise taxes on gasoline and diesel to dissuade this practice. In North America, although there are price differentials between countries, the impact of fuel tourism on total consumption is more limited due to the size of the three countries.

Average energy consumption per capita in IEA member countries has increased by 14% since 1974, a much lower rate than the 45% GDP growth. The consumption per capita varies considerably between countries.

Total primary energy supply per capita



Percentage change in TPES per capita between 1974 and 2008



TPES per GDP

▶ Energy intensity is often (although wrongly) associated with energy efficiency, and used to assess (if not to measure) how efficient the use of energy is in a country. The energy intensity of an economy is a measure of how much energy is required to produce each unit of national revenue – in this report, measured using the US dollar (USD). Efficiency is a contributing factor in intensity, but many other elements – often more significant – need also be considered. These include: the structure of the economy (presence of large energy-consuming industries, for instance); the size of the country (higher demand from the transport sector); the climate (higher demand for heating or cooling); and the exchange rate. In order to take into account the impact of the purchasing power parity (PPP) on the intensity of the countries, intensity can also be expressed in GDP PPP.

▶ Between 1974 and 2008, overall IEA intensity dropped by 41%, from 0.30 to 0.18 toe per 1000 USD. This reflects changes in the economic structure of most IEA member countries (less industry and more services, especially with the delocalisation of high-consuming industries) combined with the savings of almost 60% from energy efficiency programmes. In fact, in 2007 the IEA had the lowest intensity (TPES per GDP) of the main countries and regions, slightly more than half of the world average (0.31 toe per 1000 USD).

▶ All IEA member countries but three (Greece, Korea and Portugal) have experienced a decrease in their energy intensity since 1974. Intensity increased in these three countries as they "caught up" with other IEA member countries in terms of industrialisation and, more generally, economic development. These countries also showed the highest increases in terms of TPES per capita.

▶ The four IEA Eastern European countries (Czech Republic, Slovak Republic, Hungary and Poland) recorded the highest energy intensities, between two to three times higher than the average IEA intensity. This is largely due to the comparatively low GDP and low efficiency in some sectors. Yet it is interesting to note that these four countries are also amongst those showing the greatest reduction in energy intensity since 1974. Again, the decrease can be attributed to economic restructuring and energy efficiency policies. By contrast, Switzerland reported the lowest intensity, due in part to a service sector with high value added.

▶ Intensity trends in IEA member countries are somewhat different when compared using GDP expressed on a PPP basis. The decrease in the average intensity is the same as for GDP using market exchange rates, but large variations are evident in the countries' respective levels of intensity. Contrary to TPES per GDP using MERs, when using GDP PPP, Canada had the highest intensity and Ireland the lowest in 2008.

▶ Sources

- *National Accounts of OECD Countries*, Volume 1, 2009, OECD.
- *World Development Indicators*, 2009, the World Bank.
- *World Energy Balances* on-line data service, 2009, *http://data.iea.org*, IEA.

▶ For further information

- *World Energy Outlook*, 2009, IEA.

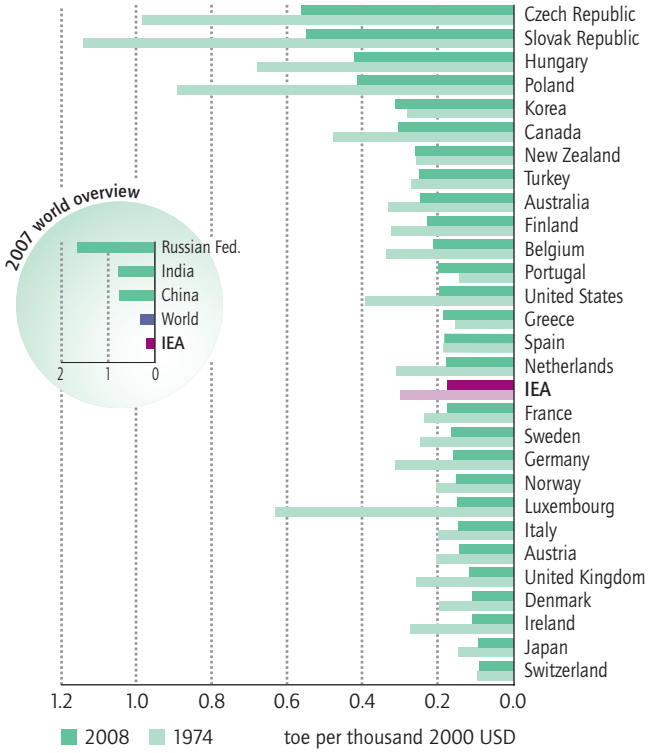
Energy intensity versus energy efficiency

TPES per GDP or TPES per GDP PPP is used to measure the energy intensity of a country's economy. Because TPES and GDP are numbers that are readily available for any country, the energy intensity is often used as a proxy for energy efficiency. This is a mistake, however, since it is not because a given country has a low energy intensity that its efficiency is high. For instance, a small service-based country with a mild climate would certainly have a much lower intensity than a large industry-based country in a very cold climate, even if energy is consumed less efficiently in the first country than in the second.

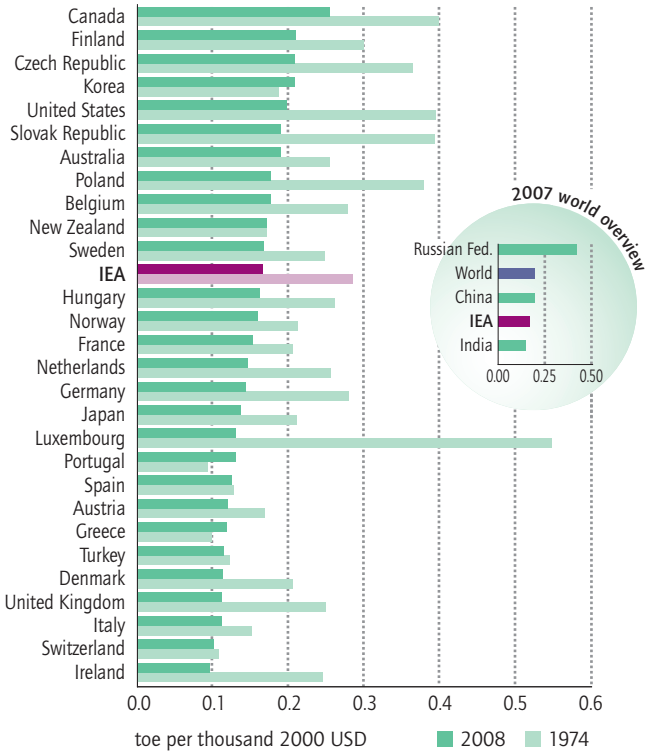
Energy efficiency is difficult to assess for a country as a whole. It is a concept associated with specific sectors and end-uses, and requires more detailed data.

Decoupling of energy consumption and GDP growth is linked to delocalisation of energy-intensive industries, a shift to a service-based economy, and improved energy efficiency.

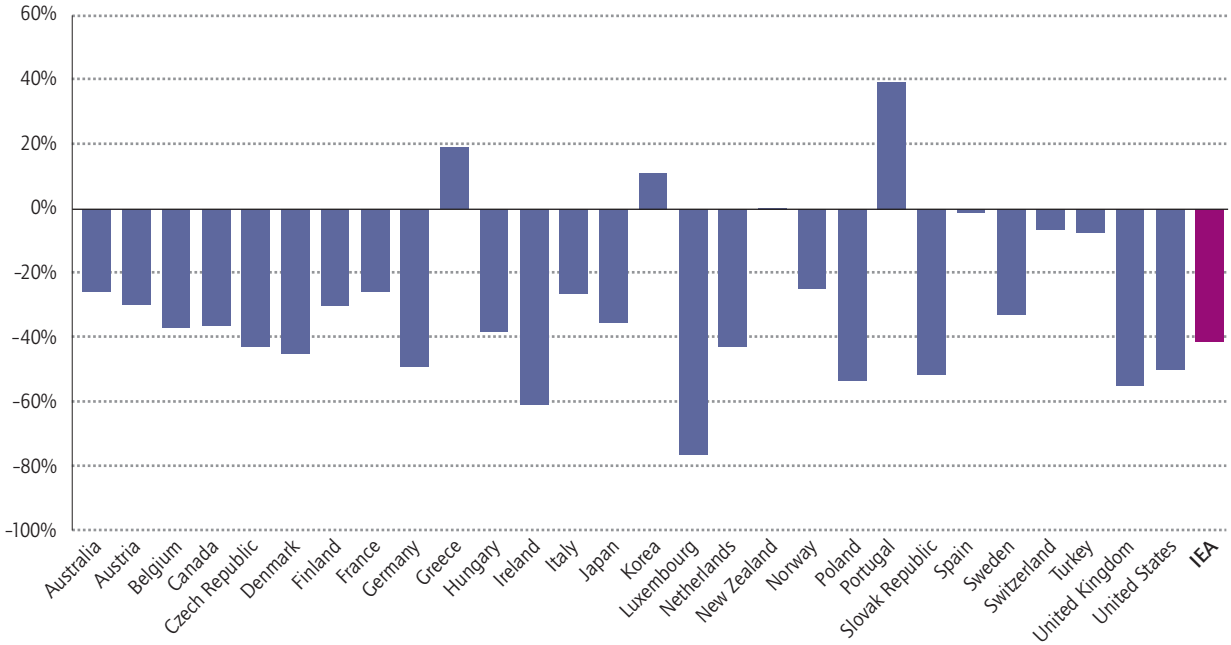
TPES per GDP



TPES per GDP PPP



Percentage change in TPES per GDP between 1974 and 2008



Energy efficiency savings in IEA member countries

▶ Over the last 35 years, IEA member countries have experienced an uncoupling of the growth in energy demand and the growth in GDP. The aggregate energy intensity (energy use per GDP) fell by 41% while GDP increased by 144%.

▶ One of the most important issues from an energy policy perspective is, therefore, to understand to what extent improvements in energy efficiency have contributed to the decline in final energy intensity. It would be misleading to use the aggregate intensity indicators to assess efficiency, as intensity is affected by numerous factors not directly related to energy such as climate, geography, travel distance, home size and manufacturing structure.

▶ Better understanding of the factors affecting energy use over time, including the role of energy efficiency, requires indicators based on more detailed data than are available in the IEA statistical balances. This more detailed information is currently available, on a comparable basis, for 17 IEA member countries (IEA17) for the period 1974 to 2006.

▶ These disaggregate indicators show that improved energy efficiency has been the main reason for the decoupling of energy use and GDP in these countries. Without the efficiency improvements that occurred between 1974 and 2006 in 11 of those countries (for which data are available for this period), energy use would have been 58% higher in 2006 than it actually was.

▶ Energy efficiency gains for the 17 IEA member countries analysed were about 1.9% per year from 1974 to 1990. Subsequently, lower energy prices have had a negative impact on efforts to increase efficiency; between 1990 and 2006, the gains decreased significantly to 1% per year.

▶ In the decomposition approach used by the IEA, changes in aggregate intensity in each country are attributed to changes in the ratio of energy services to GDP (structure) and to changes in specific energy intensity. The results show that both structure and energy efficiency contributed to reduce aggregate intensity, with each factor contributing differently depending on the period. Energy efficiency accounted for 65% of the total decline.

▶ The relative contribution of structure and efficiency to the overall trend varies among countries. With the exception of Italy and Spain, all countries analysed show that the energy efficiency effect contributed to reducing the ratio of energy use to GDP: for most, it was the dominant factor.

▶ The reasons for the different trends in energy efficiency amongst countries are complex. Canada and the United States had high levels of energy intensity in 1990; they are now slowly converging with the IEA average. Denmark and Japan initially had lower intensities, and so have experienced smaller declines. In Italy, increased energy intensity in the services sector more than offset reductions in other sectors. In Spain, residential and transport were the main drivers of the increase.

▶ *Source*

- IEA Indicators Database, 2009, IEA.

▶ *For further information*

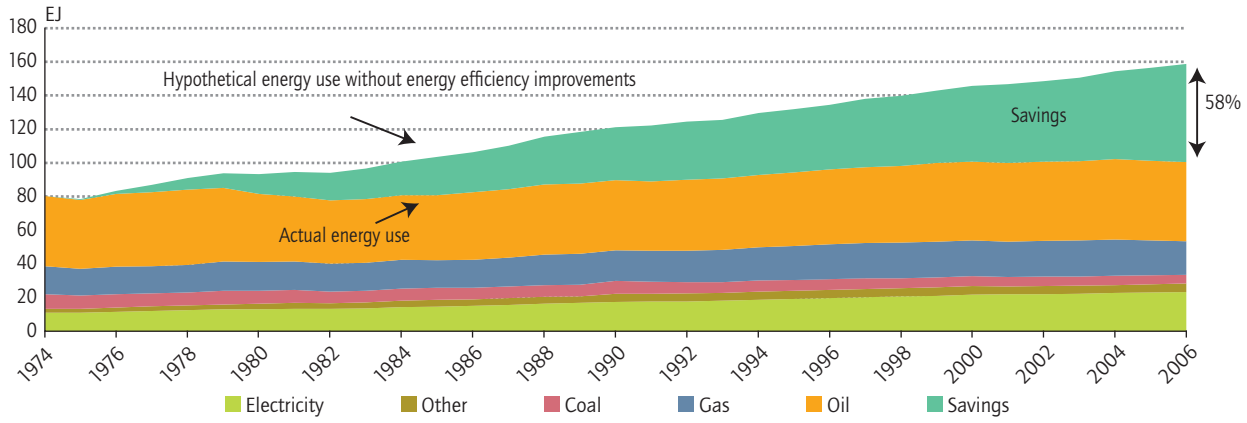
- *Energy Use in the New Millennium*, 2007, IEA.
- ODYSSEE database on energy-efficiency indicators, *www.odyssee-indicators.org.*
- *Worldwide Trends in Energy Use and Efficiency* (Brochure), 2008, IEA.

Factors affecting final energy consumption

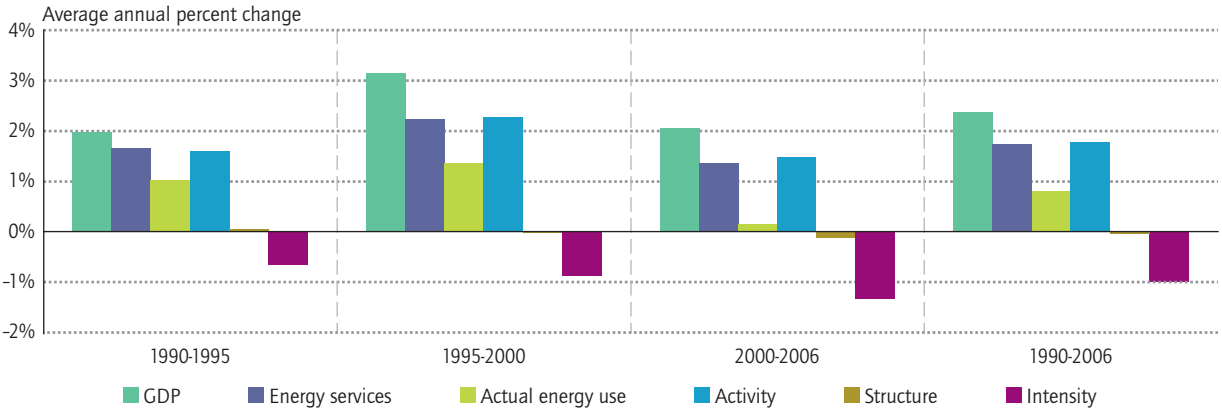
The IEA methodology for analysing trends of energy end-use distinguishes among three main components affecting energy use: activity levels, structure (the mix of activities within a sector) and energy intensities (energy use per unit of sub-sectoral activity, a proxy for energy efficiency). Depending 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 activity, energy intensities are then calculated for each of these sub-sectors, modes or end-use activities.

Without the efficiency improvements that occurred between 1974 and 2006, energy use in 11 IEA member countries would have been 58% higher in 2006 than it actually was.

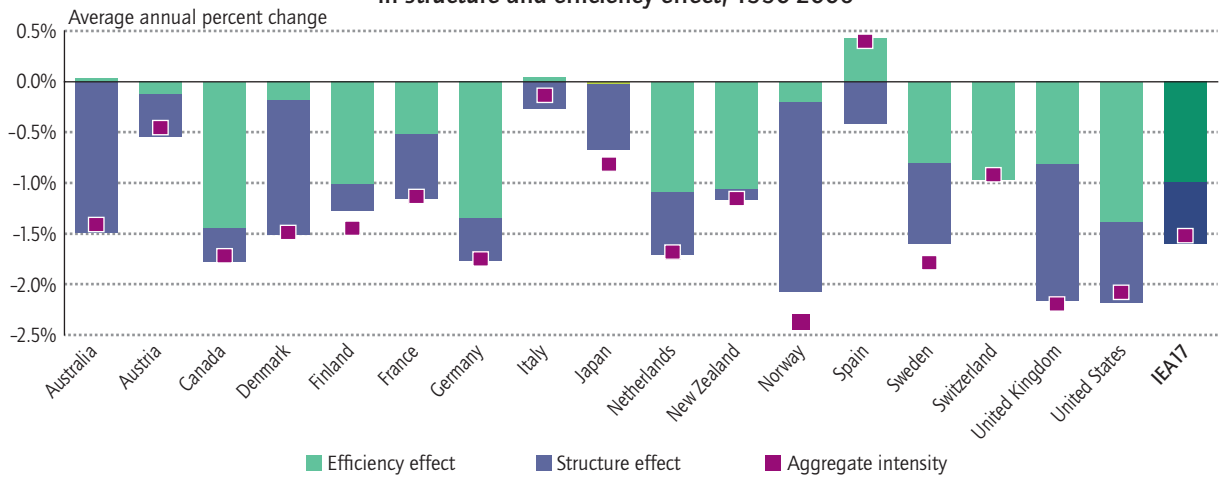
Long-term energy savings from improvements in energy efficiency, IEA11*



Factors affecting final energy consumption, IEA17*



Changes in aggregate intensity decomposed into changes in structure and efficiency effect, 1990-2006



** See Annex 2 for list of countries included in IEA groupings.*

Energy intensity in manufacturing industries

▶ A measure of aggregate manufacturing energy intensity (not efficiency) can be obtained by dividing total manufacturing energy use by total manufacturing value-added. Final energy use in industry can either include or exclude energy consumed in coke ovens, blast furnaces and steam crackers as well as feedstocks for the production of synthetic organic products. This analysis includes energy consumed but excludes feedstocks.

▶ To have a real comparison of efficiency between countries, detailed data are needed on both energy use and corresponding physical output per sub-sector and per product. At present, such data, unfortunately, are not available for most IEA member countries. There is a strong need to collect this information to facilitate more meaningful analysis.

▶ For a group of 21 IEA member countries for which consistent data are available, the aggregate energy intensity in manufacturing fell by 32% between 1990 and 2006, an average rate of 2.3% per year. This reflects a strong decoupling of energy use from output (as measured by value-added). Despite a 39% increase in output, final industrial energy consumption decreased by 0.6%.

▶ All countries analysed, except Australia, Portugal and Spain, showed reductions in their energy intensity. Variations in aggregate intensity can be explained, at least to some extent, by two main factors: the differences in the composition of the manufacturing sector (the structure effect) and the relative intensity of each sub-sector.

▶ Across this group of countries, the composition of the industrial sector changed gradually through the 1990s and into the early part of the current decade. There was a rapid increase in the share of several less energy-intensive sub-sectors, which contributed to the decoupling of energy use and value-added.

▶ IEA member countries for which data are available show significant differences in the composition of their manufacturing sector. In several countries (including Australia, Canada, Norway, Spain and Sweden), more than one-third of total output comes from the production of primary materials. By contrast, in Germany and Italy these sub-sectors account for less than one-quarter of total manufacturing output.

▶ In most countries, energy efficiency improvements (as measured by changes in the structure-adjusted intensities) were the main factor restraining growth in energy consumption over the past decade. The rate of decline in the structure-adjusted energy intensities averaged 1.6% per year for the countries analysed. However, this reduction was significantly lower than it was from 1974 to 1990.

▶ A few of the countries analysed showed results that differ from the overall trends. For example, 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.

▶ *Source*

- IEA Indicators Database, 2009, IEA.

▶ *For further information*

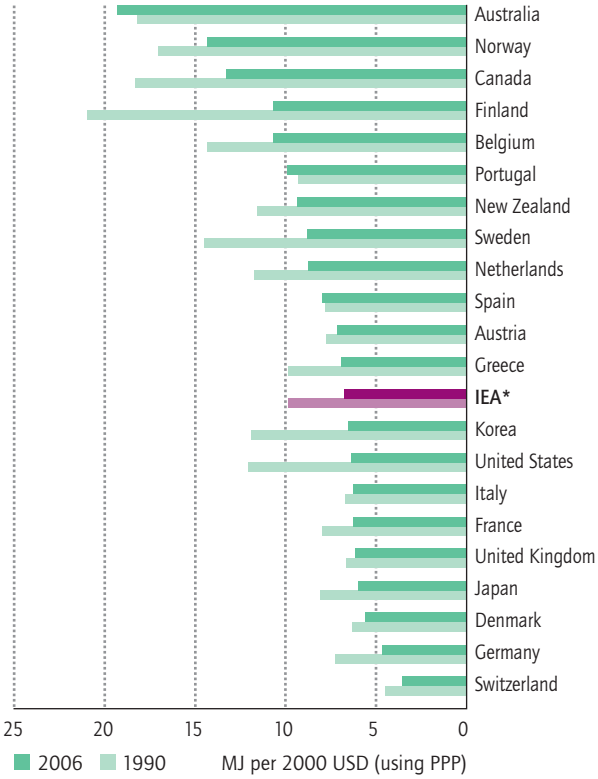
- ODYSSEE database on energy-efficiency indicators, *www.odyssee-indicators.org*.
- *Tracking Industrial Energy Efficiency and CO_2 Emissions*, 2007, IEA.
- *Worldwide Trends in Energy Use and Efficiency* (Brochure), 2008, IEA.

Technical potential for reducing energy use in intensive industries

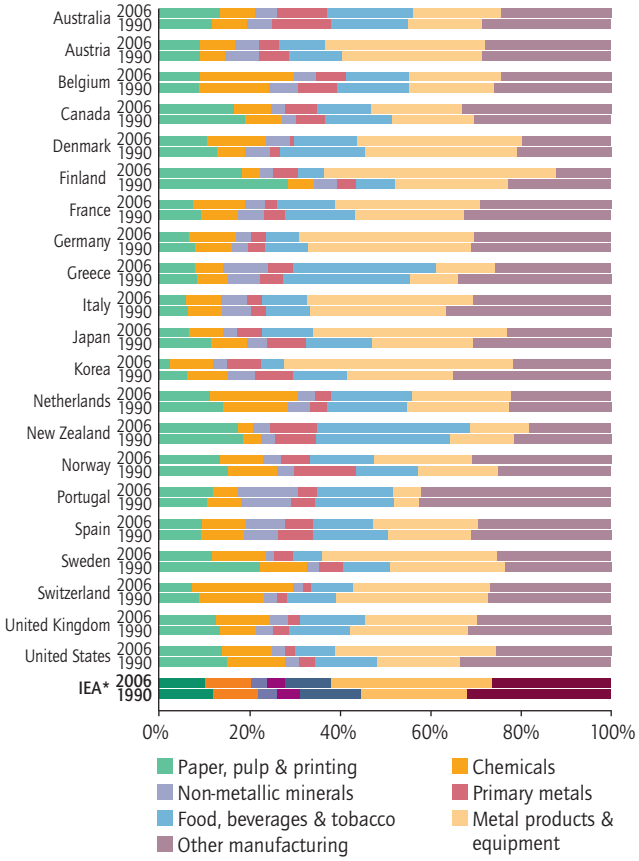
The IEA Secretariat has developed disaggregated indicators for energy-intensive sectors such as iron and steel, cement, pulp and paper, chemicals and petrochemicals, and aluminium. These indicators are used to track energy efficiency progress over time, and also to calculate the technical potential for energy reductions that could be achieved by moving to "best available" or "best practice" technologies. Analysis of the indicators shows that the application of such technologies in these intensive sectors could reduce final energy consumption by 13% to 29%. Total estimated savings for the five sectors analysed is equivalent to 13% of total IEA industrial energy consumption in 2006.

