

## EXECUTIVE SUMMARY

This publication examines energy use developments in IEA Member countries since 1973. It draws on a database with detailed information on energy demand and energy demanding activities. From this information disaggregated measures – or indicators – are developed to help show how factors such as economic structure, lifestyle, climate, energy efficiency, and fuel mix have shaped patterns of energy use and CO<sub>2</sub> emissions.

The study assesses how energy use and CO<sub>2</sub> emissions trends have evolved in individual and groups of IEA countries from both economy-wide and sectoral perspectives. The analyses show, for example, an important shift from the direct burning of fossil fuels to the use of electricity in the 1970s and early 1980s, which was driven by changes in the activities and end-uses that make up total energy use. It also shows how fossil fuels were affected by price effects from the two oil crises, which resulted in significant fuel savings. Recent trends, however, indicate that both savings of fossil fuels and electricity have slowed despite efforts to combat climate change in IEA countries.

### Economy-wide Results

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

*Three decades  
of steady growth in  
IEA energy demand...*

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

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

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

*Big variations  
in energy  
per GDP levels  
across the IEA...*

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

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

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

**Energy savings since 1973 have been substantial...**

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

**But rates of energy savings are slowing...**

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

**Energy price developments offer some explanation for long-term trends...**

Before 1973 energy prices were generally low, so when the price hikes kicked in after 1973 there was ample room for improving energy efficiency as a response. As prices fell after 1985 the incentive for maintaining energy savings rates weakened. The lower prices combined with the fact that energy intensities already were significantly reduced, resulted in considerably lower energy expenditures for both industry and private consumers from the mid 1980s.

**Are recent trends impacted by the information economy?**

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

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

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

## Manufacturing

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

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

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

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

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

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

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

***Energy has become less significant in total production costs...***

## Households

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

***Households have become more electricity intensive...***

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

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

***Energy savings have slowed in the 1990s...***

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

***Heating prices vary much less than electricity prices...***

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

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

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

## Service

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

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

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

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

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

*Energy costs per output have increased since 1973 despite reduced intensities...*

## Passenger Transport

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

*Travel is a key driver of IEA oil demand...*

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

*More and more travel by cars and airplanes...*

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

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

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

*Declines in fuel intensities have helped reduce the cost of driving...*

## Freight Transport

**Freight is the sector with the biggest increase in energy use...**

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

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

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

## CO<sub>2</sub> Emissions from Energy Use

**Wide variations in CO<sub>2</sub> emissions per GDP...**

CO<sub>2</sub> emissions per unit of GDP vary considerably among IEA countries. These variations are due to a multitude of factors including differences in: the mix of fuels used at end use levels and for electricity generation; industry structure; climate and geography; demographics; lifestyles; and energy intensities.

**High growth in emissions during the 1990s...**

All countries within the IEA-11 group experienced significant reductions in CO<sub>2</sub> emissions per unit of GDP between 1973 and 1990, but after 1990 only a few saw a continued strong decoupling. While total IEA-11 emissions in 1990 were only marginally higher than in 1973, they increased 12% between 1990 and 2001, a development that is in stark contrast to what is implied by the Kyoto targets.

**..mainly due to slowing declines in energy intensities...**

Detailed data show that the primary reason for weaker decoupling of CO<sub>2</sub> emissions from GDP growth since 1990 is that energy intensity reductions in most sectors have slowed. This is a uniform trend among the IEA-11 countries. In addition, fuel switching towards less carbon-intensive fuels in electricity generation contributed less to overall CO<sub>2</sub> emission reduction in most countries after 1990 than before.

**Shifts in manufacturing structure helped to bring down emissions...**

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

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

countries by reductions in the CO<sub>2</sub> intensity of electricity supply and a shift towards a less energy-intensive manufacturing structure. After 1990, however, the fall in energy intensities almost came to a halt and continued structural changes took over as the most important factor in restraining manufacturing CO<sub>2</sub> emissions.

For the IEA-11 group emissions from households did not increase much between 1973 and 1990. After 1990 emission growth rates accelerated, although the trends in individual countries vary. Some countries saw continued reductions in emissions from declines in energy intensities, and in some changes in the fuel mix also helped to maintain emission reduction rates. In all countries the growth in energy services demand slowed somewhat after 1990 mainly due to lower growth in dwelling area and in the ownership of some electric appliances. Thus if demand for energy services had grown at the same rate as before 1990, CO<sub>2</sub> emissions from IEA-11 households would have accelerated even more.

Service sector CO<sub>2</sub> emission growth rates accelerated significantly after 1990, as the decline in energy intensity slowed. Reduced CO<sub>2</sub> emissions per kWh of electricity generated have helped dampen the emission increase in most countries, although generally less so after 1990. On the other hand, the increased share of electricity in the service sector fuel mix inserted an upward pressure on emissions in countries with primarily fossil fuel-based electricity generation, in many cases offsetting the effect of reduced emissions per kWh in the utility sector.

Emissions from the passenger transport sector have increased steadily since 1973 driven by growth in travel activity and a shift towards more cars and airplanes in the modal mix. CO<sub>2</sub> emissions from passenger transport accelerated in the United States and Japan after 1990, as the decline in fuel intensities slowed. In Europe, a somewhat more rapid decrease in intensities helped to slow emission growth rates.

Among all sectors, freight showed the highest relative growth in IEA-11 CO<sub>2</sub> emissions since 1973. Emissions increased as freight activity grew in line with GDP and with energy-intensive trucking taking a larger share of total tonne-km hauled. The very modest decline in fuel intensity did little to moderate emissions growth, but contrary to the trends seen in the other sectors, the average intensity for freight fell more rapidly after 1990 than before.

*Emissions from households on the rise...*

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

*Emissions from cars and airplanes on a steady increase...*

*The rapid growth in freight emissions may be slowing...*