The previous chapter has described the range of different primary energy sources available, but where is all this energy used? The picture is potentially quite confusing, since there are many transformations that take place within the energy system, notably in the refining of oil and the generation of electricity. Since physics tells us that energy is conserved, the total annual energy consumption of a nation, a factory or a household must be equal to its total annual energy supply. If we draw up a balance-sheet with energy income on one side and expenditure on the other, then the books must balance.

Table 3.2 shows a much simplified energy balance sheet for the UK for the year 2000. On the supply side, we have home production. We can then add in imports and subtract the exports. Next we also subtract the non-energy uses of oil and gas (for example as lubricants, or raw material for plastics, etc.) and fuel used by ships travelling overseas, which is traditionally not included in national consumption.

Since the aim is to find the amounts of energy used in this particular year, we must allow for any changes in stocks: subtracting fuel stored and adding fuel used from the stocks. The bottom line is then the actual consumption of each fuel. (Note that 'primary electricity production' refers to the output of UK nuclear, hydro and wind generators, and 'imported electricity' is that which comes from France through the link under the English Channel). Finally, adding all the contributions, we have a total national primary energy consumption of about 9700 PJ.

Table 3.3, now describes where all this energy was used. This, of course, is now **delivered energy** as received by the consumer. The categories of consumer are fairly straightforward. **Transport** covers both public and private, carrying both people and goods, in road vehicles, trains, and planes (internal flights only). **Industry** is obvious; but note that this item doesn't include energy used by the energy industries themselves. **Domestic** includes all the buildings that people live in; and **Services** is everything else: shops and offices, schools and colleges, museums, etc. Public lighting and energy used in agriculture have been included in this table as well, though fertilizer production comes under industry.

In Table 3.2 we talked about 'coal' and 'oil'. In the final-use stage of Table 3.3, the categories of energy need to be changed slightly: 'liquid' now refers to all the oil products (diesel, petrol, heating oil, aviation fuel, etc.); 'solid' includes coke, smokeless fuels and all other solid fuels as well as coal; and 'electricity' now means all electricity, from power stations of every type.

Having carefully tracked all the delivered energy purchased by everyone in each sector, we obtain a figure of just over 6700 PJ. This is a great deal less than the 9700 PJ on the supply side, so it appears that our balance-sheet doesn't balance. However, the two tables are not talking about the same thing. The difference between the *primary energy* in Table 3.2 and the *delivered energy* in Table 3.3, well over a quarter of the original energy, is the energy 'lost' by the energy industries in converting primary energy into the convenience forms of energy that we, the consumers, want to use.

The consumption table allows us to look at the final energy use in two ways. The 'total' column on the right of Table 3.3 shows the amount going to each of the four sectors. It reveals, for instance, that we use more energy in transporting ourselves and our possessions from place to place than we do in manufacturing, or just living at home.

BOX 3.3 UK energy balance for 2000

Table 3.2 UK primary energy production and consumption

Supply	**Coal[1] /PJ**	**Oil /PJ**	**Natural gas/PJ**	**Primary electricity[2]/PJ**	**Total[3] /PJ**
Production	920	5767	4486	844	12 017
Imports (+)	673	3135	94	47	3949
Exports (–)	–34	–5231	–527	–1	–5792
Non-Energy	0	–466	–47	0	–513
Marine Bunkers	0	–92	0	0	–92
To Stock (–)	138	34	–34	0	138
Consumption	1697	3147	3972	891	9707

[1] 'Coal' here includes other solid fuels such as Municipal Solid Waste

[2] Nuclear electricity is treated as the equivalent primary energy input to produce it at an efficiency of 30%. Actual electricity production is effectively about 30% of primary energy, but conventions elsewhere in this book use 33%.

[3] Some totals may differ slightly from the sums of the items due to rounding.

Source: DTI, 2001a

Table 3.3 UK delivered energy consumption

	Solid /PJ	**Liquid /PJ**	**Natural gas/PJ**	**Delivered electricity[1]/PJ**	**Total[2] /PJ**
Transport	0	2280	0	32	2311
Industry	117	267	722	409	1515
Domestic	91	136	1332	403	1961
Services, including public lighting and agriculture	16	101	456	341	915
All Sectors	223	2783	2511	1184	6702

[1] Here treated as the energy content of the delivered electricity (i.e. 3.6 PJ per TWh)

[2] Some totals may differ slightly from the sums of the items due to rounding.

Source: DTI, 2001a

Another way to divide up the delivered energy use is shown in the four entries along the bottom line, 'all sectors'. A striking feature is how little anybody wants in the form of solid fuels. This category would have looked completely different back in 1880, but now even industry only uses a tiny 8% of its energy in this form. The demand for liquid fuel for internal combustion engines and the preference for gas central heating in the domestic sector are obvious, as is the ever-growing demand for electricity.