Decoupling of energy use and value-added in the industry sector was caused by a rapid increase of several less-intensive sub-sectors and efficiency improvements.

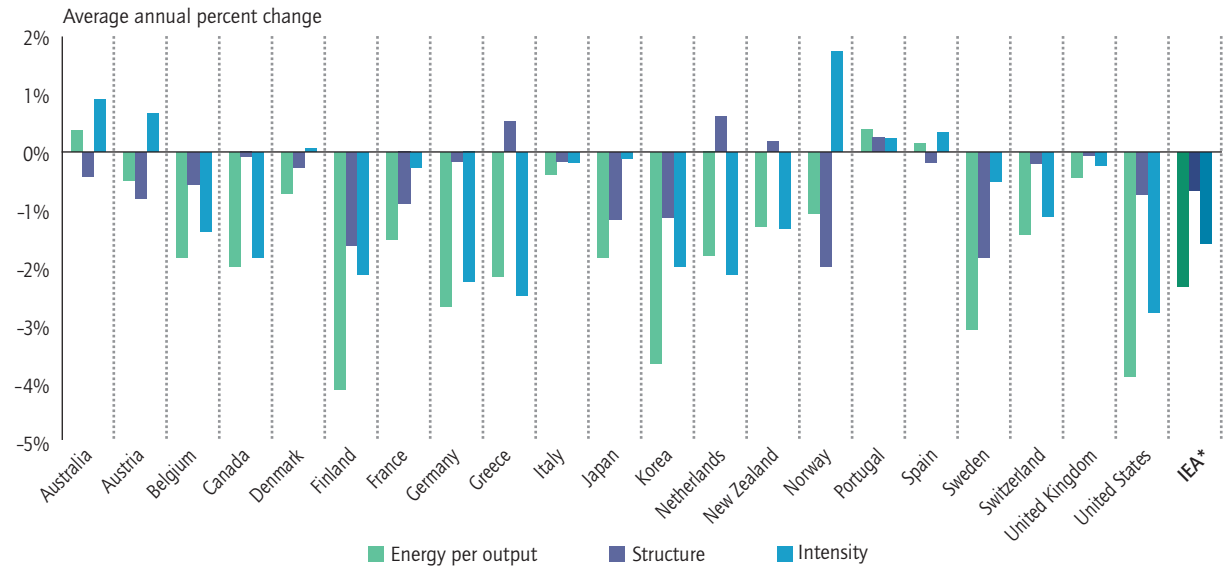
Manufacturing energy use per value-added



Composition of manufacturing value-added



Decomposition of changes in industrial energy intensity, 1990-2006



** IEA average is limited to countries shown in graph.*

Energy efficiency in freight transport

▶ For 19 IEA member countries for which comparable data are available, freight transport accounts for roughly one-third of energy use in the IEA transport sector and one-half of the consumption for IEA passenger transport. Freight consumption, largely dominated by trucks with 83% of the sector's demand, increased by 31% between 1990 and 2006.

▶ Freight haulage, as measured by tonne-kilometres (tkm), increased by 39% between 1990 and 2006, mostly due to an increase in trucking in these 19 IEA member countries. Trucks accounted for 45% of total freight haulage, followed by rail (38%) and water (18%). However, the respective shares vary dramatically from country to country, largely in relation to factors such as the size of the country, the length of coasts, the network of large rivers and the development of the rail network.

▶ For instance, lower shares can be observed in terms of tkm for trucks in large countries with coasts and rivers, such as Canada and the United States, where shipping accounts for large portions of freight. By contrast, truck shares are typically higher for smaller countries with less favourable rivers such as Ireland or Denmark. Switzerland has a strong policy for encouraging rail (including trucks on trains) and, thus, has the second-highest share for rail (43%). The Netherlands, with large ports and a well-developed network of canals, has the highest share for ships – more than half of its freight haulage.

▶ The energy intensities of trucks, ships and rail vary significantly, with trucks being the most intensive. On average, trucks use up to 16 times more energy than rail to move one tonne of goods. Taking into account the specific intensity of each mode, the energy intensity of freight transport for the countries analysed as a whole declined by 5% between 1990 and 2006. In effect, reductions in the intensity of individual modes more than offset the increased share of energy-intensive trucking.

▶ The large differences in country intensities reflect many factors, but particularly the relative importance of trucking versus rail. Countries with the lowest intensities (Australia, Canada and the United States) have high shares of rail transport. Conversely, the highest energy intensities are generally found in smaller countries with low shares of rail freight (Greece and Denmark, for example).

▶ Because of the importance of trucking in the freight sector, its intensity is a main driver of the overall energy-use pattern of freight transport. The range for energy intensity of trucking reflects numerous factors such as the type of goods moved, the size and geography of the country, average load factors, vehicle fuel efficiency and driving behaviour, as well as the split between urban delivery trucks and long-haul trucks (the latter of which are much larger and less energy intensive).

▶ Given the importance of long-distance haulage, Australia and the United States have lower energy intensities for freight trucking. Smaller hilly or mountainous countries, such as Greece, New Zealand and Norway, tend to have higher truck energy intensities.

▶ *Source*

- IEA Indicators Database, 2009, IEA.

▶ *For further information*

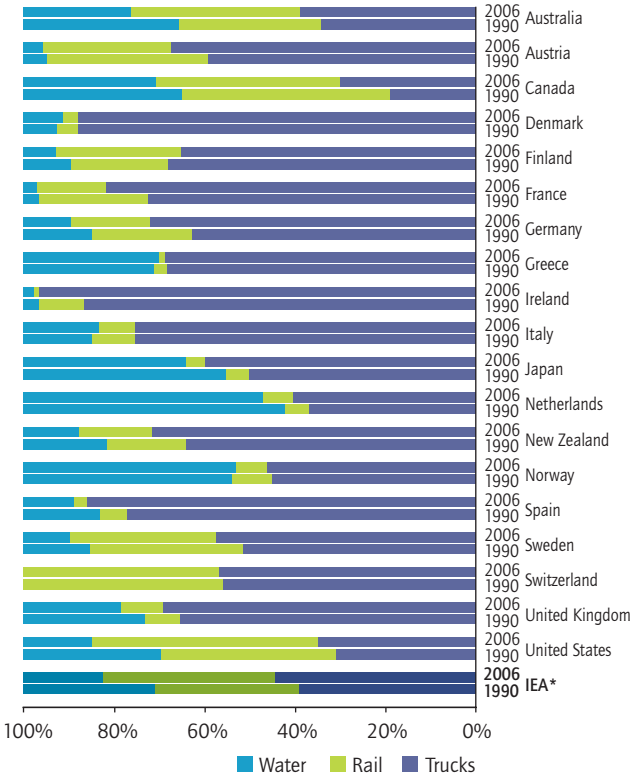
- ODYSSEE database on energy-efficiency indicators, *www.odyssee-indicators.org*.
- *Worldwide Trends in Energy Use and Efficiency* (Brochure), 2008, IEA.

Energy intensity of freight transport

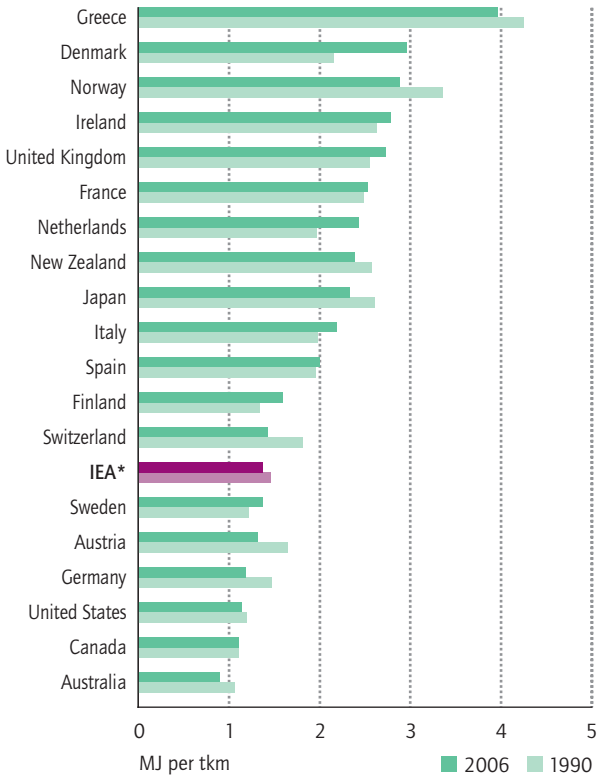
Overall energy intensity in the freight transport sector is the ratio of overall energy use divided by the overall number of tonne-kilometres (tkm). One tkm is the transport of one tonne of freight over a distance of one kilometre. For example, if a truck carries a load of three tonnes over two kilometres, the total tkm is six (but only two vehicle-kilometres). The load factor, e.g. *the number of tonnes carried by a truck is, thus, an important driver of energy intensity: a higher load factor will result in lower intensity.*

Despite a higher share of road in freight transport, more efficient trucks and freight management have reduced the overall energy consumption per tonne-km.

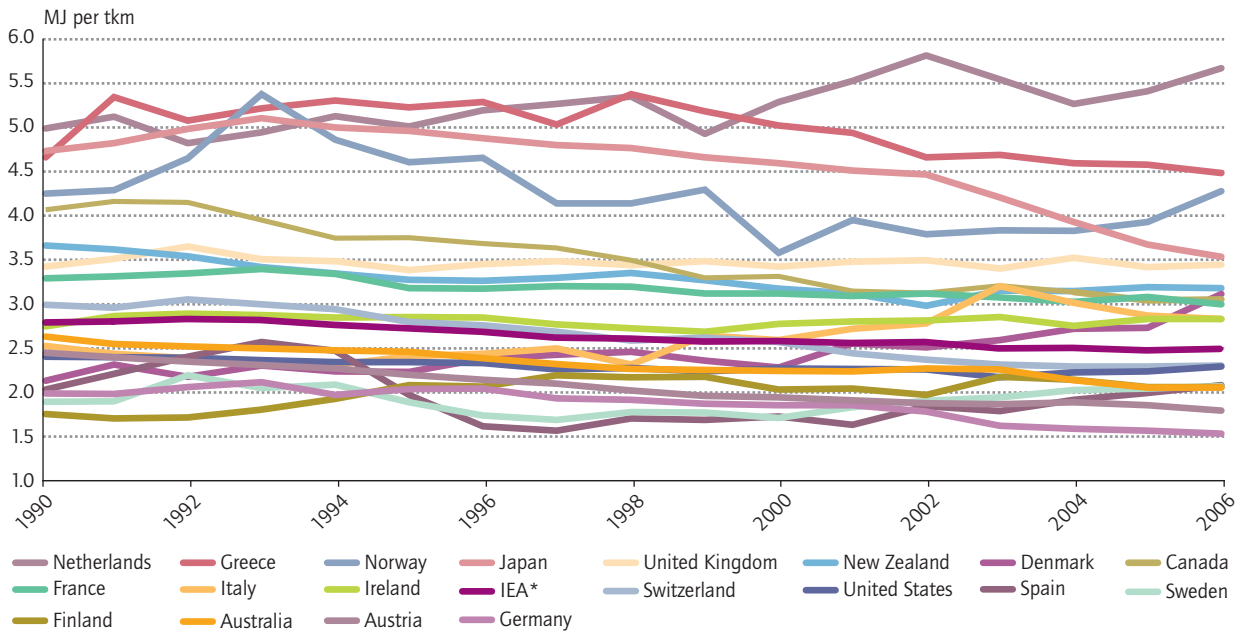
Share of tonne-km by transportation mode



Freight transport energy per tonne-km



Truck freight energy intensity



** IEA average is limited to countries shown in graph.*

Energy efficiency in passenger transport

▶ The transport sector (including both passenger and freight) accounts for roughly one-third of total IEA final energy consumption. According to 2006 data for the 19 IEA member countries for which time series data are available, 68% of the sectoral consumption goes to passenger transport. Thus, passenger transport accounts for almost one-quarter of final energy consumption in these countries.

▶ Passenger (as opposed to freight) transport accounts for a much higher share of IEA oil consumption, due to the massive dominance of cars, planes and buses (all of which depend almost exclusively on petroleum products). As a result, the share of passenger transport can reach 49% of total final oil consumption in the countries analysed. Thus, it is important to look closely at this sector when defining policies to decrease oil consumption.

▶ Many factors, such as travel patterns (including passenger travel activity), income levels, car ownership rates and average fuel economy, affect the level of passenger transport energy use. Passenger travel activity, one of the key factors, in these countries increased by 32% between 1990 and 2006, in line with the 24% increase of energy consumption for the passenger transport sector.

▶ The share of travel by mode differs from country to country, reflecting diverse demographic and geographic characteristics as well as different levels of provision for urban and intercity transport. For all countries analysed but one, cars accounted for more than 70% (and often more than 80%) of passenger-kilometres. Japan stands out because of the large share (28% in 2006) of passenger-kilometres travelled by rail.

▶ The share of each mode, together with its respective energy intensity, influences the trend in the overall energy intensity for passenger transport. From 1990 to 2006, the energy intensity of transport decreased by 6%. The reduction in the energy intensity of individual modes offset the increase in the share of car and air travel, both of which are more energy intensive than rail. In 2006, France, Italy and the United Kingdom had the lowest intensities. Despite large decreases in recent years, New Zealand, Canada and the United States were amongst the most intensive countries analysed.

▶ Cars (with an 86% share) are by far the largest energy user; thus, it is important to focus on the fuel intensity of new cars. In most countries, the fuel intensities of new cars decreased, even though the levels of intensity vary greatly from country to country (generally being lower in Europe and higher in Australia and North America). This higher intensity can be explained by consumer preferences toward bigger vehicles to drive longer distances.

▶ *Sources*

- IEA Indicators Database, 2009, IEA.
- IEA Mobility Model (MoMo), 2009, IEA.

▶ *For further information*

- ODYSSEE database on energy-efficiency indicators, *www.odyssee-indicators.org.*
- *Worldwide Trends in Energy Use and Efficiency* (Brochure), 2008, IEA.

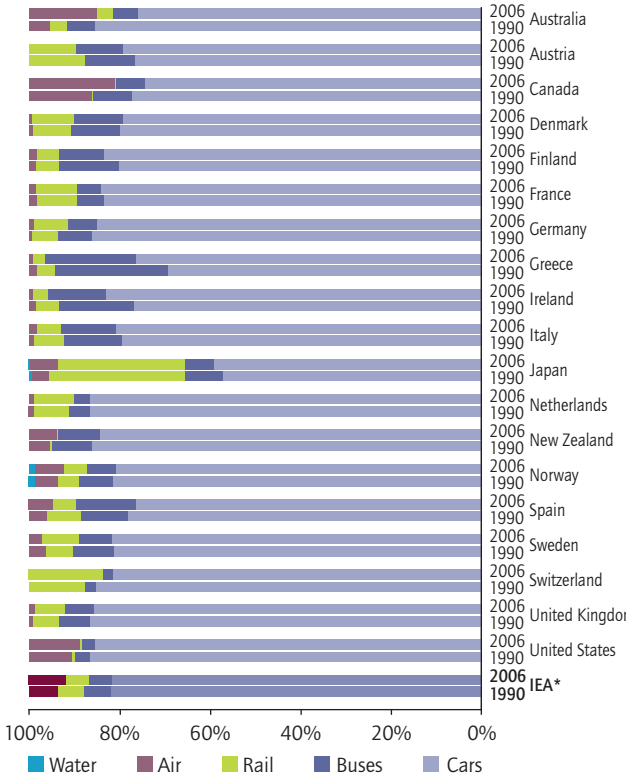
Energy intensity of passenger transport

Overall energy intensity of passenger transport is the ratio of overall energy use divided by the overall number of passenger-kilometres (pkm). Various techniques, including surveys, are used to estimate overall fuel intensity.

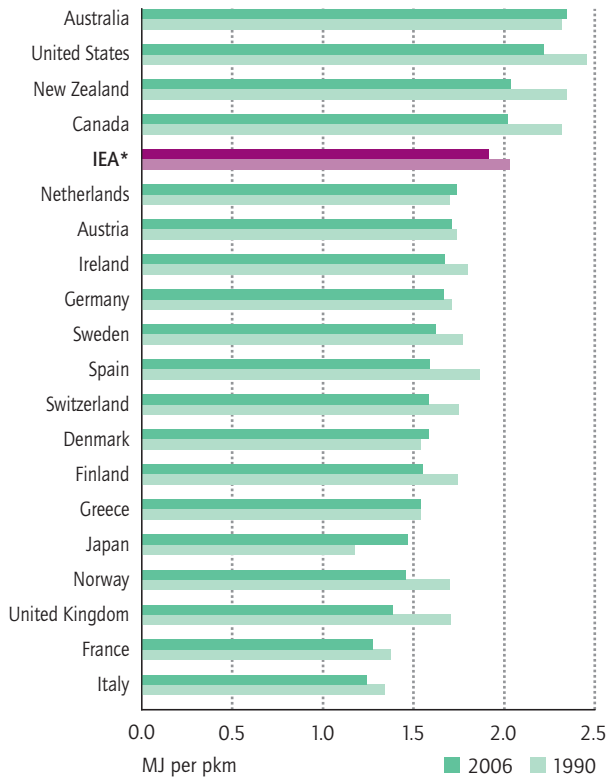
The fuel intensity of new cars is usually evaluated through test procedures. However, at present, countries are using different test procedures, which means test results are not comparable. Furthermore, the test procedures do not fully account for on-road driving factors such as: use of air conditioning and/or lights; rolling resistance of tyres; driving style; road conditions; and congestion. The IEA has estimated that on-road fuel economy can be 10% to 35% higher than lab-tested results.

Cars continue to dominate passenger transport, thus improved fuel efficiency of new cars led to a decrease in energy per passenger-km.

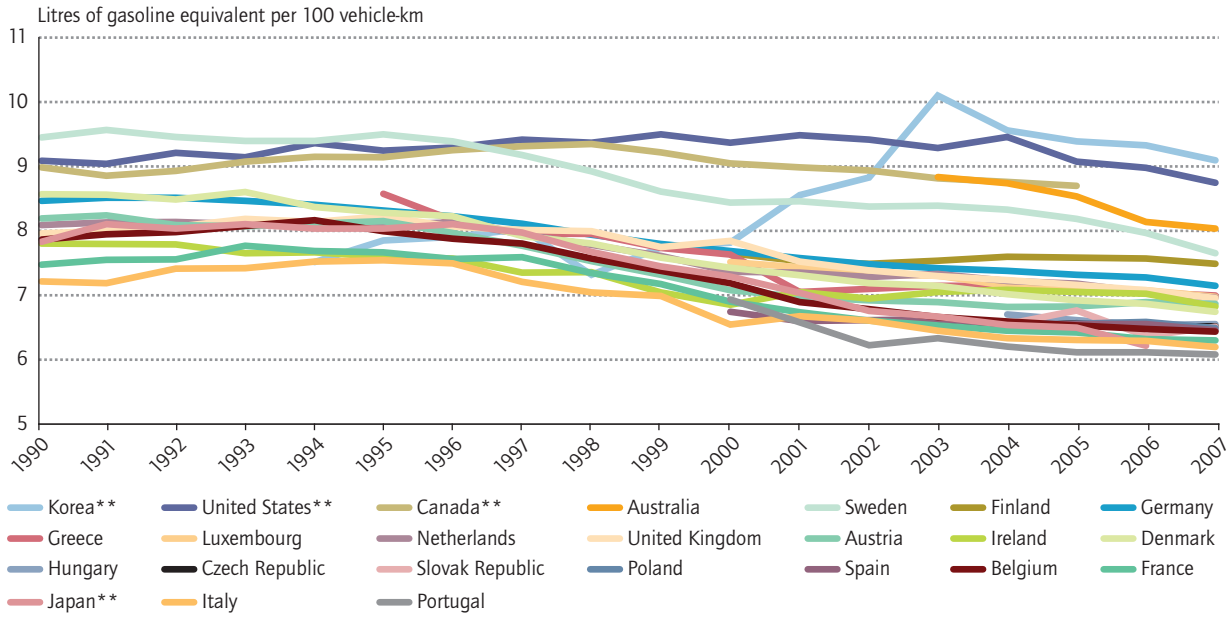
Share of total passenger-km by mode



Energy per passenger-km - all modes



Trends in new car fuel intensity



** IEA average is limited to countries shown in graph.*

*** Data for Canada, Japan, Korea and the United States are not directly comparable with the other countries.*

27 Energy efficiency in households

Improved energy efficiency

▶ Total final energy consumption in IEA households, corrected for yearly climatic variations, grew by 15% between 1990 and 2006. By contrast, per capita consumption increased by only 2.9%. This reflects the fact that the increase in household energy use was a result of population growth coupled with changes to the structure of households and increasing appliance ownership.

▶ Aggregate indicators can be developed for all IEA member countries. However, more detailed indicators that allow a deeper analysis of the factors underlying the changes in end-use energy use are available only for a group of 19 IEA member countries.

▶ For the countries analysed, space heating is by far the most important end-use in the residential sector: corrected for yearly climate variations, it increased by 5% since 1990. However, its share of energy consumption in the sector actually fell from 59% in 1990 to 53% in 2006. This reflects a rapid growth in appliances energy use, as well as a significant reduction in the per capita energy requirement for space heating, driven by higher efficiencies of space heating equipment and improved thermal performance of new and existing dwellings. On a country basis, Germany has the highest share for heating (77%) and Japan the lowest (24%).

▶ Natural gas is the main fuel for space heating, although fuel shares vary significantly from country to country. In Japan, oil remains the dominant fuel. Electricity is important for New Zealand, Norway and Sweden, but represents only 9% of the total energy use for space heating in the countries analysed. In Denmark, Finland and Sweden, district heating represents the most important energy commodity for space heating.

▶ Several factors affect energy use for space heating in households including dwelling size, number of occupants, efficiency of heating equipment and demand for useful energy per unit of area heated (useful energy intensity).

▶ For most of the countries analysed, fewer occupants and larger homes have tended to drive up energy demand for space heating. This increase was offset, however, by lower end-use 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, it is not possible with the current set of space heating indicators to analyse separately how such policies affect energy use.

▶ Source

- IEA Indicators Database, 2009, IEA.

▶ For further information

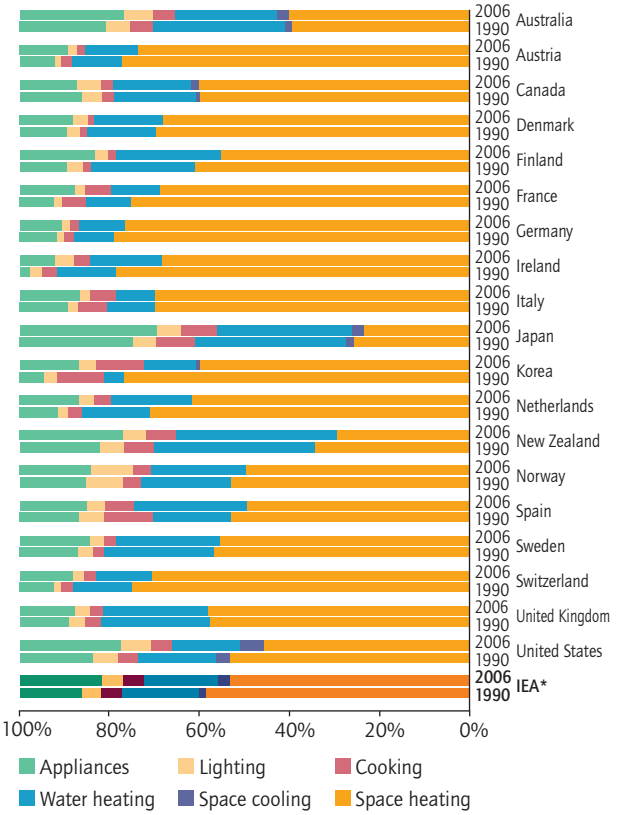
- *Gadgets and Gigawatts: Policies for Energy Efficient Electronics*, 2009, IEA.
- *Promoting Energy Efficiency Investments: Case Studies in the Residential Sector*, 2008, IEA.
- *Worldwide Trends in Energy Use and Efficiency* (Brochure), 2008, IEA.

The global building stock and a sustainable future

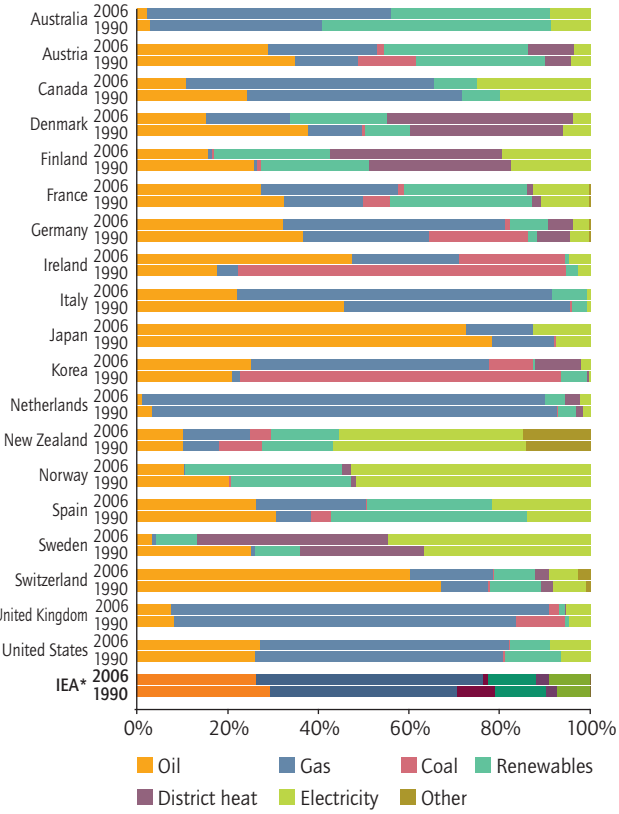
Buildings account for around 40% of final energy use at a global level. Establishing a more sustainable approach to the building sector will be essential to any aggressive climate change policy and will provide benefits in terms of enhanced energy security, reduced fuel bills and improved living conditions. The technologies exist to significantly increase the energy efficiency of both new and existing buildings; however, radical changes in policy are needed to support their deployment. By some estimates, available technologies could reduce energy consumption in buildings by 41% below the baseline level in 2050 – at a marginal cost of USD 200 per t CO_2. This represents CO_2 reductions of 11.5 Gt CO_2, or around 40% of total global CO_2 emissions in 2006.

Space heating still accounts for more than half of household energy consumption in IEA member countries; however, the share of appliances, especially small appliances, is growing quickly.

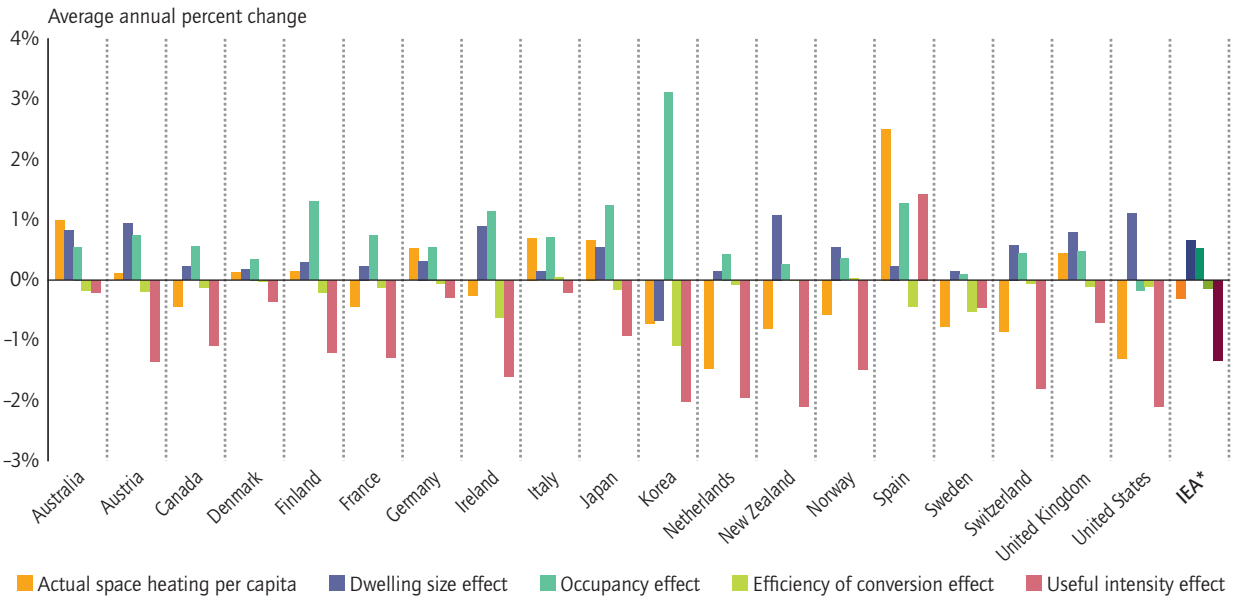
Household energy use by end use



Share of space heating by fuel



Decomposition of changes in space heating per capita, 1990-2006



** IEA average is limited to countries shown in graph.*

Power plant efficiency

▶ The production of electricity and heat from fossil fuels warrants special attention in terms of energy efficiency because efficiency improvements in the power plant sector have a direct impact on primary energy savings.

▶ In 2007, fossil fuel power plants accounted for almost two-thirds of total IEA electricity production and consumed about 1 500 Mtoe. To illustrate the significant potential impact of efficiency improvements, an average increase of 10% in power plant efficiency would equate to more than half of the electricity consumption of the residential or commercial and public services sectors.

▶ Over the past 35 years, the average IEA efficiency of fossil fuel plants increased, from 35% in 1974 to 40% in 2007. Several factors explain this increase: new and advanced technologies such as combined-cycle gas turbines; the adoption of supercritical and ultra-supercritical steam conditions at coal-fired power plants; a dramatic decrease in the use of oil-fired plants; a significant increase of more efficient natural gas-fired plants; and a greater number of combined heat and power (CHP) plants.

▶ Attempts to compare efficiency increases across countries might reveal a large range of overall and per fuel efficiencies. However, since many factors influence overall efficiency, it is best to avoid drawing any major conclusions about the relative efficiency of the countries. Factors needing to be considered for accurate comparison include: the percentage of electricity coming from fossil fuels; the fuel mix; and the share of heat and cogeneration in total electricity and heat production. For example, the highest efficiencies are seen in those countries with heat plants (sometimes CHP plants).

▶ With this note of caution in mind, it can be seen that all but five IEA member countries have increased their overall efficiency for fossil fuel power and heat generation. For the five countries that showed no efficiency improvement, the main factor is a dramatic reduction of fossil fuels in their electricity mix. In particular, Switzerland and Sweden no longer use (or use very little) fossil fuels for electricity and heat production.

▶ The most significant efficiency improvement has been in electricity and heat production fired by **natural gas**, with an increase from 37% to 48%. This is due, at least in part, to the introduction (in the 1980s) of combined-cycle gas turbines, which now have a typical 55% electrical efficiency. It is particularly the case for countries that have expanded their use of natural gas since the 1980s, such as Italy and Spain.

▶ In the case of **coal**, overall efficiency rose from 33% to 37%. For countries with little heat generation, such as the United States and the United Kingdom, the reported efficiency is close to the electrical efficiency of their coal-fired power plants (37% to 38%). In such countries, efficiency has improved with the retirement of older plants and the opening of new plants. Japan has a modern fleet of coal-fired plants with high efficiency (>40%).

▶ In countries that use brown coal (Australia, Turkey and Greece, for example), reported efficiencies are often lower due to the characteristics of the fuel. However, in Germany, the biggest consumer of brown coal, new technologies introduced at some plants have helped to improve efficiencies.

▶ *Source*

- *Energy Efficiency Indicators for Public Electricity Production from Fossil Fuels*, 2008, IEA.

▶ *For further information*

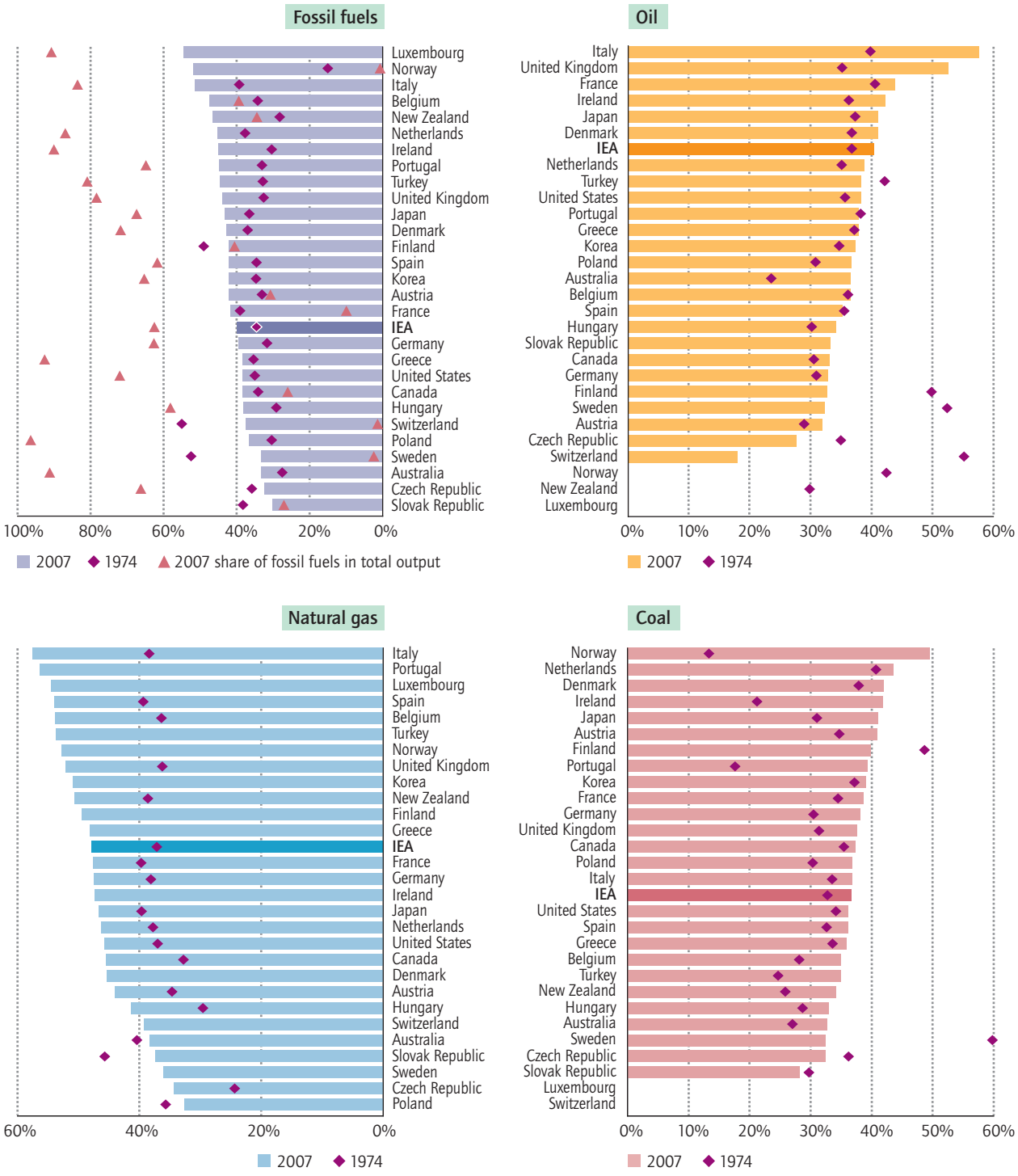
- *Fossil Fuel-Fired Power Generation: Case studies of recently constructed coal and gas-fired plants*, 2007, IEA.

Power and heat plant efficiencies

*Efficiency data are calculated using the gross electrical output plus saleable heat output of plants and the lower heating value (LHV) or net calorific value (NCV) of each fossil fuel used (*i.e. *oil, natural gas or coal). For the sake of comparison, this analysis is limited to public electricity and CHP plants. It does not include auto-producers and heat-only power plants.*

Data show a general trend towards improved efficiency in power and heat plants; however, heat and power statistics would need to be better disaggregated to understand precisely the underlying factors.

Power plant* efficiencies in 1974 and 2007



** Includes public electricity and CHP plants with a correction for the heat output from CHP plants.*

Environmentally sustainable provision & use of energy

Environmentally sustainable provision and use of energy

E

CO_2 emissions from fuel combustion

▶ Carbon dioxide (CO_2) emissions from fuel combustion account for about two-thirds of the man-made greenhouse gases (GHGs) released into the Earth's atmosphere. In 2007, fuel combustion accounted for 78% of CO_2 emissions arising from IEA member countries. More than 80% of these IEA CO_2 emissions derive from three major sources: electricity and heat (40%), transport (27%) and manufacturing industries and construction (15%).

▶ Efforts are needed across all sectors in order to meet ambitious emission reduction goals. The electricity generation sector requires urgent action in light of its long-lived capital stock and rapid growth. However, achieving reductions will be particularly challenging for countries (such as Australia, the United States and some Eastern European countries including the Czech Republic and Poland) with a high share of emissions from this sector. Most of them rely on abundant coal reserves to support electricity generation.

▶ Oil remains the largest source (42% of the total) of IEA CO_2 emissions, especially in transport. However, the share varies significantly from country to country, depending on the energy mix. Switzerland has the highest share (76%) and the Czech Republic the lowest (21%).

▶ Coal – mostly consumed in power generation – accounted for 35% of IEA CO_2 emissions (with a high of 70% in Poland and a low of 2% in Switzerland).

▶ The share of CO_2 emissions from natural gas has increased since 1974 in all IEA member countries but two (the United States and the Netherlands); this reflects overall growth in the share of natural gas supply. The natural gas share of IEA CO_2 emissions reached 22% in 2007 (with a high of 45% in Hungary and a low of 4% in Sweden).

▶ The heat and power sector accounted for 40% of IEA CO_2 emissions, and transport for 27%. Together, these sectors make up more than two-thirds of the IEA total. The combined share is even higher for large countries that are big users of coal, such as Australia (78%) and the United States (74%). It follows that the combined share is smaller for countries that depend mostly on hydro or nuclear for electricity, such as Norway, Switzerland and France.

▶ IEA CO_2 emissions from fuel combustion increased by 17% between 1990 and 2007. However, growth differs considerably among IEA member countries and changes reflect two main trends. The economic downturn of Central and Eastern European countries led to a visible downward impact on emissions. By contrast, rapid economic development and/or changing demographics resulted in correspondingly high emission growth in countries such as Korea (+113%), Turkey (+109%), New Zealand (+66%) and Australia (+53%). This trend is also evident in "cohesion" countries in the European Union (*i.e.* Greece, Ireland, Portugal and Spain).

▶ Four other countries (Germany, Sweden, the United Kingdom and Belgium) experienced a reduction in emissions, primarily due to structural changes, regulatory and policy changes, and fuel substitution. The reunification of Western and Eastern Germany also contributed to the reduction for Germany.

▶ Source

- *CO_2 Emissions from Fuel Combustion*, 2009, IEA.

▶ For further information

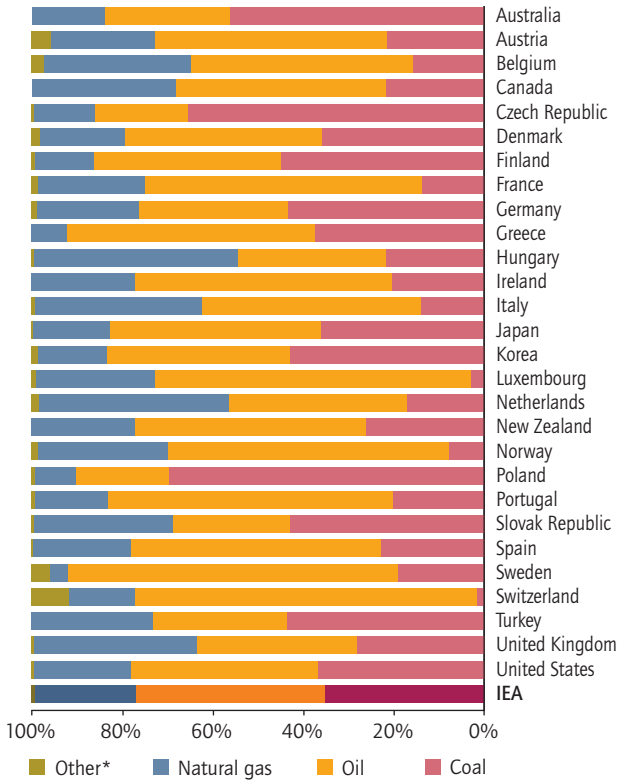
- *CO_2 Capture and Storage: A Key Carbon Abatement Option*, 2008, IEA.
- *Tracking Industrial Energy Efficiency and CO_2 Emissions*, 2007, IEA.

IEA emission estimates

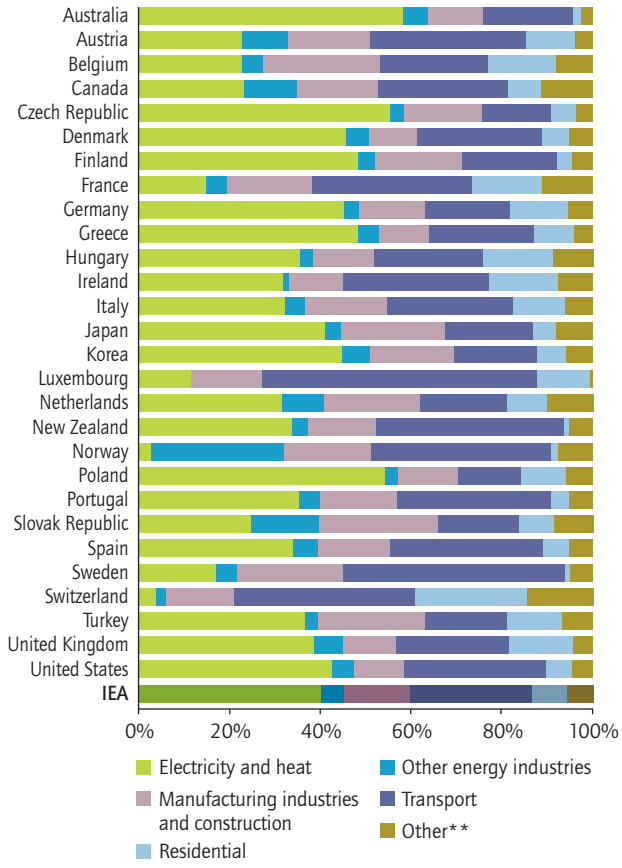
Estimates of CO_2 emissions from fuel combustion are calculated based on a Tier 1 Sectoral Approach, using IEA energy data and the default methods and emission factors from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories *(IPCC/OECD/IEA, Paris, 1997). They may differ from the national GHG inventory numbers that countries submit to the UNFCCC for a variety of reasons (discussed in detail in the IEA publication* CO_2 Emissions from Fuel Combustion*).*

On a sectoral basis, power generation represents the bulk of emissions, followed by transport. On a fuel basis, oil accounts for the largest share, ahead of coal.

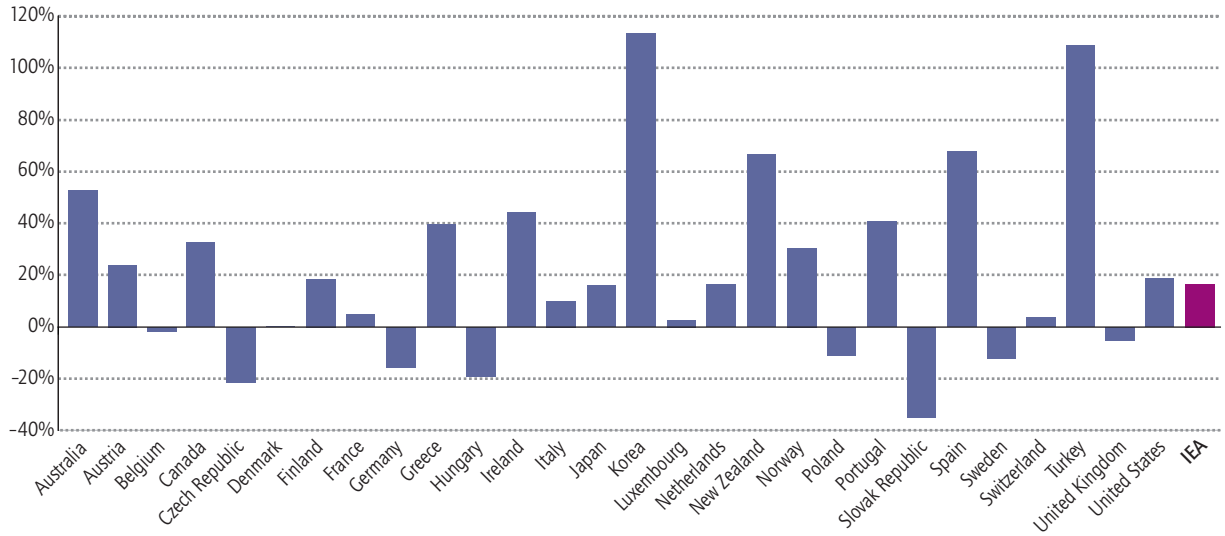
CO_2 emissions by fuel in 2007



CO_2 emissions by sector in 2007



Percentage change in CO_2 emissions between 1990 and 2007



** Other includes industrial waste and non-renewable municipal waste.*

*** Other includes commercial/public services, agriculture/forestry, fishing and other use not specified elsewhere.*

CO_2 emissions from the electricity sector

▶ Electricity and heat production in IEA member countries increased by over 40% between 1990 and 2007 while CO_2 emissions from the electricity and heat sector increased by 31%. This reflects a decarbonisation of the production of IEA electricity and heat, which can be attributed to a doubling of the natural gas share in electricity production, displacing mostly oil but also coal.

▶ This substitution of natural gas for oil and coal in the overall IEA electricity mix reduced the share of CO_2 emissions from oil (from 11% to 5%) and, to a lesser degree, of coal (from 78% to 75%). Conversely, the share of CO_2 emissions from natural gas almost doubled (from 10% to 19%). The spectacular growth in gas use in power generation is largely due to the low-capital cost and high conversion rate of gas turbines. These traits make gas turbine technology well suited to compete in countries pursuing electricity reform.