Figure 3.10 shows the data of Tables 3.2 and 3.3 in a graphical form. In the top bar is the primary energy supply and below it the delivered energy consumption divided by fuel, by sector and by also end use.

The second bar of this chart clearly shows the magnitude of the energy losses in conversion and delivery. The minute amount of solid fuel shown in this bar indicates that the bulk of UK coal consumption goes for electricity generation.

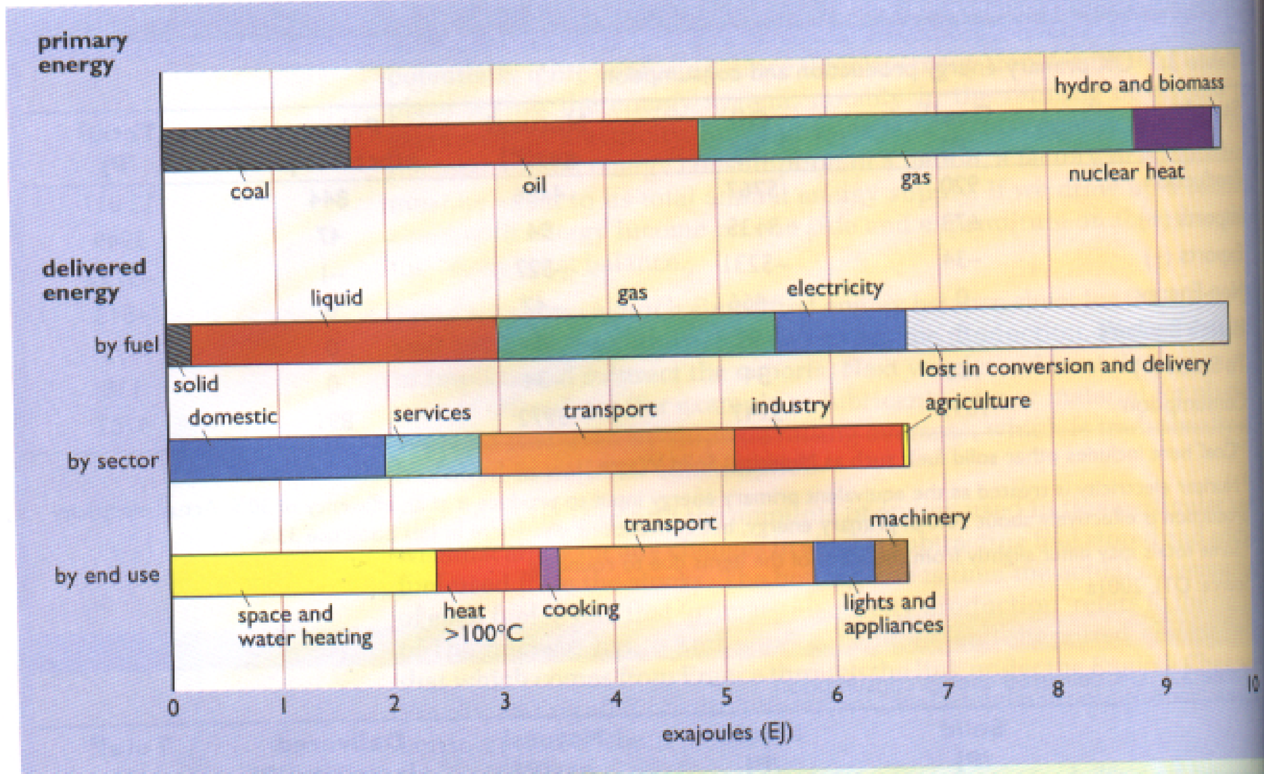


Figure 3.10 UK primary and delivered energy use for 2000 (sources DTI, 2001a; DTI, 2001b)

The third bar shows the breakdown between the different sectors. The energy use in the commercial sector is roughly equally divided between commercial offices in the private sector and public administration, government, schools, hospitals, etc. We will look at the transport energy use breakdown a little later on. Modern industry covers a whole range of activities. Their relative energy use is shown in Figure 3.11. Iron, steel and the manufacturing of metal products consumes over a quarter of the industrial energy use. The chemical industry, which includes the production of plastics, uses a further 21%.

The processing of food and drink, which might have been seen as a 'domestic' activity back in the 1300s is now a significant part of 'industry'.

Right at the end of the bar is a tiny section of 50 PJ labelled 'Agriculture'. This is only the energy required to run the UK's farms. The energy content of the fertilizers they use is probably about the same amount again, but its production is classified under 'Industry'.