▶ Due to varying sizes of production and the diversity of energy mix (with the weight of fossil fuels being of key importance) for electricity and heat production, country shares in total IEA emissions range widely. In 2007, the United States accounted for 42% of total IEA electricity production, of which 72% derived from fossil fuels. As a result, the US share (49%) of IEA emissions was the highest in this sector, followed by Japan (10%) and Germany (7%). Because of its high share of hydro, Norway emits almost no CO_2 from this sector.

▶ The average CO_2 intensity of electricity and heat production in 2007 in IEA member countries was 446 g CO_2 per kWh. However, the CO_2 intensity differs significantly across countries. The value is very low (under 50 g CO_2 per kWh) in countries with a large non-fossil fuel component (*e.g.* Norway, Sweden and Switzerland) but very high (above 500 g CO_2 per kWh) in countries with large amounts of fossil fuels (especially coal). High value countries include Australia, the Czech Republic, Greece, Poland and the United States.

▶ Most IEA member countries have lowered the CO_2 intensity of their electricity and heat production. There are, however, some notable differences between countries. Australia saw a 12% increase in its intensity as use of fossil fuels (mainly coal) increased to compensate for less hydro generation. At the opposite extreme, Luxembourg's intensity fell by 87% due to the complete replacement of coal by natural gas. As a consequence, the general IEA trend since 1990 has been a moderate improvement (8%) in the carbon intensity of power generation.

▶ The global CO_2 intensity from electricity generation was around 500 g CO_2 per kWh in 2007. Because of larger contributions of natural gas and CHP, the Russian Federation's intensity was only 320 g CO_2 per kWh. By contrast, due to a large share of coal, much higher intensities were seen in China (760 g CO_2 per kWh) and India (930 g CO_2 per kWh).

▶ Source

- *CO_2 Emissions from Fuel Combustion*, 2009, IEA.

▶ For further information

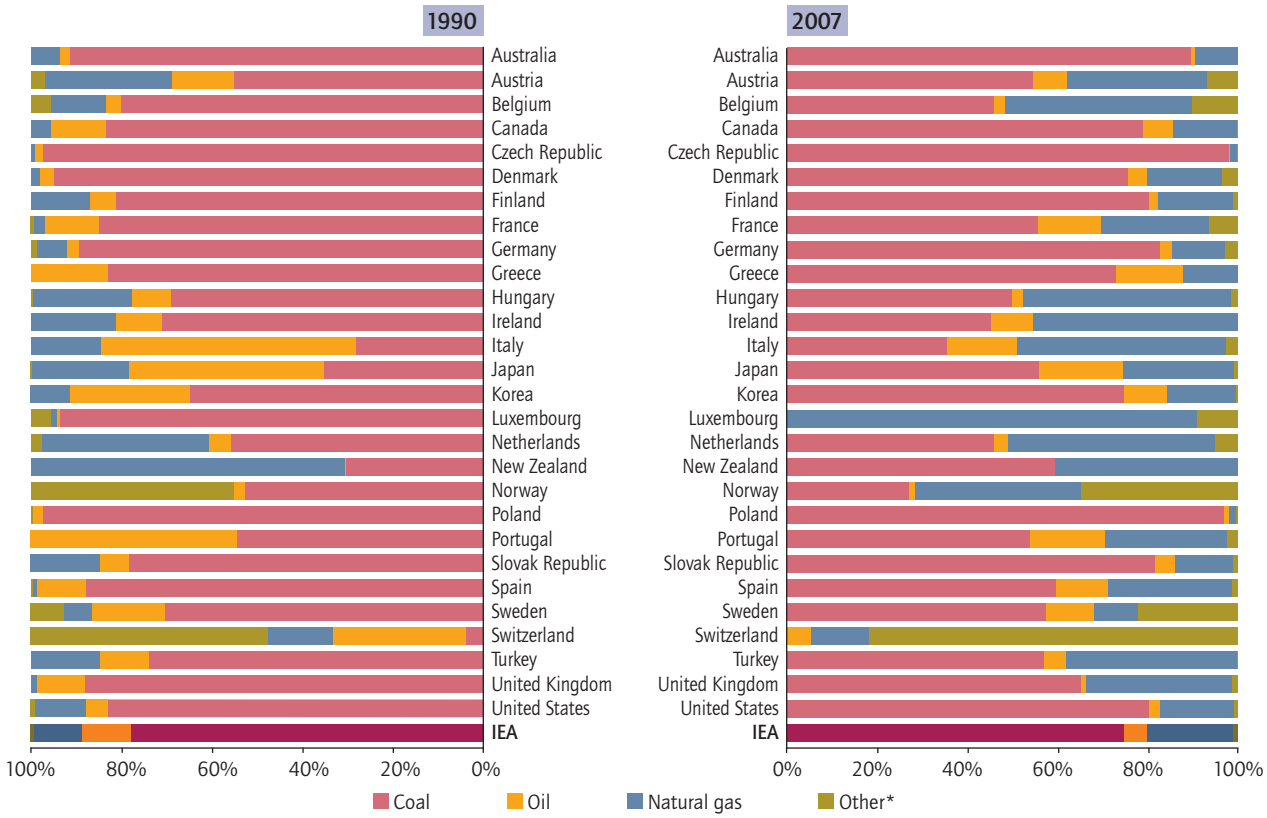
- *Act Locally, Trade Globally: Emissions Trading for Climate Policy*, 2005, IEA.
- *CO_2 Capture and Storage: A Key Carbon Abatement Option*, 2008, IEA.
- *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*, 2008, IEA.
- *Tracking Industrial Energy Efficiency and CO_2 Emissions*, 2007, IEA.

Curbing emissions from power generation

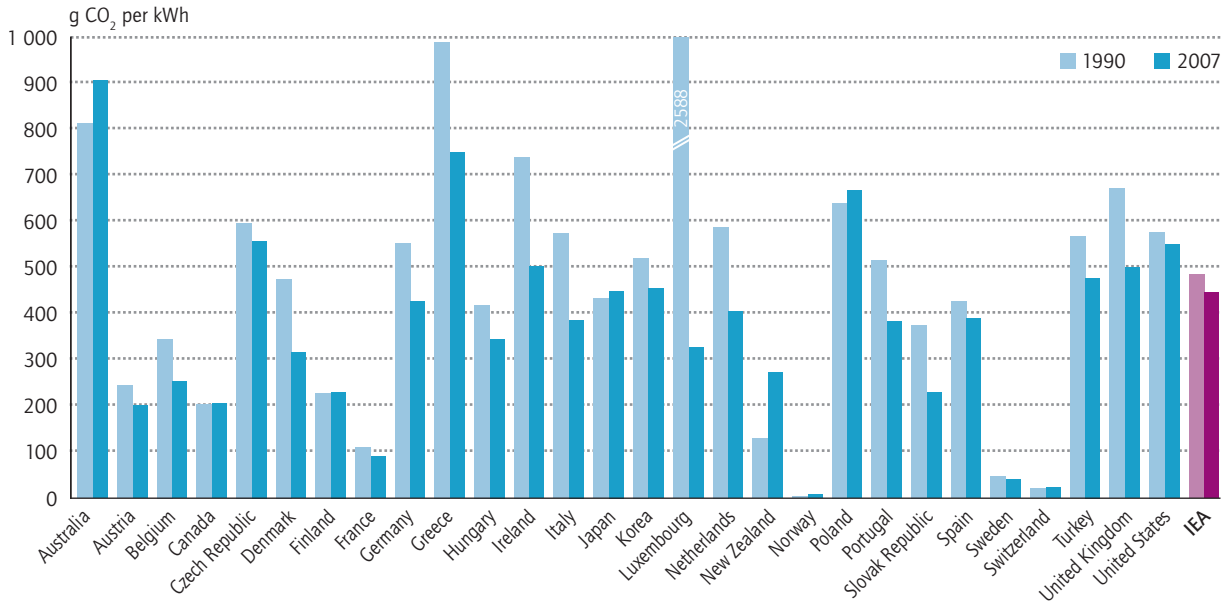
The EU Member States recently introduced an emissions trading system to curb CO_2 emissions of heavy industry and power generation from 2005 onwards. There is evidence to show that the system has prompted efforts to reduce emissions in electricity. In December 2008, EU Member States agreed to a revision of the system that puts a cap on medium-term emissions and mandates auctioning of allowances to power generators. These changes are expected to put more pressure on Member States to reduce the sector's emissions. The sector can also buy allowances to counterbalance increased emissions.

Nuclear contributed to decarbonise electricity generation, thereby helping to reduce CO_2 emissions. Coal still accounts for 75% of the sector's CO_2 emissions despite the growth of gas-based electricity generation.

Electricity sector CO_2 emissions by fuel in 1990 and 2007



CO_2 intensity of electricity and heat production in 1990 and 2007



** Other includes industrial waste and non-renewable municipal waste.*

31 CO_2 emission intensities

▶ Annual CO_2 emissions differ considerably amongst IEA member countries, regardless of whether they are considered in absolute numbers, per capita amounts, or through carbon intensities (*e.g.* CO_2 emissions per unit of GDP). These differences stem from diverse national circumstances, particularly natural resource endowments, energy mix and climate.

▶ For example, Norway has comparably low emission levels because it generates significant quantities of electricity from renewable sources (98% hydro). In the case of Sweden and Switzerland, both hydro and nuclear contribute to a lower carbon intensity. Nuclear capacities also explain, in part, the lower emissions per GDP for countries such as France and Japan.

▶ Analysis of the relative CO_2 intensities of countries highlights the importance of historical choices. Eastern European countries oriented toward heavy industry remain the most energy-intensive of IEA economies. Choices to implement energy subsidies and rely on centrally-planned energy systems also play a role in CO_2 intensities of these countries. More recently (*i.e.* since 1990) these countries have chosen to pursue extensive economic restructuring, and have made impressive progress in reducing their CO_2 intensities.

▶ All the countries (except Turkey) use less CO_2–emitting energy to generate wealth than they did in 1990. In the case of Turkey, rapid economic development and industrialisation led to a slight (4%) increase. Turkey still has the lowest emissions on a per capita basis, despite a strong (59%) increase.

▶ Country size (causing larger transport consumption), population and density all play a part in energy-use behaviour and overall emissions per capita. Australia, Canada and the United States, all large countries with high per capita emissions, also happen to have vast fossil fuel resources and, consequently, rather high CO_2 intensities of power generation.

▶ Average IEA emissions per capita rose by 4% over the last 17 years. However, when looking at individual countries, emissions grew in 15 and declined in 13. Korea, Australia, Turkey and Spain have experienced the highest increases; the Slovak Republic, the Czech Republic and Germany show the most significant decreases.

▶ The very high per capita emissions of Luxembourg result, to a large degree, from the lower taxation of gasoline and diesel oil compared to neighbouring countries. The price differential attracts drivers from Belgium, France and Germany, as well as transiting freight, to refuel in the country. As emissions are calculated based on fuel deliveries, Luxembourg is accountable for emissions from the totality of those sales.

▶ Source

- *CO_2 Emissions from Fuel Combustion*, 2009, IEA.

▶ For further information

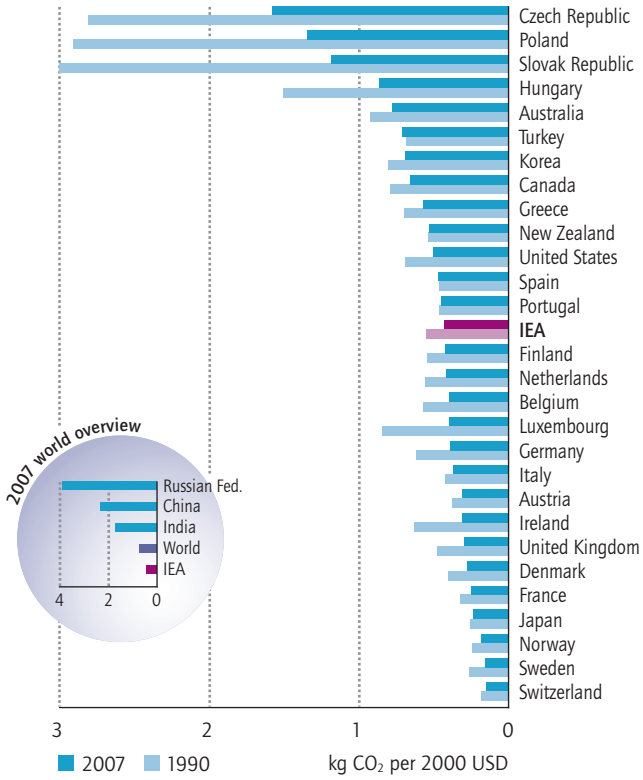
- *CO_2 Capture and Storage: A Key Carbon Abatement Option*, 2008, IEA.
- *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*, 2008, IEA.
- *Tracking Industrial Energy Efficiency and CO_2 Emissions*, 2007, IEA.

The limits of CO_2 indicators

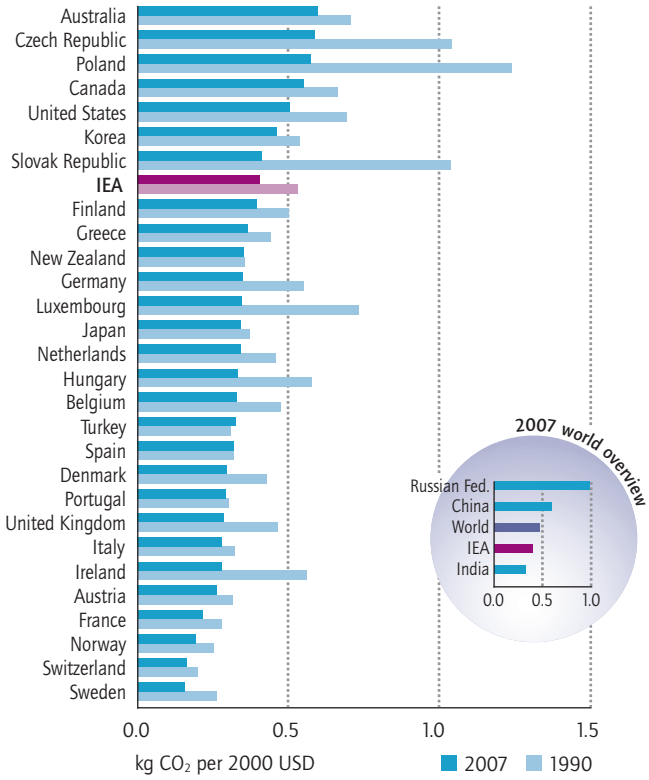
No single indicator can provide a complete picture of a country's CO_2 emissions performance or its relative capacity to reduce emissions. Measures of both CO_2 emissions per GDP and CO_2 per TPES provide some guidance, but are certainly incomplete. Due to different economic structures, it is more appropriate to analyse trends of any selected indicator for a given country than to compare performance between countries.

Economic restructuring, natural endowments and geography are the main drivers of CO_2 intensity.

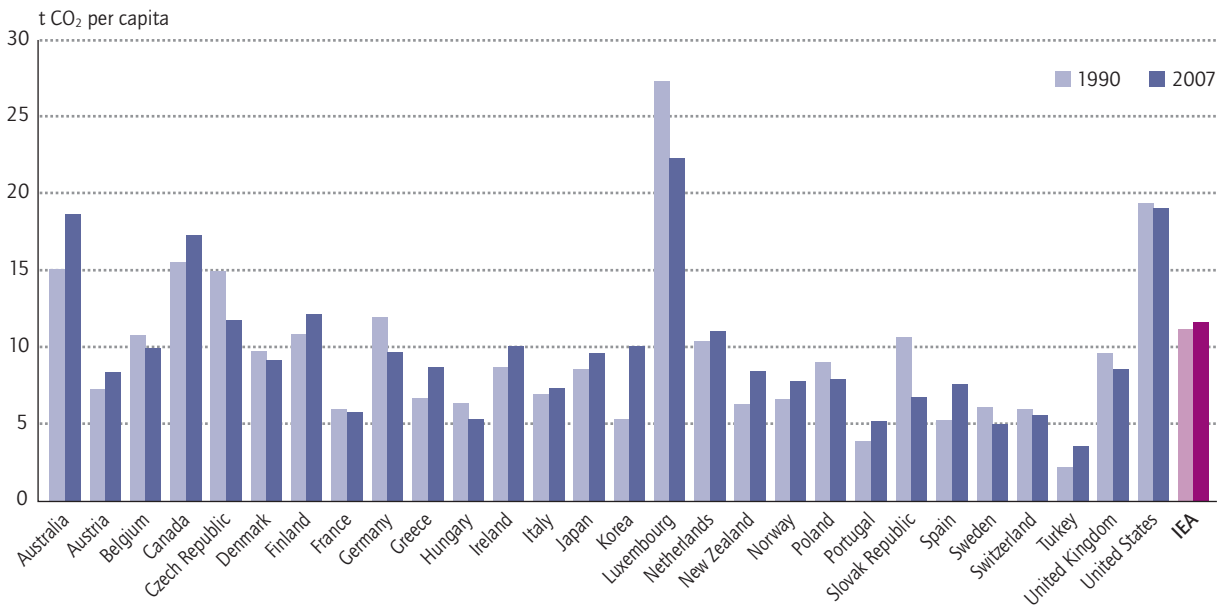
CO_2 emissions per GDP



CO_2 emissions per GDP PPP



CO_2 emissions per capita



Undistorted energy prices

F

Undistorted energy prices

Prices and taxes of selected products

▶ If there is one area for which liberalisation of energy markets has made information less transparent, it is undoubtedly prices and taxes. This lack of transparency arises from the rapid changes in prices (to reflect primary energy price fluctuations and volatility, or to adjust to competition), as well as increased confidentiality due to negotiated tariffs.

▶ Taking this into account, it is possible to conduct two comparisons between countries: one on an ex-tax price basis and the other on the total price (including the tax component). On an ex-tax price basis, prices for premium unleaded gasoline do not vary significantly amongst IEA member countries (relative to prices that include taxes). For the first quarter 2009, gasoline prices ranged from a low of USD 0.35/litre in the United Kingdom to a high of USD 0.57/litre in Turkey (63% higher).

▶ Comparison of total gasoline prices (including the tax component) shows much larger differences. Pump prices range from a low of USD 0.50/litre in the United States to a high of USD 1.73/litre in Turkey. Thus, gasoline is 3.5 times more expensive in some IEA member countries than in others.

▶ The Netherlands has the largest tax component, with a difference of USD 1.18/litre between the ex-tax price and total price. It should be noted that the tax component is not linked to a country's volume of imports or the dependency rate. For example, Norway, the largest IEA oil exporter, has one of the highest taxation rates (USD 1.09/litre).

▶ The pump price of diesel oil shows a slightly lower gap between countries (2.9 times) than for gasoline: a low of USD 0.53/litre in New Zealand compared to a high of USD 1.52/litre in Norway. It should be noted that several IEA member countries recently changed their taxation policies and increased their taxes on diesel oil; seven IEA member countries now have a more expensive price for diesel oil than for gasoline.

▶ Over time, the price trend of gasoline and diesel tends to roughly mirror that of crude oil, but with less intensity. For example, both pump prices and the crude oil spot price peaked in the second quarter of 2008. By the first quarter of 2009, pump prices had fallen 40% whereas crude oil spot prices were about 60% lower.

▶ Comparing electricity prices for households is even more difficult due to the variety of tariff structures, the fixed part of the bill and the time delay in reporting. As a result, any comparison should be made with caution. Taking this into account, data for the first quarter 2009 show a factor of 5.5 between the lowest average kWh price (USD 0.07 in Korea) and the highest (USD 0.37 in Denmark).

▶ *Source*

- *Energy Prices and Taxes*, Second quarter 2009, IEA.

▶ *For further information*

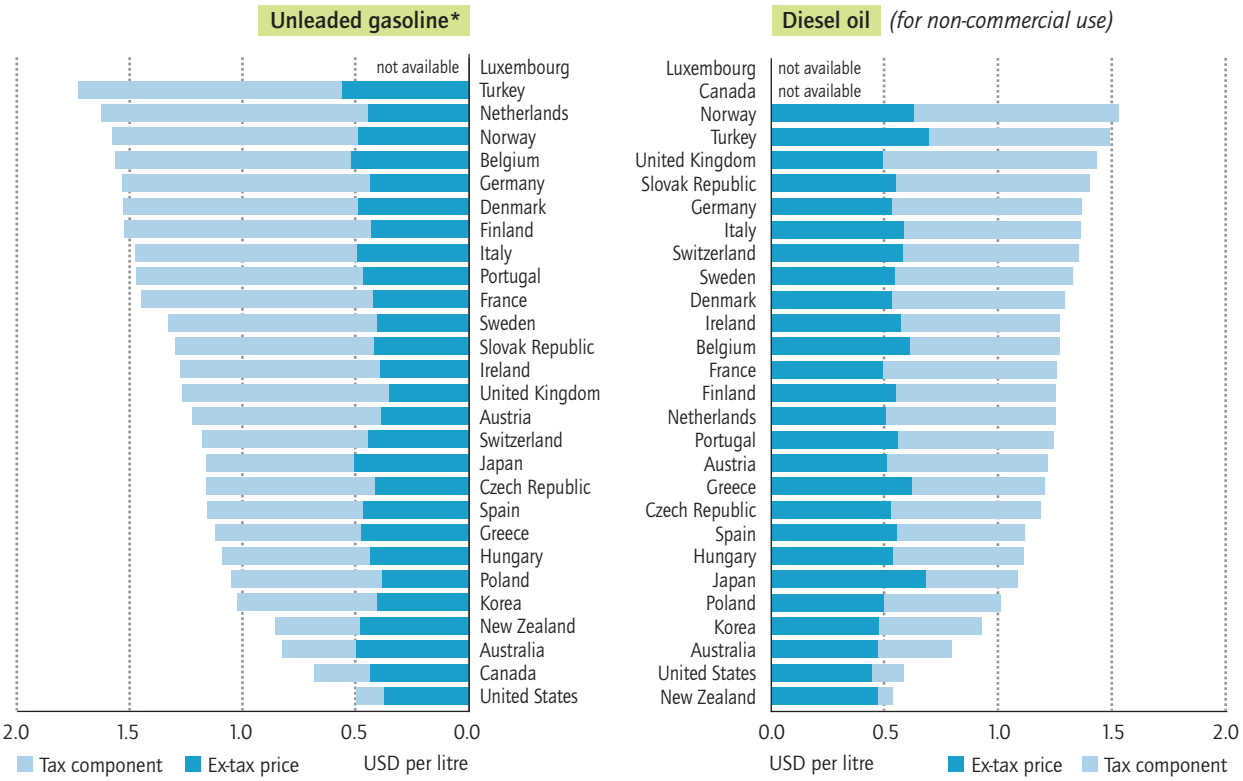
- *Oil Market Report*
  www.oilmarketreport.org.

New challenges in compiling price information

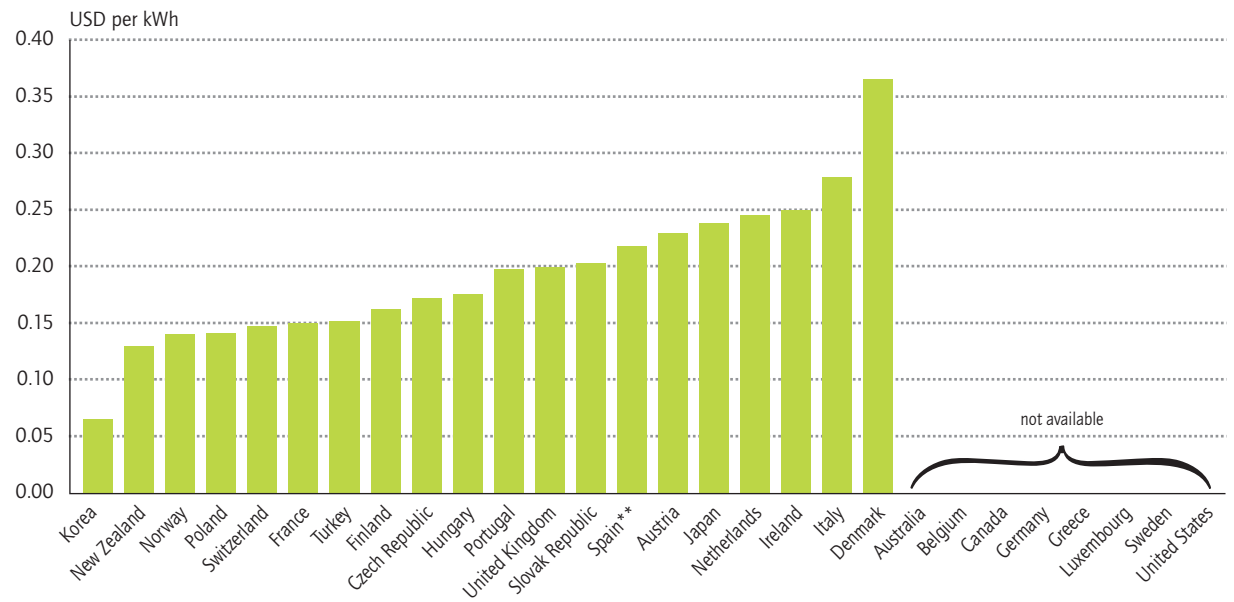
Deregulation of energy markets has led to an exponential increase in the number of market players - and to more and more difficulties in collecting price data on an equivalent basis. For example, electricity can be supplied under a multitude of contract or tariff conditions that link prices to quantity delivered, continuity of supply, load factors and diurnal (daily) patterns of use. The multiplication of utilities sometimes makes it harder to obtain basic information on average prices (average revenue per unit delivered). In addition, some countries collect information only on an annual basis and publish it long after the period to which the prices relate. Similar difficulties arise with natural gas prices, especially for the industry sector.

The fuel taxation policies of IEA member countries vary widely, regardless of whether countries are energy producers, exporters, importers or consumers.

Energy prices and taxes for first quarter 2009



Electricity prices for households in first quarter 2009



** Premium unleaded 95 RON gasoline for all countries except Canada, Japan, Korea and United States, which are for regular unleaded gasoline.*

*** Annual electricity prices are shown for Spain (2008).*

Continued R&D and market deployment

Continued research, development and market deployment

G

RD&D budgets in the energy sector

▶ The total amount and allocation of funding by category of energy technologies for research, development and demonstration (RD&D) is a direct result of national energy policies. It is often also influenced by global energy prices.

▶ Following the oil shock of 1973-74, government RD&D budgets for energy increased substantially from 1974-80. With the oil price collapse in the 1980s and generally low energy prices in the 1990s, energy RD&D efforts were reduced. Over the last 35 years, total public sector energy RD&D budgets declined in real terms, with 2008 nominal levels only slightly above 1976 budgeted amounts. Moreover, the share of energy RD&D in total research and development has declined significantly in the last 27 years, from 12% in 1981 to 4% in 2008.

▶ This overall decline masks the fact that the share of total RD&D budgets has steadily increased in some areas but decreased in others: funding for energy efficiency rose (from 4% in 1974 to 13% in 2008), as did the share for renewable energy sources (from 3% to 12%). Fossil fuel budgets remained relatively stable (from 8% to 12%). The share for nuclear fission and fusion decreased dramatically (from 74% to 39%), yet this category remains by far the largest portion of funding. Other power and storage technologies (electric power conversion, electricity transmission and distribution, and energy storage), combined with other technologies or research (*e.g.* energy systems analysis), accounted for 18% of total budgets in 2008.

▶ Focusing on national RD&D budgets for energy technology, the United States leads all countries in absolute terms, followed by Japan. However, Finland and Japan have the highest energy RD&D budgets as a percentage of GDP, followed by Korea, France, Canada and Denmark.

▶ Individual country budgets are based on natural resources, infrastructure and consumption. They typically seek either to further refine existing capacity or to fill in gaps. For example, Norway (54%) and Turkey (40%) had the largest shares of fossil fuel research in 2008, while Spain and Portugal budgeted the largest percentage of fossil fuel research on carbon capture and storage.

▶ In 2008, Hungary (82%) and New Zealand (53%) directed the largest share of their RD&D budget to renewable energy sources. By contrast, Canada and the United States, the largest renewable energy producers, allocated only 11% and 10% respectively (it should be noted that these amounts are higher in absolute values than most other IEA member countries). Most IEA member countries have a relative balance across all categories; however, a few focus only on two or three energy categories. This is the case of Ireland, which concentrates almost exclusively on energy efficiency and renewables research.

▶ *Sources*

- Country submissions for the SLT/CERT annual review of energy policies, 2008/2009, IEA.
- *Main Economic Indicators*, March 2009, OECD.
- *National Accounts*, 2009, OECD.
- *OECD Economic Outlook*, 2009, OECD.

▶ *For further information*

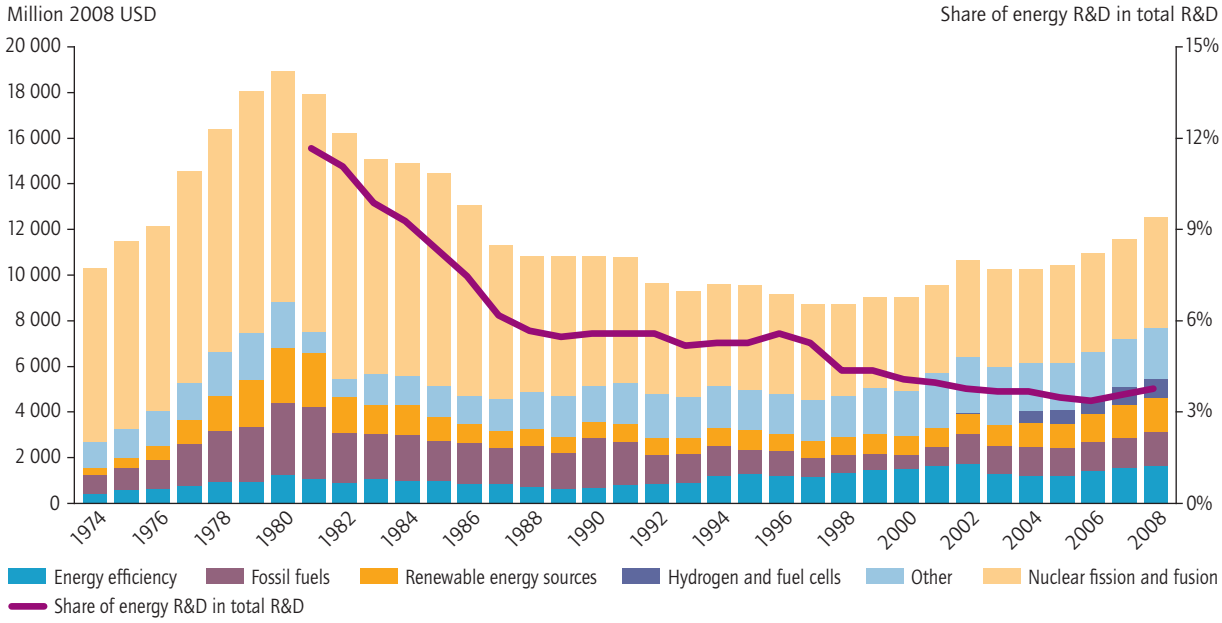
- Committee on Energy Research and Technology Expert Group on RD&D Priority Setting, *www.iea.org/about/experts.asp.*
- *Energy Technology Perspectives*, 2008, IEA.
- *Frascati Manual 2002: Proposed standard practice for surveys on research and experimental development*, 2002, OECD.
- IEA energy RD&D statistics, *www.iea.org/Textbase/stats/rd.asp.*

The *Frascati Manual*

The Frascati Manual *has become the internationally recognised methodology for collecting and using research and development (R&D) statistics. Energy R&D data reflect many components of the R&D chain: basic research, applied research and experimental (technology) development. Yet considering the specificities of energy, such as the inclusion of technical demonstration, it would be useful to develop a companion manual on energy RD&D.*

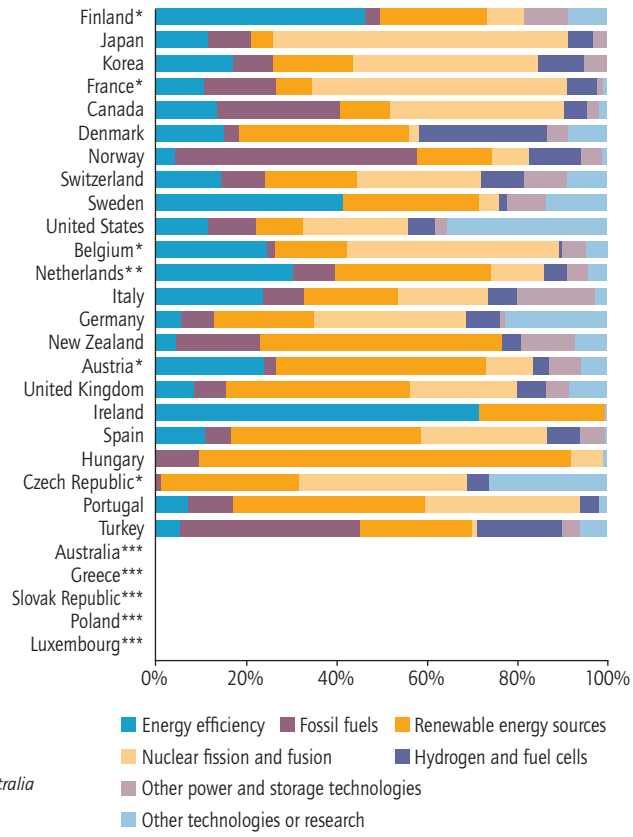
The share of R&D investments directed toward energy dropped from 12% to 4% since 1980; current budgets are insufficient to meet growing concerns related to supply disruptions and climate change.

Public sector energy RD&D in IEA member countries



Energy RD&D budgets as share of GDP

RD&D shares by activity in 2008



** Data for Austria, Belgium, the Czech Republic, Finland and France are for 2007.*
*** Data for the Netherlands are for 2006.*
**** The most recent RD&D budgets received from Greece are for 2002 and from Australia for 2003. Very limited and incomplete information is available for Luxembourg and the Slovak Republic. No RD&D budgets have been submitted by Poland.*

34 RD&D budgets for renewable energy

▶ A key challenge for some renewable technologies is that they are not yet cost-competitive with conventional energy sources. Thus, support from government RD&D budgets is essential for reducing the cost of these technologies and helping to bring them to market competitiveness. Governments can also play a role in supporting market development for uptake of these technologies.

▶ After the oil shocks of the 1970s, renewable energy RD&D budgets in IEA member countries experienced rapid growth. These budgets peaked in 1980, then dropped to less than one-third of the peak value over the next decade and remained relatively constant in the 1990s. Since 2000, renewable energy RD&D budgets have again been rising; however, they have not yet achieved the record level of 1980, in either absolute or percentage terms. In 2008, renewable energy RD&D represented more than 12% of the total energy RD&D spending for the IEA as a whole.

▶ Based on the latest available data, IEA member countries with the highest renewable energy RD&D budgets are the United States, Japan, Germany, the United Kingdom, Italy, Korea and France. This reflects a slight shift from situation in 1990, at which time the United Kingdom and France did not appear amongst the leaders. Both countries have since made significant effort to increase their renewable energy RD&D budgets. It should be noted that the United States, which was already a leader in 1990, has since more than doubled its renewable energy RD&D budget and is now far ahead of all other countries in absolute terms.

▶ The absolute levels of renewable energy RD&D budgets are an important indicator of countries' efforts to finance the development of new technologies. However, it is also interesting to consider an indicator that takes into account the economy of a given country – that of the renewable energy RD&D budget as a percentage of GDP. This indicator offers a very different picture of recent spending on renewable energy RD&D, placing Finland, Denmark, Korea, New Zealand, Sweden and the Netherlands in the lead positions.

▶ The composition of renewable energy RD&D budgets differs across countries and is often related to natural resource endowments. For example, countries such as Italy and Spain dedicate a significant fraction of their budgets to solar technology. By contrast, countries with large forested areas (such as Hungary, Finland, Austria and Sweden) focus their renewable RD&D budgets on biomass.

▶ Choices taken by governments as to how they direct spending on renewable energy RD&D also have a direct influence on the evolution of national energy and energy technology markets. There is, for example, a clear link between spending of the United States and Germany on solar technology in recent years and rapid deployment of this technology. A similar trend is seen in Denmark and Germany, with spending on wind and impressive growth of wind installed capacities over the last decade.

▶ *Source*

- Country submissions for the SLT/CERT annual review of energy policies, 2008/2009, IEA.

▶ *For further information*

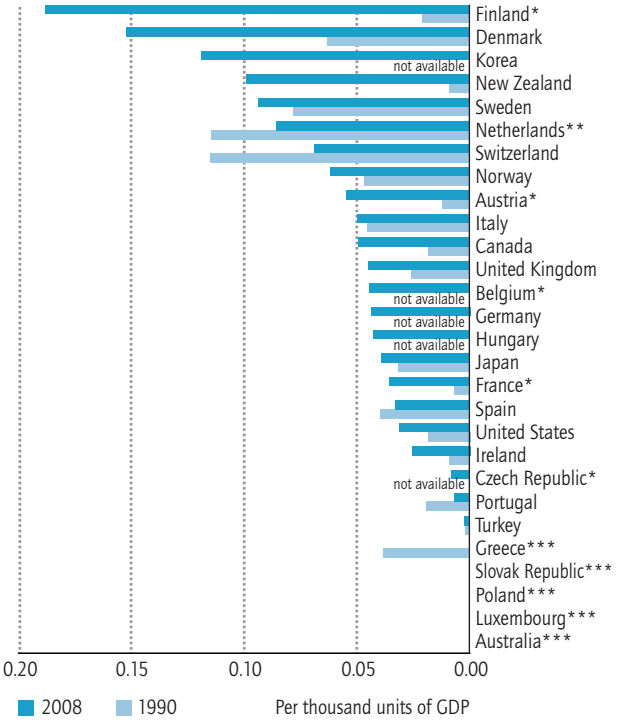
- *Deploying Renewables: Principles for Effective Policies*, 2008, IEA.
- IEA energy RD&D statistics, *www.iea.org/Textbase/stats/rd.asp.*
- *Renewable Energy: RD&D Priorities: Insights from IEA Technology Programmes*, 2006, IEA.

Recent developments in RD&D spending of IEA member countries

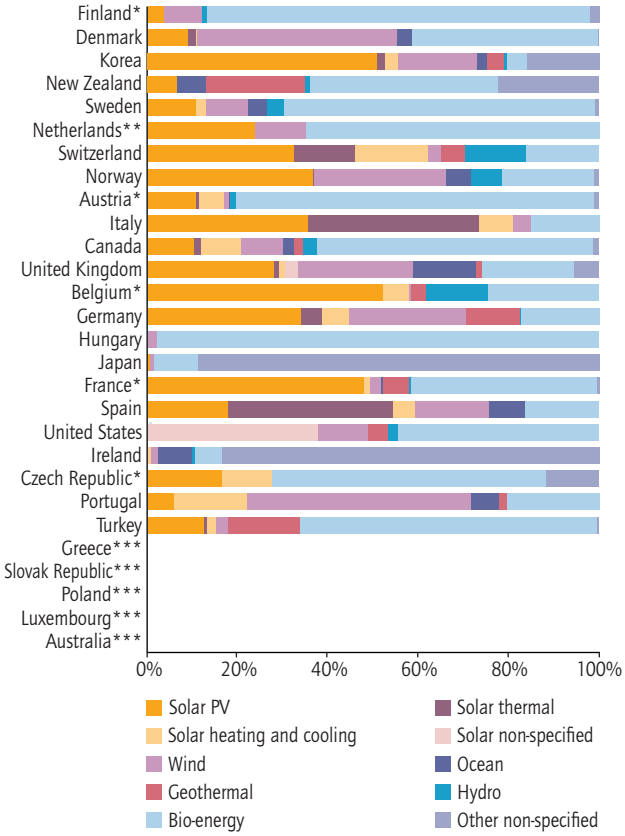
RD&D budgets of IEA member countries have been increasing in recent years, reflecting growing concerns about climate change, rising energy prices and the scarcity of fossil fuels. Trends in renewable energy RD&D budgets and the evolution of markets show that countries are directing this spending toward resources with which they are endowed, and that increased spending on a given technology leads to higher deployment of the technology. This is the case of wind for some countries or solar PV for others. Renewable sources of energy should remain a priority of energy RD&D spending, in order to help decrease their cost and accelerate their market deployment.

Renewable energy RD&D budgets follow the same trends as overall energy RD&D budgets, although a higher increase in funding can be observed over the last few years.

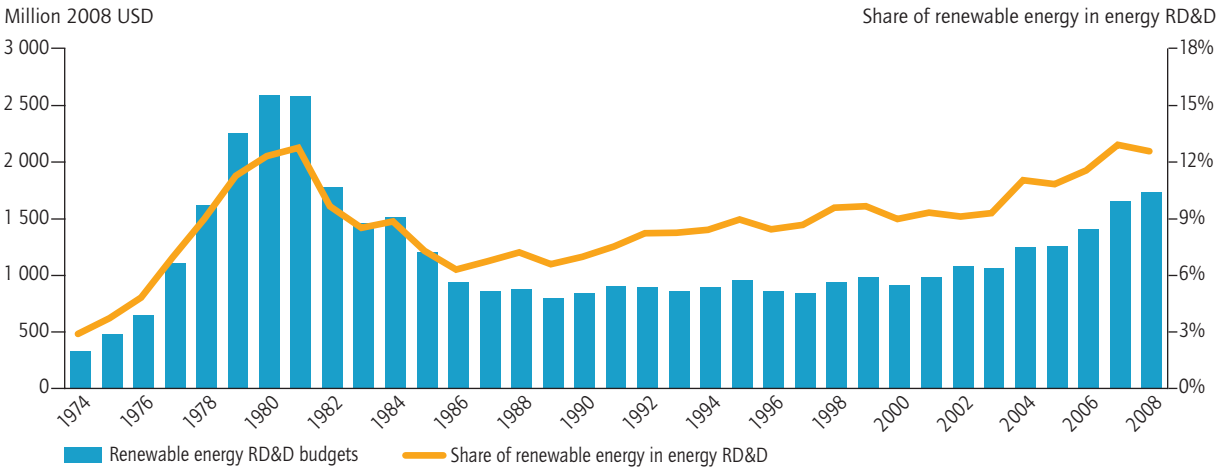
Renewable energy RD&D budgets as share of GDP



Renewable energy RD&D shares by activity in 2008



Share of renewable energy RD&D in energy RD&D for the IEA



** Data for Austria, Belgium, the Czech Republic, Finland and France are for 2007.*

*** Data for the Netherlands are for 2006.*

**** The most recent RD&D budgets received from Greece are for 2002 and from Australia for 2003. Very limited and incomplete information is available for Luxembourg and the Slovak Republic. No RD&D budgets have been submitted by Poland.*

35 IEA Implementing Agreements

Continued R&D and market deployment

▶ Accelerating research, development and deployment (RD&D) of energy technologies and systems is a crucial component of resolving key challenges such as promoting efficient use and production of energy, and ensuring energy security. To provide a platform for member countries to address such challenges, the IEA created Implementing Agreements (IAs) in 1975.

▶ Since then, Implementing Agreements have been a direct reflection of national priorities. In the 1980s, their main focus was on fossil fuels. In the 1990s, several IAs were created to address energy saving, greenhouse gas emissions and renewable energy. More recently, IAs were launched in areas such as renewable technology deployment, electricity networks and energy-efficient equipment. Climate change has also become a large enough concern to warrant specific IAs.

▶ In 2009, there are 42 Implementing Agreements. Most cover the areas of fossil fuels, renewables, buildings, electricity, industry, transport and fusion. Others focus on a few cross-cutting activities such as modelling, technology transfer and a database for research and development literature.

▶ The United States participates in the largest number (39) of Implementing Agreements, followed by Canada (31) and Japan (30). Since 1983, each of these three countries has more than doubled their participation. Korea has experienced the fastest growth in participation, from no Agreements in 1993 to 19 in 2009.

▶ The growing importance of energy efficiency policies in IEA member countries is reflected in the fact that the largest share of IA participations is in the end-use or energy savings (in sectors such as buildings, electricity, industry and transport). The United States (14 Agreements) leads participation in this area followed closely by Canada and Sweden (13). The United States (9) also leads participation in the fusion power Agreements, followed by Japan (8). Regarding renewables, Germany (9) has the largest participation, followed by France, Norway and the United States (8).

▶ In recent years, the IEA Secretariat has seen broader interest in IAs, as more private companies, IEA non-member countries and international organisations seek to voluntarily join IAs that are relevant to their aims. IEA non-member countries show a strong interest in renewables; commercial partners are more interested in IAs related to fossil fuel. As of 2009, 16 IEA non-member countries participated in 26 Agreements. Many of the non-member countries participated in only one whereas Mexico was a member of 11 Agreements. The European Commission participated in 21 Agreements while the Organization of the Petroleum Exporting Countries (OPEC) participated in only one Agreement.

▶ Sources

- *Energy Technologies at the Cutting Edge*, 2007, IEA.
- *IEA Framework for International Energy Technology Co-operation*, 2003, IEA.

▶ For further information

- IEA OPEN Bulletin, *www.iea.org/impagr/cip/index.htm.*
- IEA Energy Technology Agreements, *www.iea.org/techagr.*

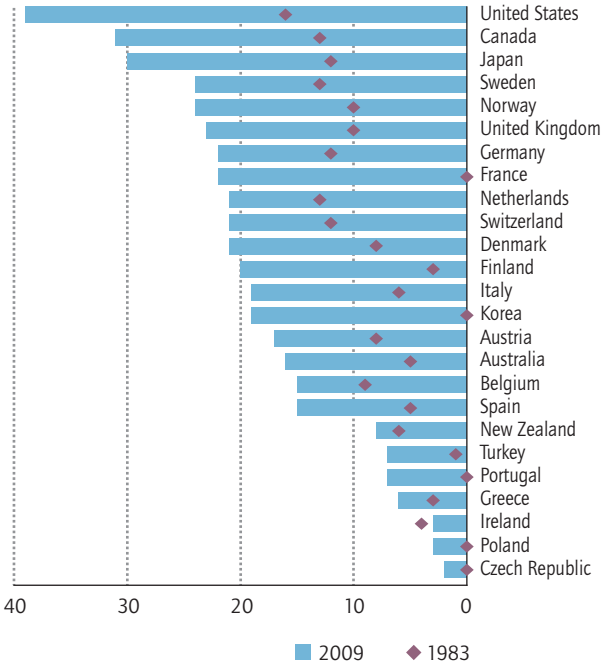
What are Implementing Agreements?

Implementing Agreements (IAs) provide a platform for participants to jointly address issues of common concern in a manner that helps to reduce costs, enhance national capabilities, bridge competencies and expand potentials. The Agreements are regulated by the IEA Framework for International Energy Technology Co-operation, and are open on a voluntary basis to IEA member countries, IEA non-member countries, commercial partners/industry, international organisations and non-governmental organisations.