In the final bar of Figure 3.10 we can see a breakdown in terms of end use. This kind of data can only be determined from surveys of sample groups of consumers. As such, the results can be subject to errors. Nevertheless it is useful information. It is, perhaps, striking that over a half of delivered energy is used as heat. For example, in the domestic sector, the bulk of the delivered energy is used for space heating (see Figure 3.12). The same is true in the Services sector. It is also remarkable that the 170 PJ we use for cooking food is far larger than the 100 PJ or so used on farms to grow it.

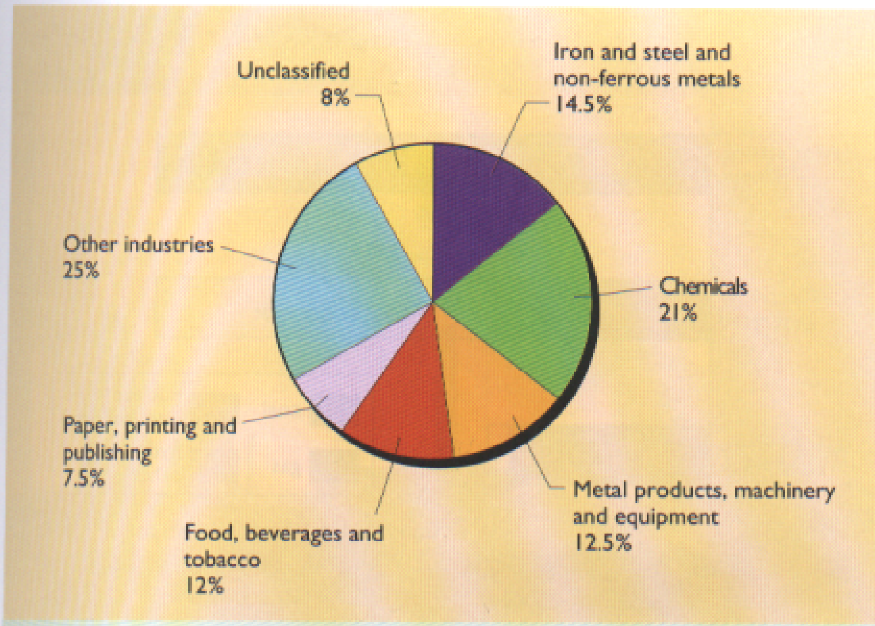


Figure 3.11 Breakdown of UK industrial energy use (source: DTI, 2001a)

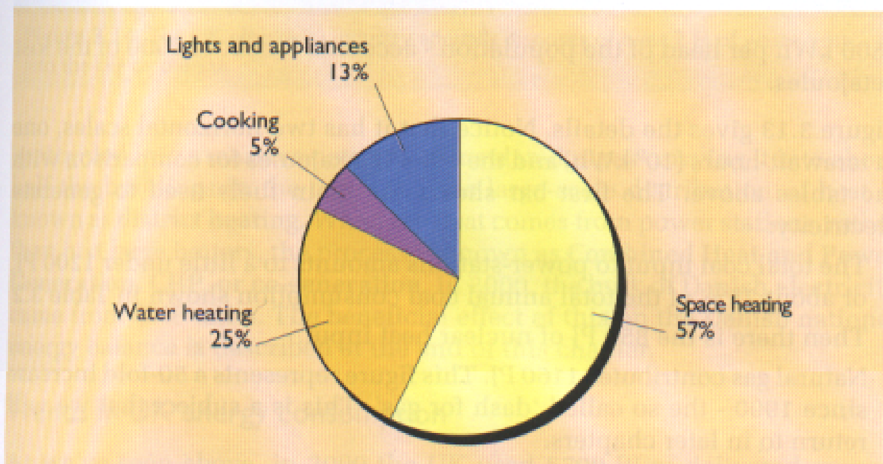


Figure 3.12 Breakdown of UK domestic delivered energy use – 1995 estimate (source: DTI, 1997)

Electricity conversion losses

Tables 3.2 and 3.3 tell us nothing about the reason for the difference between the total primary energy consumption and the total delivered energy consumption. For that we need more detailed statistics, showing all the intermediate conversion processes. There are many of these, each involving some 'lost' energy. For example, about 10% of the energy content of the petroleum in the 'primary energy' bar of Figure 3.10 is lost in the oil refinery by the time it has been converted to the 'delivered' liquid fuels in the second bar of the chart. Other losses are incurred in the conversion of coal to other solid fuels and pumping gas through pipelines. But the chief culprit is the generation of electricity. The 1.2 EJ of electricity we consume each year -