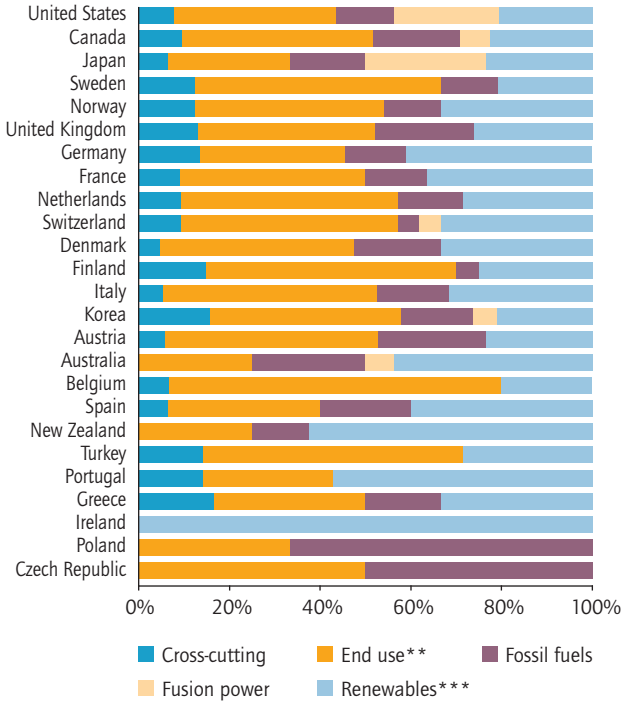
Since the creation of IAs in 1975, more than 5 000 participants have carried out more than 1 500 joint projects, topical reports or expert workshops. In addition, IEA member countries and other interested parties undertake a large number of other types of collaborative projects such as construction of demonstration plants, scientist exchanges on multi-million dollar projects, on-site and in situ testing, negotiating standards and establishing databases. Such activities are financed by participating entities through cost-sharing, task-sharing or other arrangements. As the vast majority (97%) of participants represent governmental entities, direct or indirect government funding is predominant.

International research collaboration provides a platform to reduce costs, enhance national capabilities, bridge competencies and expand potentials.

Participation in IEA Implementing Agreements*

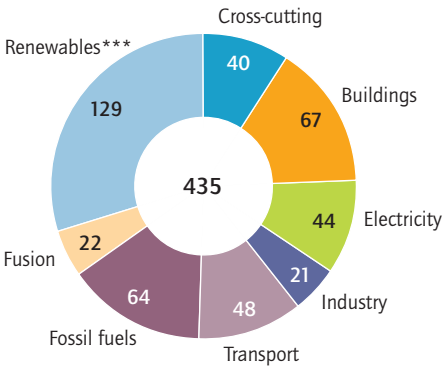


Share by category in 2009

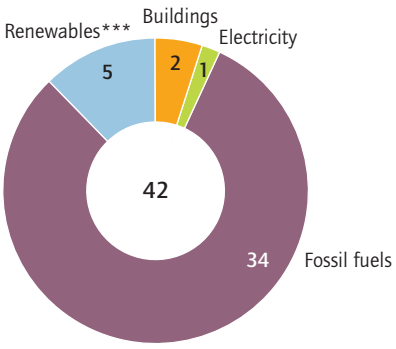


Participation in IEA Implementing Agreements by category in 2009

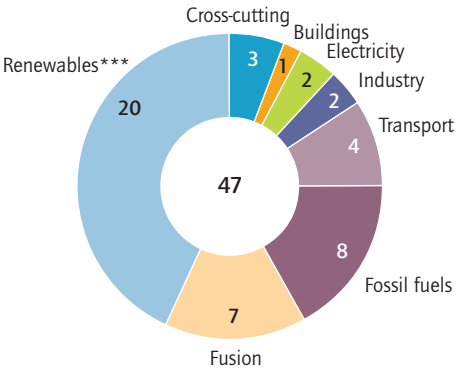
IEA member country organisations



Industry organisations



IEA non-member country organisations



** Several countries that are included joined the IEA after 1983: the Czech Republic (2002), Finland and France (1992), Korea (2002) and Poland (2008). Hungary, Luxembourg and the Slovak Republic are not included as they do not as yet participate in IEA Implementing Agreements. Participation of international organisations is not shown.*
*** The end-use category includes buildings, electricity, industry and transport.*
**** Renewables includes hydrogen.*

Annexes

Annexes

1 IEA Shared Goals

The member countries of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA member countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants.

In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

- **Diversity, efficiency and flexibility within the energy sector** are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA member countries as a group.

- Energy systems should have **the ability to respond promptly and flexibly to energy emergencies**. In some cases this requires collective mechanisms and action: IEA member countries co-operate through the Agency in responding jointly to oil supply emergencies.

- **The environmentally sustainable provision and use of energy** are central to the achievement of these shared goals. Decision-makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the Polluter Pays Principle where practicable.

- **More environmentally acceptable energy sources** need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

- **Improved energy efficiency** can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

- **Continued research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

- **Undistorted energy prices** enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

- **Free and open trade** and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

- **Co-operation among all energy market participants** helps to improve information and understanding and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

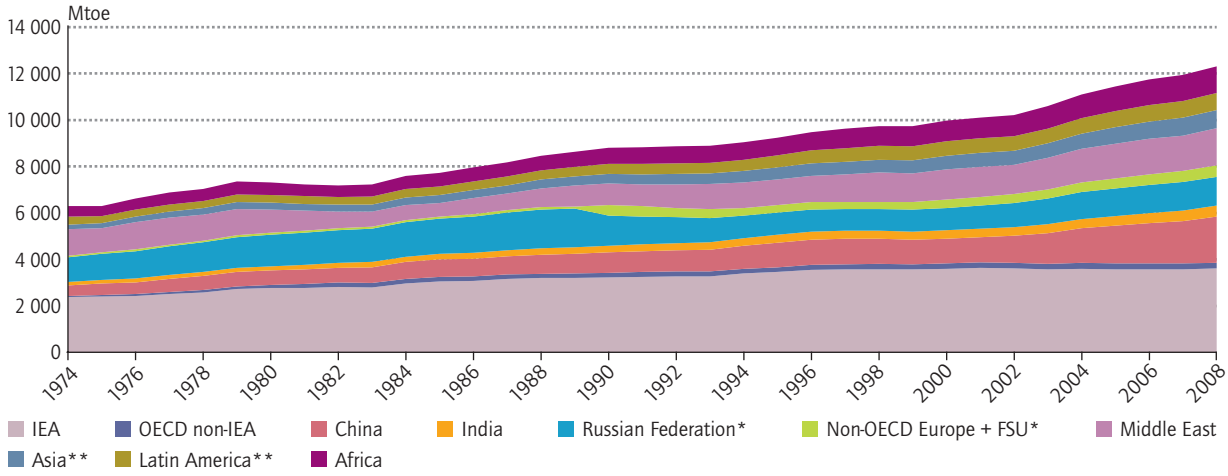
The "Shared Goals" were adopted by IEA Ministers at their 4 June 1993 meeting in Paris.

Geographical coverage

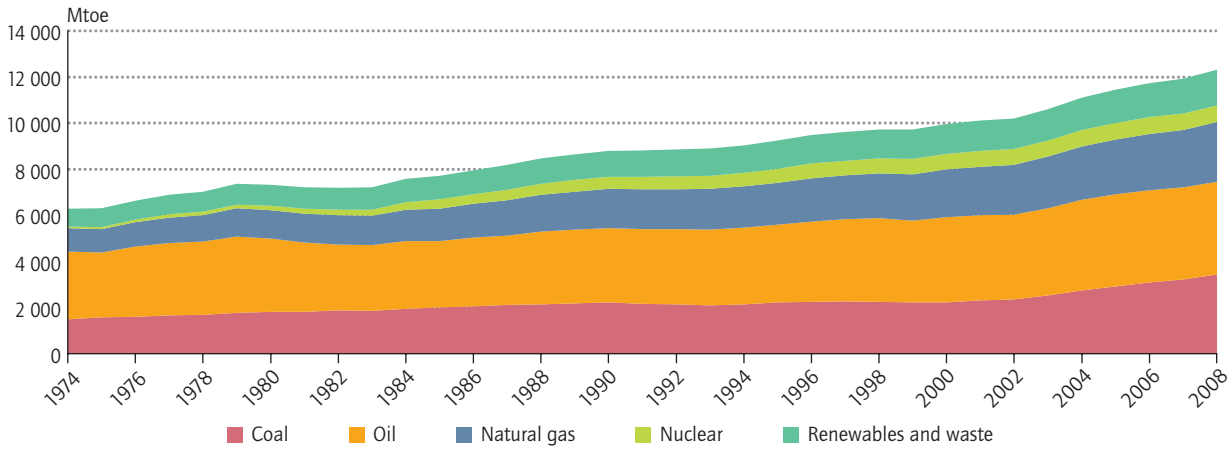
IEA	Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. IEA11: Australia, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, the United Kingdom and the United States. IEA17: Australia, Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States.
OECD	IEA plus Iceland and Mexico.
Africa	Algeria, Angola, Benin, Botswana, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libyan Arab Jamahiriya, Morocco, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, United Republic of Tanzania, Togo, Tunisia, Zambia, Zimbabwe and other Africa.
Asia	Bangladesh, Brunei Darussalam, Cambodia, Chinese Taipei, Indonesia, Democratic People's Republic of Korea, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Vietnam and other Asia.
China	People's Republic of China and Hong Kong (China).
Former Soviet Union (FSU)	Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Republic of Moldova, the Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.
Latin America	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela and other Latin America.
Middle East	Bahrain, Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates and Yemen.
Non-OECD Europe	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Gibraltar, the Former Yugoslav Republic of Macedonia, Malta, Montenegro (data are not available after 2004), Romania, Serbia and Slovenia.

Note: The countries listed above are those for which the IEA Secretariat has direct statistical contacts.

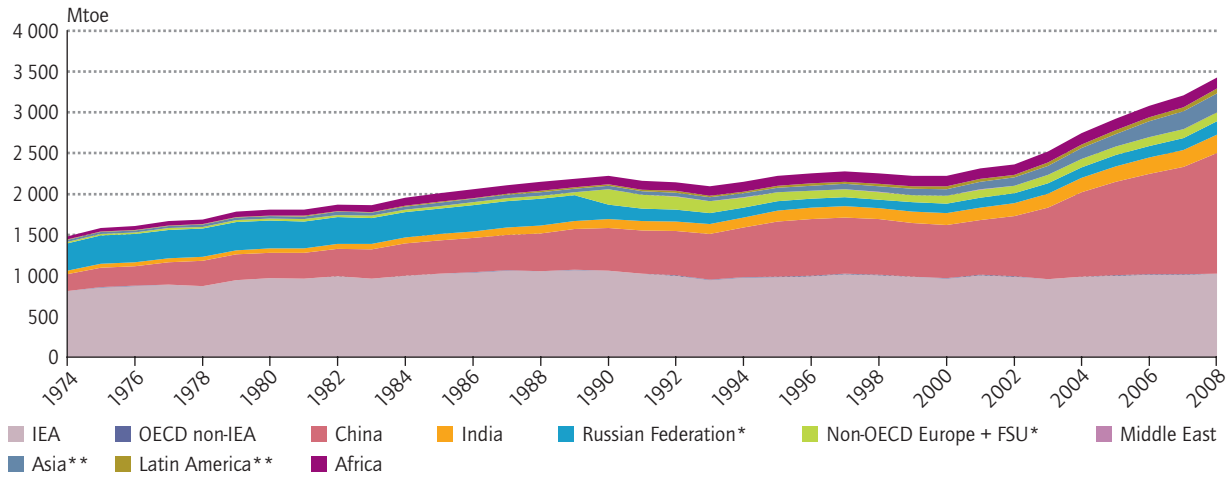
Energy production by region



Energy production by fuel

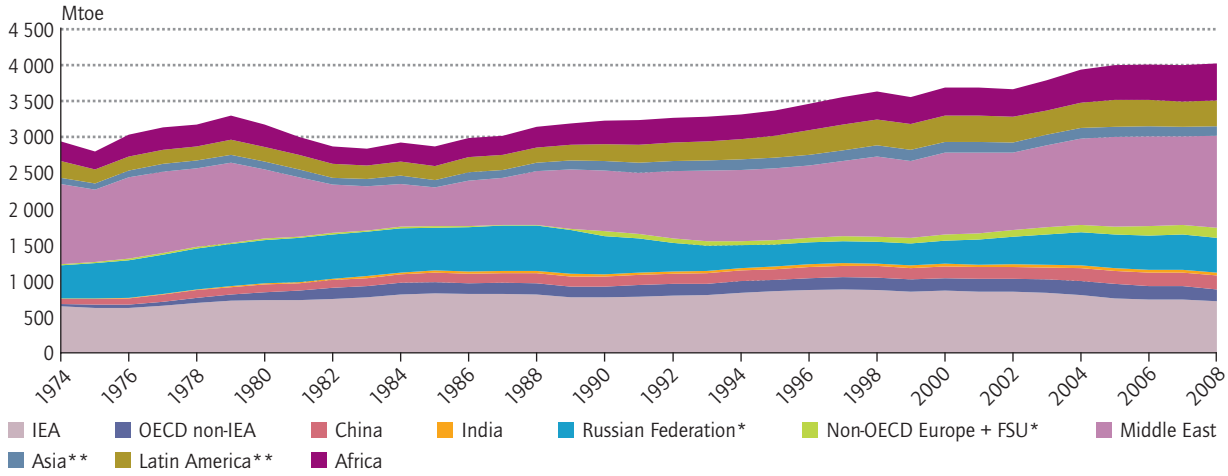


Coal production by region

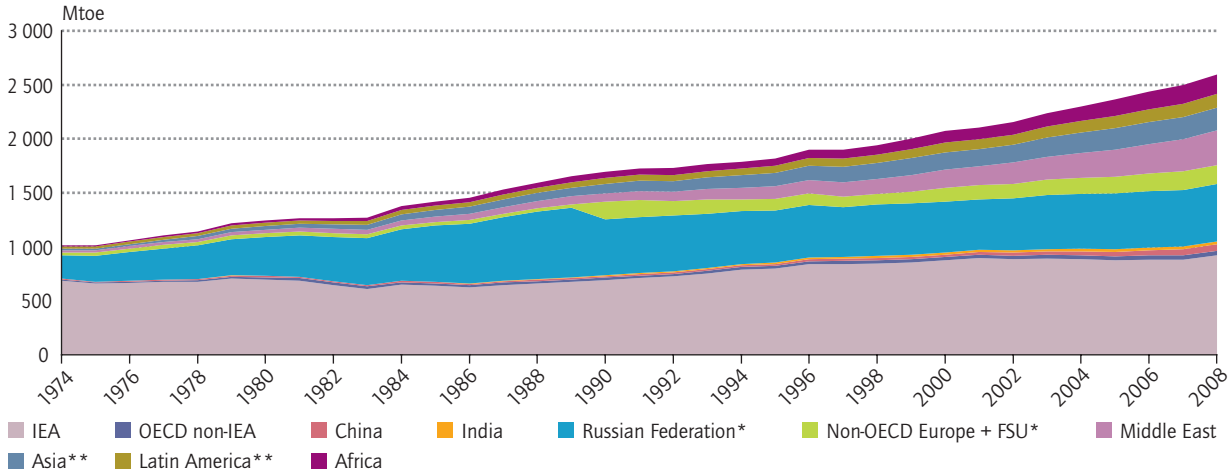


** Prior to 1990, the Russian Federation includes the rest of Former Soviet Union (FSU). From 1990 onwards, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

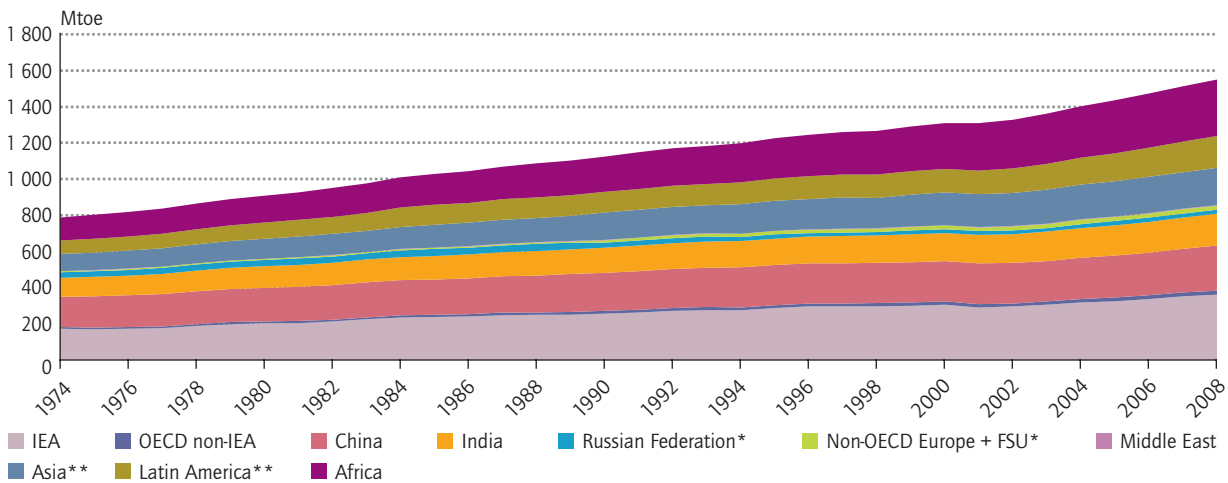
Oil production by region



Natural gas production by region



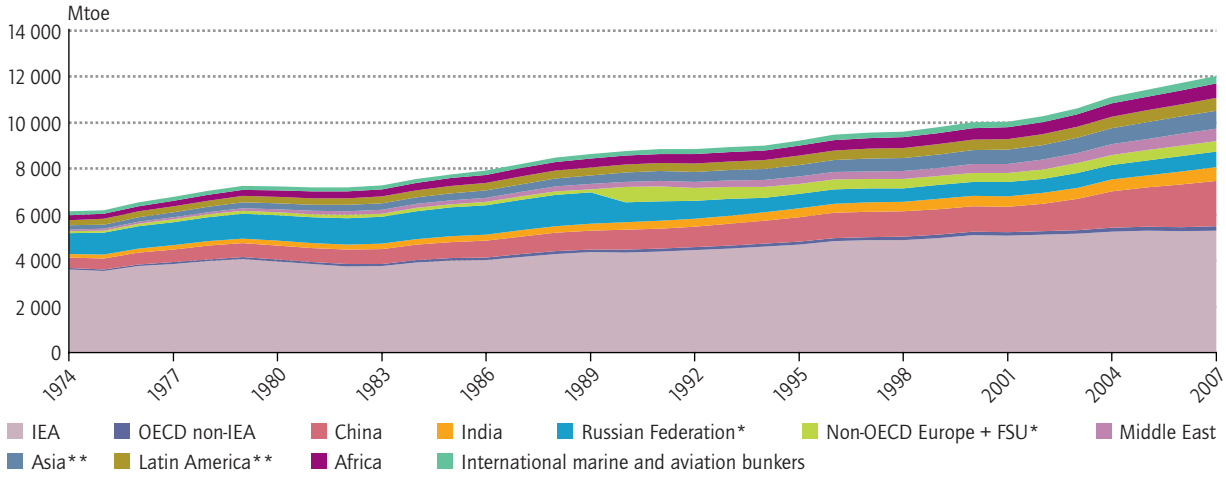
Renewables and waste production by region



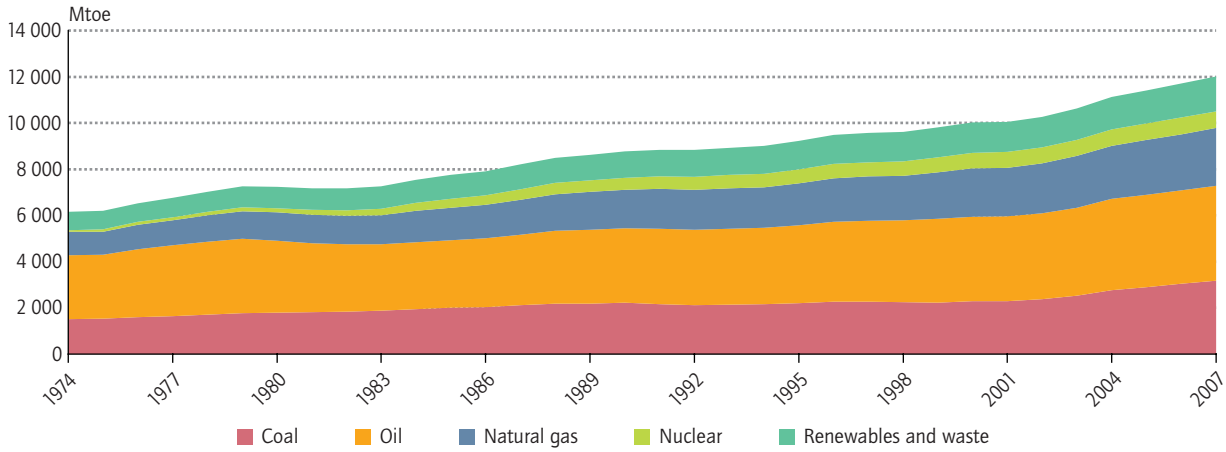
** Prior to 1990, the Russian Federation includes the rest of Former Soviet Union (FSU). From 1990 onwards, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

Selected graphs for the world (continued)

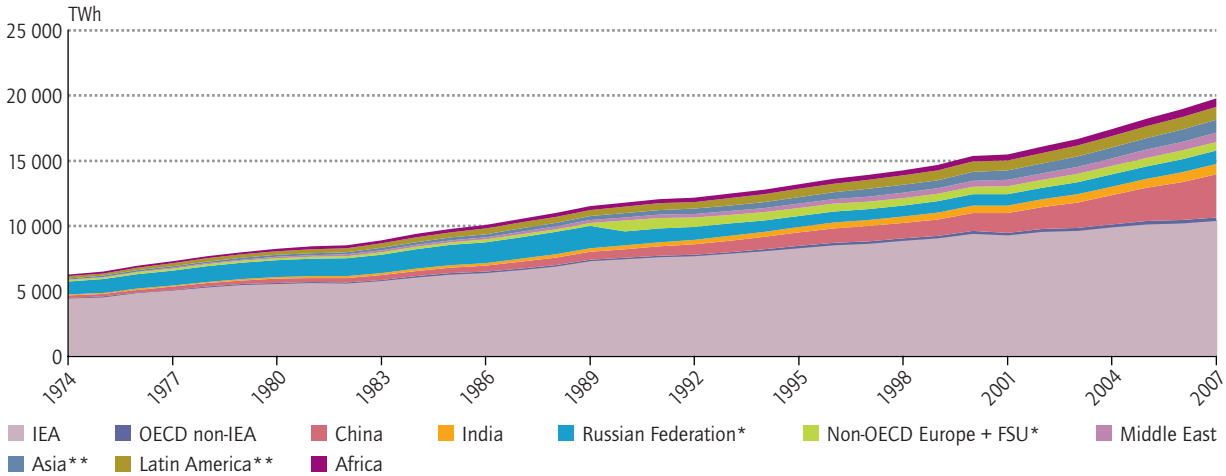
TPES by region



TPES by fuel

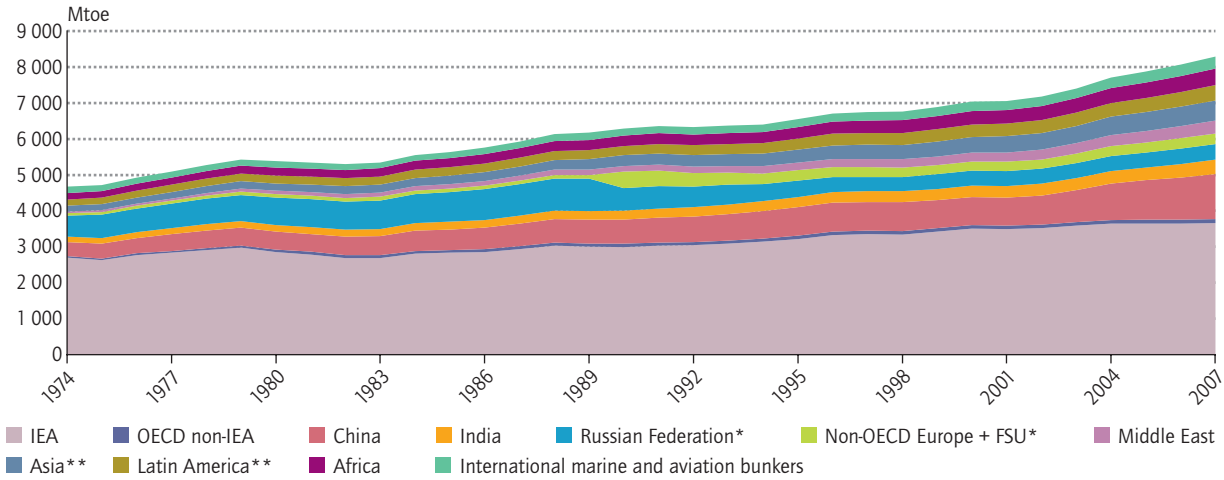


Electricity production by region

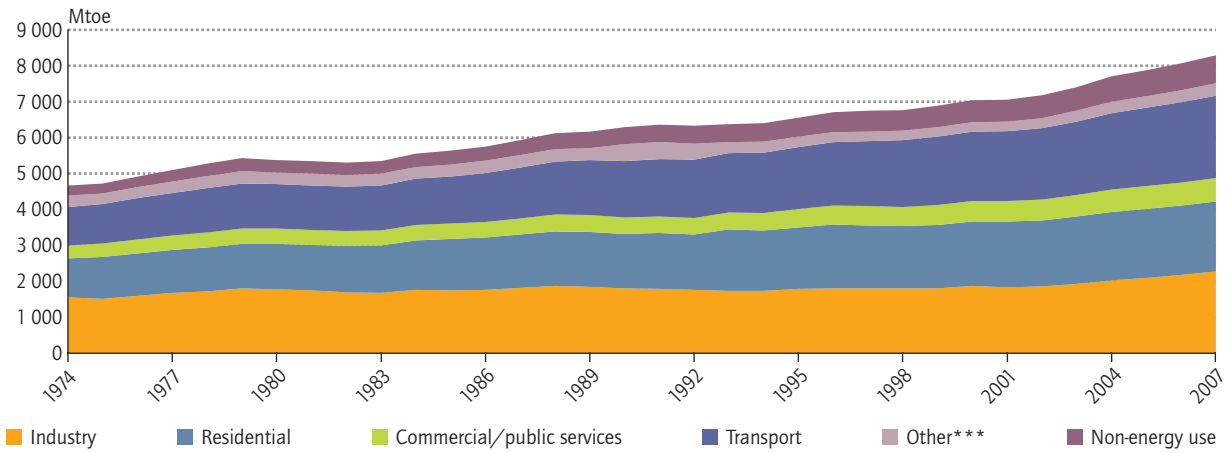


** Prior to 1990, the Russian Federation includes the rest of Former Soviet Union (FSU). From 1990 onwards, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico.*

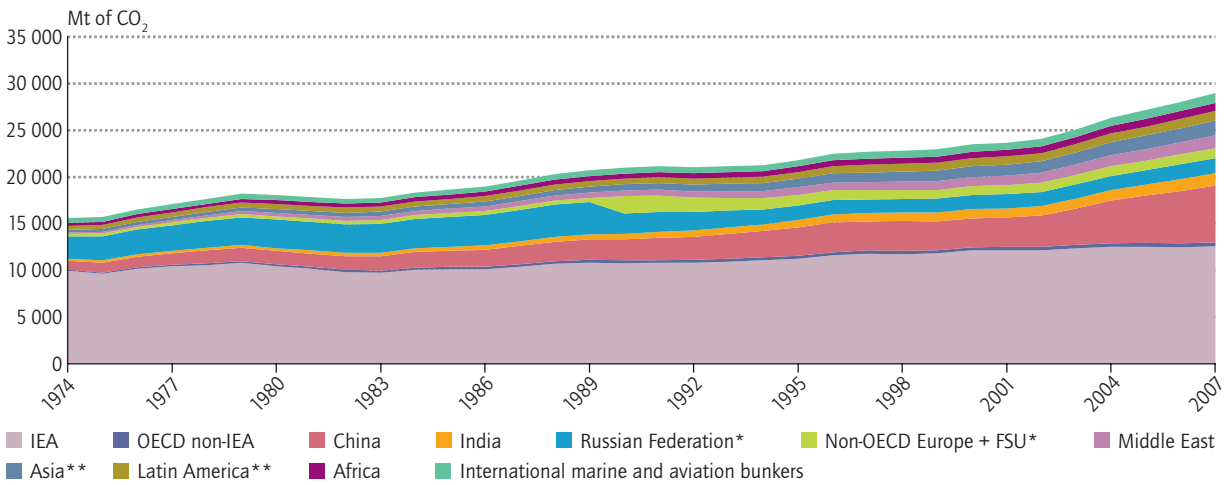
Final consumption by region



Final consumption by sector



CO_2 emissions by region



** Prior to 1990, the Russian Federation includes the rest of Former Soviet Union (FSU). From 1990 onwards, Non-OECD Europe + FSU excludes the Russian Federation.*
*** Asia excludes China, India and OECD Pacific. Latin America excludes Mexico. *** Other includes agriculture/forestry, fishing and other use not specified elsewhere.*

Selected key indicators for 140 countries, economies and regions

Year: 2007	Population	GDP	GDP PPP	Energy prod.	Net imports	TPES	Elec. cons.	CO_2 emissions	TPES/ pop.	TPES/ GDP	TPES/ GDP PPP	Elec. cons./ pop.	CO_2/ TPES	CO_2/ pop.	CO_2/ GDP	CO_2/ GDP PPP
	(million)	(billion 2000$)	(billion 2000$)	(Mtoe)	(Mtoe)	(Mtoe)	(TWh)	(Mt of CO_2)	(toe/ capita)	(toe/000 2000$)	(toe/000 2000$)	(kWh/ capita)	(t CO_2/ toe)	(t CO_2/ capita)	(kg CO_2/ 2000$)	(kg CO_2/ 2000$)
World	6609	39493	61428	11940	-	12029	18187	28962	1.82	0.30	0.20	2752	2.41	4.38	0.73	0.47
OECD	1185	30110	32361	3833	1821	5497	10048	13001	4.64	0.18	0.17	8477	2.37	10.97	0.43	0.40
Middle East	193	891	1552	1527	-945	552	628	1389	2.86	0.62	0.36	3252	2.52	7.19	1.56	0.89
Former Soviet Union	284	620	2472	1645	-608	1019	1308	2412	3.59	1.64	0.41	4608	2.37	8.50	3.89	0.98
Non-OECD Europe	53	174	509	61	48	106	176	272	1.99	0.61	0.21	3302	2.57	5.10	1.56	0.53
China	1327	2623	10156	1814	194	1970	3114	6071	1.48	0.75	0.19	2346	3.08	4.58	2.31	0.60
Asia	2148	2308	8292	1224	197	1377	1514	2898	0.64	0.60	0.17	705	2.11	1.35	1.26	0.35
Latin America	461	1938	3714	705	-136	550	847	1016	1.19	0.28	0.15	1838	1.85	2.21	0.52	0.27
Africa	958	830	2372	1129	-488	629	554	882	0.66	0.76	0.27	578	1.40	0.92	1.06	0.37
Albania	3.18	5.34	16.48	1.06	1.26	2.17	3.72	4.02	0.68	0.41	0.13	1168	1.85	1.27	0.75	0.24
Algeria	33.85	73.01	216.24	164.30	-127.47	36.86	30.56	85.72	1.09	0.50	0.17	903	2.33	2.53	1.17	0.40
Angola	17.02	21.45	47.56	94.96	-84.15	10.63	3.24	10.66	0.62	0.50	0.22	190	1.00	0.63	0.50	0.22
Argentina	39.50	369.62	580.36	81.91	-7.47	73.07	104.99	162.57	1.85	0.20	0.13	2658	2.22	4.12	0.44	0.28
Armenia	3.00	4.38	17.11	0.82	2.08	2.84	5.20	4.79	0.95	0.65	0.17	1733	1.68	1.60	1.09	0.28
Australia	21.14	507.75	666.78	289.21	-156.29	124.07	237.05	396.26	5.87	0.24	0.19	11216	3.19	18.75	0.78	0.59
Austria	8.32	221.33	266.51	10.90	23.31	33.18	66.68	69.66	3.99	0.15	0.12	8020	2.10	8.38	0.31	0.26
Azerbaijan	8.57	16.69	63.06	52.09	-39.61	11.91	20.54	27.58	1.39	0.71	0.19	2397	2.32	3.22	1.65	0.44
Bahrain	0.75	12.30	16.12	17.02	-8.09	8.77	10.75	21.26	11.65	0.71	0.54	14276	2.42	28.23	1.73	1.32
Bangladesh	158.57	69.63	294.14	21.26	4.67	25.76	22.78	40.01	0.16	0.37	0.09	144	1.55	0.25	0.57	0.14
Belarus	9.70	21.77	82.11	4.01	23.76	28.05	32.45	62.70	2.89	1.29	0.34	3345	2.24	6.46	2.88	0.76
Belgium	10.62	265.96	323.58	14.36	51.87	57.02	91.54	105.95	5.37	0.21	0.18	8617	1.86	9.97	0.40	0.33
Benin	9.03	2.96	9.21	1.77	1.14	2.88	0.61	3.13	0.32	0.97	0.31	67	1.09	0.35	1.06	0.34
Bolivia	9.52	10.72	25.33	15.06	-9.64	5.44	4.90	12.31	0.57	0.51	0.21	515	2.26	1.29	1.15	0.49
Bosnia and Herzegovina	3.77	7.22	29.34	3.94	1.65	5.60	9.00	17.99	1.49	0.78	0.19	2385	3.21	4.77	2.49	0.61
Botswana	1.88	8.83	20.94	1.11	0.93	2.02	2.72	4.76	1.07	0.23	0.10	1443	2.35	2.53	0.54	0.23
Brazil	191.60	808.95	1561.26	215.58	24.81	235.56	412.69	347.09	1.23	0.29	0.15	2154	1.47	1.81	0.43	0.22
Brunei Darrussalam	0.39	5.05	6.03	20.19	-17.40	2.77	3.23	5.82	7.11	0.55	0.46	8303	2.10	14.97	1.15	0.97
Bulgaria	7.64	18.39	71.38	9.97	10.57	20.23	34.13	50.24	2.65	1.10	0.28	4466	2.48	6.57	2.73	0.70
Cambodia	14.45	7.15	43.50	3.62	1.54	5.13	1.35	4.43	0.36	0.72	0.12	93	0.86	0.31	0.62	0.10
Cameroon	18.53	12.91	35.76	10.17	-2.73	7.29	4.95	4.64	0.39	0.56	0.20	267	0.64	0.25	0.36	0.13
Canada	32.98	869.28	1046.87	413.19	-149.79	269.37	560.43	572.94	8.17	0.31	0.26	16995	2.13	17.37	0.66	0.55
Chile	16.60	101.34	189.63	8.45	24.13	30.79	55.20	71.04	1.86	0.30	0.16	3326	2.31	4.28	0.70	0.37
People's Rep. of China	1319.98	2387.68	9911.78	1813.98	166.75	1955.77	3072.67	6027.85	1.48	0.82	0.20	2328	3.08	4.57	2.52	0.61
Chinese Taipei	22.86	416.00	636.32	12.71	101.58	109.86	233.53	276.18	4.81	0.26	0.17	10216	2.51	12.08	0.66	0.43
Colombia	46.12	131.09	389.60	87.60	-55.97	29.05	43.33	55.92	0.63	0.22	0.07	940	1.93	1.21	0.43	0.14
Congo	3.77	4.16	4.68	12.54	-11.25	1.27	0.48	1.26	0.34	0.30	0.27	127	1.00	0.34	0.30	0.27

Year: 2007	Population	GDP	GDP PPP	Energy prod.	Net imports	TPES	Elec. cons.	CO_2 emissions	TPES/ pop.	TPES/ GDP	TPES/ GDP PPP	Elec. cons./ pop.	CO_2/ TPES	CO_2/ pop.	CO_2/ GDP	CO_2/ GDP PPP
	(million)	(billion 2000$)	(billion 2000$)	(Mtoe)	(Mtoe)	(Mtoe)	(TWh)	(Mt of CO_2)	(toe/ capita)	(toe/000 2000$)	(toe/000 2000$)	(kWh/ capita)	(t CO_2/ toe)	(t CO_2/ capita)	(kg CO_2/ 2000$)	(kg CO_2/ 2000$)
Dem. Rep. of Congo	62.40	5.86	41.00	18.41	-0.17	18.09	6.08	2.44	0.29	3.09	0.44	97	0.13	0.04	0.42	0.06
Costa Rica	4.46	22.85	45.98	2.51	2.42	4.77	8.31	6.56	1.07	0.21	0.10	1861	1.38	1.47	0.29	0.14
Cote d'Ivoire	19.27	10.67	27.22	11.25	-1.25	9.98	3.59	5.06	0.52	0.94	0.37	186	0.51	0.26	0.47	0.19
Croatia	4.44	25.70	57.25	4.05	5.34	9.32	16.58	22.03	2.10	0.36	0.16	3736	2.36	4.96	0.86	0.38
Cuba	11.26	42.69	98.51	5.16	5.08	9.90	14.67	26.16	0.88	0.23	0.10	1303	2.64	2.32	0.61	0.27
Cyprus	0.79	11.86	17.25	0.07	2.88	2.44	4.65	7.35	3.10	0.21	0.14	5903	3.02	9.34	0.62	0.43
Czech Republic	10.32	77.10	209.12	33.73	11.52	45.76	67.13	122.14	4.43	0.59	0.22	6503	2.67	11.83	1.58	0.58
Denmark	5.46	178.98	171.82	27.04	-5.51	19.65	36.43	50.46	3.60	0.11	0.11	6671	2.57	9.24	0.28	0.29
Dominican Republic	9.75	28.10	79.46	1.54	6.43	7.89	13.52	19.28	0.81	0.28	0.10	1387	2.44	1.98	0.69	0.24
Ecuador	13.34	22.14	55.20	28.91	-16.13	11.80	10.52	27.00	0.88	0.53	0.21	788	2.29	2.02	1.22	0.49
Egypt	75.47	135.87	322.98	82.27	-13.19	67.25	110.82	168.70	0.89	0.49	0.21	1468	2.51	2.24	1.24	0.52
El Salvador	6.85	16.01	35.19	2.83	2.24	4.88	5.73	6.22	0.71	0.31	0.14	836	1.27	0.91	0.39	0.18
Eritrea	4.84	0.72	4.14	0.53	0.16	0.72	0.25	0.51	0.15	1.00	0.17	51	0.71	0.11	0.71	0.12
Estonia	1.34	9.63	22.03	4.40	1.54	5.63	8.42	18.05	4.20	0.58	0.26	6271	3.20	13.45	1.87	0.82
Ethiopia	79.09	13.76	91.24	20.86	1.98	22.81	3.17	5.96	0.29	1.66	0.25	40	0.26	0.08	0.43	0.07
Finland	5.29	151.26	164.81	15.95	19.98	36.47	90.76	64.44	6.90	0.24	0.22	17164	1.77	12.19	0.43	0.39
France	63.57	1505.62	1737.96	135.45	135.86	263.72	481.41	369.31	4.15	0.18	0.15	7573	1.40	5.81	0.25	0.21
Gabon	1.33	5.90	8.66	11.99	-10.03	1.85	1.52	2.56	1.39	0.31	0.21	1140	1.38	1.92	0.43	0.30
Georgia	4.40	5.36	16.52	1.07	2.32	3.34	7.06	5.12	0.76	0.62	0.20	1606	1.53	1.17	0.96	0.31
Germany	82.26	2065.35	2315.34	137.03	201.58	331.26	591.03	798.44	4.03	0.16	0.14	7185	2.41	9.71	0.39	0.34
Ghana	23.46	7.20	55.23	6.47	3.15	9.50	5.93	9.00	0.41	1.32	0.17	253	0.95	0.38	1.25	0.16
Gibraltar	0.03	0.88	0.92	0.00	1.36	0.15	0.16	0.47	5.49	0.17	0.17	5536	3.06	16.79	0.53	0.51
Greece	11.19	169.74	268.13	12.15	24.38	32.18	62.99	97.84	2.88	0.19	0.12	5628	3.04	8.74	0.58	0.36
Guatemala	13.35	24.93	58.43	5.33	3.31	8.28	7.45	11.70	0.62	0.33	0.14	558	1.41	0.88	0.47	0.20
Haiti	9.61	3.95	13.20	2.01	0.79	2.78	0.29	2.31	0.29	0.70	0.21	31	0.83	0.24	0.59	0.18
Honduras	7.09	10.08	31.21	2.12	2.53	4.74	4.96	8.17	0.67	0.47	0.15	700	1.72	1.15	0.81	0.26
Hong Kong (China)	6.93	235.73	244.06	0.05	26.76	13.75	40.86	43.38	1.98	0.06	0.06	5899	3.16	6.26	0.18	0.18
Hungary	10.06	62.13	162.30	10.22	16.55	26.73	39.99	53.93	2.66	0.43	0.16	3976	2.02	5.36	0.87	0.33
Iceland	0.31	11.63	10.83	3.95	1.17	4.89	11.48	2.34	15.74	0.42	0.45	36920	0.48	7.53	0.20	0.22
India	1123.32	771.09	4024.89	450.92	150.03	594.91	609.74	1324.05	0.53	0.77	0.15	543	2.23	1.18	1.72	0.33
Indonesia	225.63	233.20	846.86	331.10	-139.59	190.65	127.17	377.18	0.84	0.82	0.23	564	1.98	1.67	1.62	0.45
Islamic Rep. of Iran	71.02	151.80	554.02	323.07	-137.79	184.94	165.12	465.90	2.60	1.22	0.33	2325	2.52	6.56	3.07	0.84
Iraq	27.50	20.86	28.52	104.83	-70.88	33.09	32.34	91.45	1.20	1.59	1.16	1176	2.76	3.33	4.38	3.21
Ireland	4.36	141.90	159.91	1.41	14.18	15.06	27.29	44.14	3.46	0.11	0.09	6263	2.93	10.13	0.31	0.28
Israel	7.17	152.46	191.09	2.66	20.37	21.96	50.28	65.89	3.06	0.14	0.11	7010	3.00	9.19	0.43	0.34
Italy	59.32	1183.77	1570.36	26.38	157.99	178.16	339.20	437.56	3.00	0.15	0.11	5718	2.46	7.38	0.37	0.28
Jamaica	2.68	8.27	9.60	0.50	4.79	4.96	6.80	12.69	1.85	0.60	0.52	2541	2.56	4.74	1.53	1.32

Selected key indicators for 140 countries, economies and regions (continued)

Year: 2007	Population	GDP	GDP PPP	Energy prod.	Net imports	TPES	Elec. cons.	CO_2 emissions	TPES/ pop.	TPES/ GDP	TPES/ GDP PPP	Elec. cons./ pop.	CO_2/ TPES	CO_2/ pop.	CO_2/ GDP	CO_2/ GDP PPP
	(million)	(billion 2000$)	(billion 2000$)	(Mtoe)	(Mtoe)	(Mtoe)	(TWh)	(Mt of CO_2)	(toe/ capita)	(toe/000 2000$)	(toe/000 2000$)	(kWh/ capita)	(t CO_2/ toe)	(t CO_2/ capita)	(kg CO_2/ 2000$)	(kg CO_2/ 2000$)
Japan	127.76	5205.02	3620.16	90.47	434.68	513.52	1082.72	1236.34	4.02	0.10	0.14	8475	2.41	9.68	0.24	0.34
Jordan	5.72	12.86	30.61	0.28	7.33	7.20	11.18	19.17	1.26	0.56	0.24	1956	2.66	3.35	1.49	0.63
Kazakhstan	15.48	36.11	127.68	135.99	-69.74	66.46	68.88	190.45	4.29	1.84	0.52	4449	2.87	12.30	5.27	1.49
Kenya	37.53	17.25	43.04	14.72	3.63	18.30	5.71	11.43	0.49	1.06	0.43	152	0.62	0.30	0.66	0.27
Korea	48.46	705.65	1065.75	42.48	190.28	222.20	411.97	488.71	4.59	0.31	0.21	8502	2.20	10.09	0.69	0.46
DPR of Korea	23.78	11.38	40.03	19.69	-1.31	18.38	18.12	62.32	0.77	1.61	0.46	762	3.39	2.62	5.48	1.56
Kuwait	2.66	62.16	70.73	146.57	-120.24	25.20	43.13	66.83	9.46	0.41	0.36	16198	2.65	25.09	1.08	0.94
Kyrgyzstan	5.24	1.84	9.88	1.43	1.49	2.91	9.28	5.71	0.56	1.58	0.29	1769	1.96	1.09	3.10	0.58
Latvia	2.28	14.37	34.71	1.80	3.03	4.67	6.97	8.34	2.05	0.32	0.13	3064	1.79	3.66	0.58	0.24
Lebanon	4.10	20.94	20.20	0.21	3.92	3.99	8.97	11.35	0.97	0.19	0.20	2188	2.84	2.77	0.54	0.56
Libyan Arab Jamahiriya	6.16	49.61	67.42	101.59	-83.49	17.82	23.88	43.13	2.90	0.36	0.26	3880	2.42	7.01	0.87	0.64
Lithuania	3.38	19.49	52.07	3.80	5.73	9.25	11.53	14.44	2.74	0.47	0.18	3414	1.56	4.28	0.74	0.28
Luxembourg	0.48	27.05	31.20	0.08	4.54	4.22	7.83	10.73	8.79	0.16	0.14	16315	2.54	22.35	0.40	0.34
FYR of Macedonia	2.04	4.20	14.25	1.50	1.47	3.02	7.71	9.12	1.48	0.72	0.21	3785	3.02	4.48	2.17	0.64
Malaysia	26.55	132.99	290.31	94.35	-19.76	72.59	97.39	177.38	2.73	0.55	0.25	3668	2.44	6.68	1.33	0.61
Malta	0.41	4.35	7.72	0.00	1.80	0.87	1.98	2.72	2.12	0.20	0.11	4846	3.14	6.65	0.63	0.35
Mexico	105.68	755.11	1169.19	251.05	-62.16	184.26	214.34	437.92	1.74	0.24	0.16	2028	2.38	4.14	0.58	0.37
Republic of Moldova	3.79	1.96	8.58	0.09	3.29	3.34	4.84	7.50	0.88	1.71	0.39	1276	2.25	1.98	3.83	0.87
Mongolia	2.61	1.78	6.92	3.55	-0.40	3.09	3.58	11.28	1.18	1.73	0.45	1369	3.65	4.32	6.32	1.63
Morocco	30.86	52.24	157.80	0.65	14.08	14.36	22.08	40.84	0.47	0.27	0.09	715	2.84	1.32	0.78	0.26
Mozambique	21.37	7.47	28.31	10.99	-1.74	9.15	10.32	1.97	0.43	1.22	0.32	483	0.22	0.09	0.26	0.07
Myanmar	48.78	18.33	110.86	23.94	-8.15	15.65	4.62	12.37	0.32	0.85	0.14	95	0.79	0.25	0.67	0.11
Namibia	2.07	4.70	15.22	0.33	1.23	1.56	3.22	3.18	0.75	0.33	0.10	1552	2.05	1.54	0.68	0.21
Nepal	28.11	6.92	40.85	8.53	1.10	9.55	2.27	3.21	0.34	1.38	0.23	81	0.34	0.11	0.46	0.08
Netherlands	16.38	439.76	534.06	61.45	38.57	80.42	116.26	182.20	4.91	0.18	0.15	7099	2.27	11.13	0.41	0.34
Netherlands Antilles	0.19	1.31	2.95	0.00	4.06	2.18	1.09	4.50	11.39	1.66	0.74	5691	2.07	23.57	3.44	1.53
New Zealand	4.19	66.38	101.07	14.00	4.33	16.77	40.69	35.47	4.01	0.25	0.17	9722	2.12	8.48	0.53	0.35
Nicaragua	5.61	4.96	19.40	2.06	1.49	3.47	2.49	4.40	0.62	0.70	0.18	445	1.27	0.79	0.89	0.23
Nigeria	147.98	69.63	159.92	231.71	-124.25	106.68	20.27	51.38	0.72	1.53	0.67	137	0.48	0.35	0.74	0.32
Norway	4.71	198.09	190.75	213.91	-186.78	26.86	117.64	36.93	5.71	0.14	0.14	24997	1.37	7.85	0.19	0.19
Oman	2.60	28.86	44.73	59.27	-41.63	15.48	12.22	35.85	5.95	0.54	0.35	4702	2.32	13.79	1.24	0.80
Pakistan	162.39	106.21	376.24	63.64	20.22	83.27	77.09	138.42	0.51	0.78	0.22	475	1.66	0.85	1.30	0.37
Panama	3.34	17.37	26.67	0.70	1.99	2.82	5.32	6.49	0.85	0.16	0.11	1594	2.30	1.94	0.37	0.24
Paraguay	6.12	8.94	28.15	7.14	-2.91	4.20	5.87	3.70	0.69	0.47	0.15	959	0.88	0.60	0.41	0.13
Peru	27.90	76.74	176.54	12.21	3.77	14.08	27.39	30.32	0.50	0.18	0.08	982	2.15	1.09	0.40	0.17
Philippines	87.89	106.78	429.74	22.40	18.64	39.98	52.00	71.77	0.45	0.37	0.09	592	1.80	0.82	0.67	0.17
Poland	38.12	225.85	532.45	72.65	25.30	97.11	139.58	304.69	2.55	0.43	0.18	3662	3.14	7.99	1.35	0.57

Year: 2007	Population	GDP	GDP PPP	Energy prod.	Net imports	TPES	Elec. cons.	CO_2 emissions	TPES/ pop.	TPES/ GDP	TPES/ GDP PPP	Elec. cons./ pop.	CO_2/ TPES	CO_2/ pop.	CO_2/ GDP	CO_2/ GDP PPP
	(million)	(billion 2000$)	(billion 2000$)	(Mtoe)	(Mtoe)	(Mtoe)	(TWh)	(Mt of CO_2)	(toe/ capita)	(toe/000 2000$)	(toe/000 2000$)	(kWh/ capita)	(t CO_2/ toe)	(t CO_2/ capita)	(kg CO_2/ 2000$)	(kg CO_2/ 2000$)
Portugal	10.61	121.57	188.34	4.62	21.82	25.07	51.56	55.20	2.36	0.21	0.13	4861	2.20	5.20	0.45	0.29
Qatar	0.84	32.40	29.02	102.99	-79.99	22.19	14.69	48.49	26.54	0.68	0.76	17573	2.19	58.01	1.50	1.67
Romania	21.55	55.93	199.67	27.55	12.09	38.91	52.83	91.93	1.81	0.70	0.19	2452	2.36	4.27	1.64	0.46
Russian Federation	141.64	406.18	1603.73	1230.63	-544.40	672.14	897.68	1587.36	4.75	1.65	0.42	6338	2.36	11.21	3.91	0.99
Saudi Arabia	24.20	242.05	360.74	551.30	-396.05	150.33	175.07	357.90	6.21	0.62	0.42	7236	2.38	14.79	1.48	0.99
Senegal	12.41	6.32	21.33	1.26	1.89	2.67	1.52	4.24	0.22	0.42	0.13	122	1.59	0.34	0.67	0.20
Serbia	7.39	13.14	48.37	9.75	6.05	15.81	30.67	49.71	2.14	1.20	0.33	4153	3.14	6.73	3.78	1.03
Singapore	4.59	132.91	135.88	0.00	54.03	26.75	39.07	44.97	5.83	0.20	0.20	8513	1.68	9.80	0.34	0.33
Slovak Republic	5.40	31.05	90.15	5.98	12.34	17.85	28.34	36.80	3.31	0.57	0.20	5251	2.06	6.82	1.18	0.41
Slovenia	2.02	26.91	46.66	3.46	3.88	7.33	14.41	15.92	3.63	0.27	0.16	7138	2.17	7.89	0.59	0.34
South Africa	47.59	178.01	516.63	159.59	-21.86	134.34	238.56	345.77	2.82	0.75	0.26	5013	2.57	7.27	1.94	0.67
Spain	44.87	734.34	1084.35	30.33	123.77	143.95	282.54	344.70	3.21	0.20	0.13	6296	2.39	7.68	0.47	0.32
Sri Lanka	19.95	22.81	93.09	5.08	4.37	9.28	8.34	12.83	0.47	0.41	0.10	418	1.38	0.64	0.56	0.14
Sudan	38.56	20.31	81.40	34.63	-18.80	14.67	3.64	10.87	0.38	0.72	0.18	94	0.74	0.28	0.54	0.13
Sweden	9.15	297.82	298.31	33.58	19.00	50.42	139.40	46.20	5.51	0.17	0.17	15238	0.92	5.05	0.16	0.15
Switzerland	7.51	284.50	259.18	12.62	14.14	25.72	61.64	42.18	3.42	0.09	0.10	8209	1.64	5.62	0.15	0.16
Syrian Arab Republic	19.89	26.62	73.24	24.36	-4.47	19.64	29.49	53.73	0.99	0.74	0.27	1483	2.74	2.70	2.02	0.73
Tajikistan	6.74	1.55	7.91	1.58	2.32	3.90	14.64	6.90	0.58	2.51	0.49	2172	1.77	1.02	4.45	0.87
United Rep. of Tanzania	40.43	14.32	27.81	16.90	1.50	18.28	3.37	5.42	0.45	1.28	0.66	83	0.30	0.13	0.38	0.19
Thailand	63.83	173.15	547.96	59.37	47.95	103.99	137.68	225.75	1.63	0.60	0.19	2157	2.17	3.54	1.30	0.41
Togo	6.58	1.57	8.58	2.10	0.35	2.46	0.61	0.90	0.37	1.57	0.29	92	0.36	0.14	0.57	0.10
Trinidad and Tobago	1.33	14.21	20.35	36.98	-21.62	15.28	7.49	29.13	11.46	1.08	0.75	5622	1.91	21.85	2.05	1.43
Tunisia	10.25	27.12	83.75	7.90	1.14	8.84	12.77	20.44	0.86	0.33	0.11	1246	2.31	1.99	0.75	0.24
Turkey	73.90	371.84	821.01	27.27	75.79	100.01	163.35	265.00	1.35	0.27	0.12	2210	2.65	3.59	0.71	0.32
Turkmenistan	4.96	7.08	38.18	66.09	-48.01	18.07	11.34	45.31	3.64	2.55	0.47	2285	2.51	9.13	6.40	1.19
Ukraine	46.38	52.22	331.61	81.60	59.61	137.34	164.13	313.96	2.96	2.63	0.41	3539	2.29	6.77	6.01	0.95
United Arab Emirates	4.37	115.24	113.85	178.35	-108.94	51.64	70.54	130.58	11.83	0.45	0.45	16161	2.53	29.91	1.13	1.15
United Kingdom	60.78	1765.77	1832.63	176.23	44.88	211.31	373.36	523.01	3.48	0.12	0.12	6142	2.48	8.60	0.30	0.29
United States	302.09	11468.00	11468.00	1665.18	713.97	2339.94	4113.07	5769.31	7.75	0.20	0.20	13616	2.47	19.10	0.50	0.50
Uruguay	3.32	24.88	35.23	1.21	2.19	3.17	7.30	5.73	0.95	0.13	0.09	2200	1.81	1.73	0.23	0.16
Uzbekistan	26.87	21.04	56.45	60.05	-11.34	48.68	44.56	113.37	1.81	2.31	0.86	1658	2.33	4.22	5.39	2.01
Venezuela	27.47	158.96	189.96	183.83	-118.74	63.75	84.55	143.79	2.32	0.40	0.34	3078	2.26	5.24	0.90	0.76
Vietnam	85.14	52.56	267.04	73.93	-19.96	55.79	61.97	93.59	0.66	1.06	0.21	728	1.68	1.10	1.78	0.35
Yemen	22.38	12.42	19.39	16.50	-8.79	7.21	4.50	20.55	0.32	0.58	0.37	201	2.85	0.92	1.65	1.06
Zambia	11.92	4.60	11.95	6.83	0.74	7.44	8.87	2.37	0.62	1.62	0.62	744	0.32	0.20	0.51	0.20
Zimbabwe	13.40	5.02	21.37	8.67	0.77	9.45	11.18	9.32	0.70	1.88	0.44	834	0.99	0.70	1.86	0.44

Products

Coal	Coal includes all coal, both primary (hard coal and lignite/brown coal) and derived fuels (patent fuel, coke oven coke, gas coke, BKB, coke oven gas, blast furnace gas and oxygen steel furnace gas). Peat is also included in this category.
Combustible renewables and waste	Combustible renewables and waste comprises solid biomass, liquid biomass, biogas, industrial waste and municipal waste. Biomass is defined as any plant matter used directly as fuel or converted into fuels (*e.g.* charcoal) or electricity and/or heat. Included here are wood, vegetal waste (including wood waste and crops used for energy production), ethanol, animal materials and/or wastes, and sulfite lyes. Municipal waste comprises wastes produced by the residential and commercial and public service sectors (which are collected by local authorities for disposal in a central location for the production of heat and/or power).
Crude oil, NGL and feedstocks	Crude oil, NGL and feedstocks comprises crude oil, natural gas liquids, refinery feedstocks and additives, as well as other hydrocarbons.
Electricity	Electricity is accounted for at the same heat value as electricity in final consumption (*i.e.* 1 GWh = 0.000086 Mtoe).
Geothermal	Geothermal is the energy available as heat emitted from within the Earth's crust, usually in the form of hot water or steam. It can be used directly as heat for district heating, agriculture, etc., or to produce electricity. Unless the actual efficiency of the geothermal process is known, the quantity of geothermal energy entering electricity generation is inferred from the electricity production at geothermal plants assuming an average thermal efficiency of 10%.
Heat	Heat includes heat that is produced for sale. The large majority of the heat results from the combustion of fuels, although some small amounts are produced from electrically powered heat pumps and boilers. Any heat extracted from the ambient environment by heat pumps is shown as production.
Hydro	Hydro shows the energy content of the electricity produced in hydro power plants. Hydro output excludes output from pumped storage plants.
Natural gas	Natural gas includes natural gas (excluding natural gas liquids) and gas works gas. The latter appears as part of consumption, but is not part of indigenous production.
Nuclear	Nuclear shows the primary heat equivalent of the electricity produced by a nuclear power plant with an average thermal efficiency of 33%.

Oil	Oil refers to the sum of crude oil, NGL, feedstocks and petroleum products.
Petroleum products	Petroleum products comprises refinery gas, ethane, liquid petroleum gas (LPG), aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirit, lubricants, bitumen, paraffin waxes, and petroleum coke and other petroleum products.
Renewables and waste	Renewables and waste includes hydro, geothermal, solar, wind, tide/wave/ocean energy, as well as combustible renewables and waste.
Solar	Solar includes solar thermal and solar PV. The quantities of solar PV entering electricity generation are equal to the electrical energy generated. Direct use of solar thermal heat is also included.
Tide/wave/ocean energy	Tide, wave and ocean represents the mechanical energy deriving from tidal movement, wave motion or ocean current and exploited for electricity generation. The quantities entering electricity generation are equal to the electrical energy generated.
Wind	Wind represents the kinetic energy of wind exploited for electricity generation in wind turbines. The quantities entering electricity generation are equal to the electrical energy generated.

Flows

Combined heat and power plants	Combined heat and power (CHP) plants refers to plants designed to produce both heat and electricity (sometimes referred to as co-generation power stations). If possible, fuel inputs and electricity/heat outputs are on a unit basis, rather than on a plant basis. However, if data are not available on a unit basis, the convention for defining a CHP plant noted above is adopted. Both main activity producers and auto-producer plants are included.
Electricity and heat plants	Electricity and heat plants refers to the sum of electricity plants, CHP plants and heat plants.
Electricity plants	Electricity plants refers to plants designed to produce only electricity. If one or more units of the plant is a CHP unit and the inputs and outputs can not be distinguished on a unit basis, the whole plant is designated as a CHP plant. Both main activity producers and auto-producer plants are included.
Heat plants	Heat plants refers to plants (including heat pumps and electric boilers) designed to produce heat only, which is sold to a third party under the provisions of a contract. Both main activity producers and auto-producer plants are included.

Imports and exports

Imports and exports comprise amounts crossing the national territorial boundaries of a given country, regardless of whether or not customs clearance has occurred.

a) Oil and gas

Quantities of crude oil and oil products imported or exported under processing agreements (*i.e.* refining on account) are included; quantities of oil in transit are excluded. Crude oil, NGL and natural gas are reported as coming from the country of origin; refinery feedstocks and oil products are reported as coming from the country of last consignment. Re-exports of oil imported for processing within bonded areas are shown as exports of product from the processing country to the final destination.

b) Coal

Coal imports and exports comprise the amount of fuels obtained from or supplied to other countries, regardless of whether there is an economic or customs union between the relevant countries. Coal in transit is not included.

c) Electricity

Amounts are considered as imported or exported when they have crossed the national territorial boundaries of the country.

Industry

Industry sector consumption is specified in the following sub-sectors (energy used by industry for transport is not included here, but reported under transport):

- Iron and steel industry [ISIC Group 271 and Class 2731].
- Chemical and petrochemical industry [ISIC Division 24] excluding petrochemical feedstocks.
- Non-ferrous metals basic industries [ISIC Group 272 and Class 2732].
- Non-metallic mineral products such as glass, ceramic, cement, etc. [ISIC Division 26].
- Transport equipment [ISIC Divisions 34 and 35].
- Machinery comprises fabricated metal products, machinery and equipment other than transport equipment [ISIC Divisions 28 to 32].
- Mining (excluding fuels) and quarrying [ISIC Divisions 13 and 14].
- Food and tobacco [ISIC Divisions 15 and 16].
- Paper, pulp and printing [ISIC Divisions 21 and 22].
- Wood and wood products (other than pulp and paper) [ISIC Division 20].
- Construction [ISIC Division 45].
- Textile and leather [ISIC Divisions 17 to 19].
- Non-specified (any manufacturing industry not included above) [ISIC Divisions 25, 33, 36 and 37].

International aviation bunkers

International aviation bunkers include deliveries of aviation fuels to aircraft for international aviation. Fuels used by airlines for their road vehicles are excluded. The domestic/international split should be determined on the basis of departure and landing locations, not by the nationality of the airline. For many countries this incorrectly excludes fuel used by domestically owned carriers for international departures.

International marine bunkers	International marine bunkers covers quantities of fuel delivered to ships of all flags that are engaged in international navigation. The international navigation may take place at sea, on inland lakes and waterways, and in coastal waters. Consumption by ships engaged in domestic navigation is excluded. The domestic/international split is determined on the basis of port of departure and port of arrival, not by the flag or nationality of the ship. Consumption by fishing vessels and military forces is excluded.
Non-energy use	Non-energy use covers fuels that are used as raw materials in various sectors, but are not consumed as a fuel or transformed into another fuel. Non-energy use also includes petrochemical feedstocks. Quantities are shown separately in final consumption, under the heading non-energy use.
Production	Production is the production of primary energy – *i.e.* hard coal, lignite/brown coal, peat, crude oil, NGLs, natural gas, combustible renewables and waste, nuclear, hydro, geothermal, solar and the ambient heat extracted from the environment using heat pumps. Production is calculated after removal of impurities.
Stock changes	Stock changes reflects the difference between opening stock levels on the first day of the year and closing levels on the last day of the year, based on stocks within a national territory held by producers, importers, energy transformation industries and large consumers.
Stocks	Stocks refer to the inventory levels of oil and oil products at the end of a given period. They include stocks in refinery tanks, bulk terminals, pipeline tankage, barges, coastal tankers and inland ships. Stocks may be on national territory or held abroad, belonging to the country and held by importers, refiners, stockholding organisations, governments and major consumers (if subject to government control).
Total final consumption (TFC)	Total final consumption (TFC) is the sum of consumption by various end-use sectors. Backflows from the petrochemical industry are not included in final consumption.
Total primary energy supply (TPES)	Total primary energy supply (TPES) is sum deriving from production + imports – exports – international marine bunkers – international aviation bunkers ± stock changes. For the world total, international marine and aviation bunkers are not subtracted from TPES.
Transport	Transport sector includes all fuels used for transport [ISIC Divisions 60 to 62]. It includes transport in the industry sector and covers road, railway, domestic aviation, domestic navigation, fuels used for transport of materials by pipeline and non-specified transport. Fuel used for ocean, coastal and inland fishing should be included in fishing (other sectors). International marine and aviation bunkers are also included for the world total.

General conversion factors for energy

To: / From:	TJ	Gcal	Mtoe	MBtu	GWh
	multiply by:				
terajoule (TJ)	1	238.8	2.388×10^{-5}	947.8	0.2778
gigacalorie (Gcal)	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
million tonne of oil equivalent (Mtoe)	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
million British thermal unit (MBtu)	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
gigawatt hour (GWh)	3.6	860	8.6×10^{-5}	3412	1

Conversion factors for mass

To: / From:	kg	t	lt	st	lb
	multiply by:				
kilogramme (kg)	1	0.001	9.84×10^{-4}	1.102×10^{-3}	2.2046
tonne (t)	1000	1	0.984	1.1023	2204.6
long ton (lt)	1016	1.016	1	1.120	2240.0
short ton (st)	907.2	0.9072	0.893	1	2000.0
pound (lb)	0.454	4.54×10^{-4}	4.46×10^{-4}	5.0×10^{-4}	1

Conversion factors for volume

To: / From:	gal U.S.	gal U.K.	bbl	ft^3	l	m^3
	multiply by:					
U.S. gallon (gal)	1	0.8327	0.02381	0.1337	3.785	0.0038
U.K. gallon (gal)	1.201	1	0.02859	0.1605	4.546	0.0045
barrel (bbl)	42.0	34.97	1	5.615	159.0	0.159
cubic foot (ft^3)	7.48	6.229	0.1781	1	28.3	0.0283
litre (l)	0.2642	0.220	0.0063	0.0353	1	0.001
cubic metre (m^3)	264.2	220.0	6.289	35.3147	1000.0	1

Decimal prefixes

10^{1}	deca (da)	10^{-1}	deci (d)
10^{2}	hecto (h)	10^{-2}	centi (c)
10^{3}	kilo (k)	10^{-3}	milli (m)
10^{6}	mega (M)	10^{-6}	micro (μ)
10^{9}	giga (G)	10^{-9}	nano (n)
10^{12}	tera (T)	10^{-12}	pico (p)
10^{15}	peta (P)	10^{-15}	femto (f)
10^{18}	exa (E)	10^{-18}	atto (a)

Coal

Coal is converted from 1000 tonnes to Mtoe using separate net calorific values for production, imports, exports, inputs to electricity/heat generation and coal used in coke ovens, blast furnaces and industry. All other flows are converted using an average net calorific value.

Crude oil

Country-specific net calorific values (NCV) for production, imports and exports by country are used to convert from 1000 tonnes to Mtoe. The average value is used to convert all the other flows to heat values.

Gas

Gas is often expressed in terajoules on a gross calorific values basis.

1 terajoule = 0.00002388 Mtoe.

The net heat content of a gas is calculated from its gross heat content by multiplying by the appropriate factor.

Gas	Gross to net ratio
Natural gas	0.9
Gas works gas	0.9
Coke oven gas	0.9
Blast furnace gas	1.0
Oxygen steel furnace gas	1.0

Combustible renewables and waste

For solid biomass, biogas, municipal waste and industrial waste the Secretariat receives the information directly in terajoules on a net calorific value basis.

1 terajoule = 0.00002388 Mtoe.

Data for charcoal are converted from tonnes using country-specific net calorific values.

Unless country-specific information has been provided, data for bio-ethanol are converted from tonnes using 26 800 kJ/kg. Biodiesels and other liquid biofuels are assumed to have a net calorific value of 36 800 kJ/kg unless otherwise specified.

Petroleum products

For IEA member countries, petroleum products are converted using regional conversion factors (in conjunction with Eurostat for the European countries) for the petroleum products.

	Europe	North America	Pacific
Regional net calorific values	kJ/kg	kJ/kg	kJ/kg
Refinery gas	49 500	48 100	48 100
Ethane	49 500	49 400	49 400
Liquefied petroleum gases	46 000	47 300	47 700
Motor gasoline	44 000	44 800	44 600
Aviation gasoline	44 000	44 800	44 600
Gasoline type jet fuel	43 000	44 800	44 600
Kerosene type jet fuel	43 000	44 600	44 500
Kerosene	43 000	43 800	42 900
Gas/diesel oil	42 600	42 600	42 600
Residual fuel oil	40 000	40 200	42 600
Naphtha	44 000	45 000	43 200
White spirit	43 600	43 000	43 000
Lubricants	42 000	42 000	42 900
Bitumen	39 000	40 000	38 800
Paraffin waxes		40 000	
Petroleum coke	32 000	32 000	33 800
Non-specified petroleum products		40 000	

Electricity

Figures for electricity production, trade and final consumption are calculated using the energy content of the electricity (*i.e.* at a rate of 1 TWh = 0.086 Mtoe). Hydroelectricity production (excluding pumped storage) and electricity produced by other non-thermal means (wind, tide/wave/ocean, photovoltaic, etc.) are accounted for similarly using 1 TWh = 0.086 Mtoe. However, the primary energy equivalent of nuclear electricity is calculated from the gross generation by assuming a 33% conversion efficiency, *i.e.* 1 TWh = (0.086 ÷ 0.33) Mtoe. In the case of electricity produced from geothermal heat, if the actual geothermal efficiency is not known, then the primary equivalent is calculated assuming an efficiency of 10%, so 1 TWh = (0.086 ÷ 0.1) Mtoe.

Heat

Information on heat is supplied in terajoules and 1 terajoule = 0.00002388 Mtoe.

EJ	exajoule
g	gramme
GW	gigawatt
kg	kilogramme
kWh	kilowatt hour
MJ	megajoule
Mt	million tonne
Mtoe	million tonnes of oil equivalent
MW	megawatt
pkm	passenger-kilometre
t	tonne
t CO_2	tonne of carbon dioxide
tkm	tonne-kilometre
toe	tonne of oil equivalent
TWh	terawatt hour
USD	United States dollar

CHP	combined heat and power
GDP	gross domestic product calculated using market exchange rates
GDP PPP	gross domestic product calculated using purchasing power parities
IA	Implementing Agreement
LNG	liquefied natural gas
LPG	liquefied petroleum gases
MER	market exchange rate
NCV	net calorific value
PPP	purchasing power parity
PV	solar photovoltaic
R&D	research and development
RD&D	research, development and demonstration
TPES	total primary energy supply

FSU	Former Soviet Union
IEA	International Energy Agency
OECD	Organisation for Economic Co-operation and Development

Notes

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