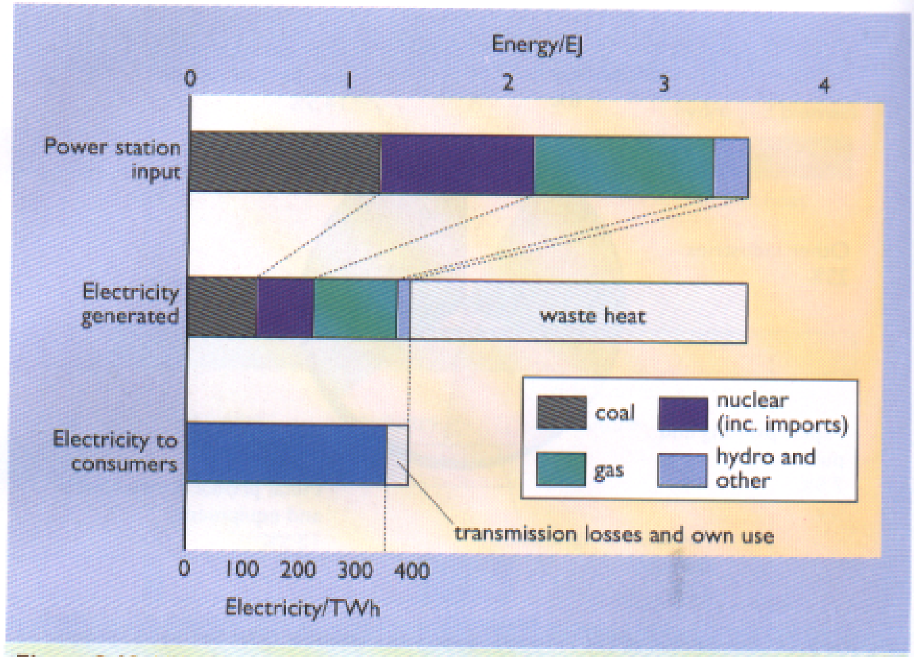


Figure 3.13 UK generation and distribution of electricity – 2000

5500 kWh per head of the population - accounts for about 2000 of the lost petajoules.

Figure 3.13 gives the details. Notice that it has two horizontal scales, one in terawatt-hours (10^9 kWh) and the other in exajoules for comparison with the tables above. The first bar shows the main fuels used to generate electricity:

- The total coal input to power-stations amounts to a little under 1200 PJ, or about 75% of the total annual coal consumption shown in Table 3.2
- Then there is the 850 PJ of nuclear heat input.
- Natural gas contributes 1160 PJ. This figure represents a 50-fold increase since 1990 - the so called 'dash for gas'. This is a subject that we will return to in later chapters.
- Other sources contribute about 180 PJ. These include oil, waste materials and also hydro and wind power.

We have then a total input to all the public supply power stations of about 3400 PJ. The second bar shows the actual electrical output, approximately 1350 PJ or 40% of the input. Nearly all the rest has become waste heat either dumped into the sea or into the sky via large cooling towers. A further 4% of the generated power is used by the power-stations themselves, and therefore doesn't enter the distribution network. Finally, around 8% of the energy leaving the power stations is lost on the way to the consumers in the electrical resistance of the cables and losses in transformers. Ultimately, we find the consumers receiving the 1184 PJ shown in Table 3.3. Just over a third of the input energy has become useful output, or to put it another way, the overall 'system efficiency' is 35%.

Couldn't the waste heat be put to use? Indeed it could. In countries such as Denmark, power stations don't just make electricity; their waste heat output

Figure 3.14 The UK electricity industry annually disposes of over 2 EJ of waste heat into the sky or the sea

is recycled into a massive network of insulated pipes carrying it into about half the buildings in the country. This large-scale distribution of heat is known as **district heating**. When the heat comes from power stations, rather than just large boilers, the process is known as **Combined Heat and Power Generation, CHP, or co-generation**. In 2000, the bulk of Danish electricity came from CHP units. The beneficial effect of this on the Danish national energy balance is described at the end of this chapter.

Trends in UK energy consumption

As we've seen above, in 2000 the UK used 6700 PJ of delivered energy. Distributed between the 60 million inhabitants, this works out at about 110 GJ per capita per year. At the beginning of the 20th century, in the year 1903, the UK used 167 million tonnes of coal and about 2 million tonnes of oil (Jevons, 1915). The vast bulk of this energy, probably over 85%, was delivered energy. The fledgling electricity industry was tiny and the bulk of 'conversion losses' were in the mining industry's own use of coal and in the provision of town gas. Divide this amongst the 37 million inhabitants (in 1903) and the figure for per capita annual delivered energy consumption is 110 GJ, identical to that nearly 100 years later.

There are key differences between 1903 and 2000. In 1903 the fuel (almost all coal) was delivered to the factory and home and used with the poor efficiencies of the time. The heating efficiency of a domestic coal fire is typically about 25% and we already have seen the poor efficiency figures for gas lighting. The fuel had to be burnt on site and the losses took place right there. In 2000, we were using the convenience fuel of electricity with a high efficiency at the point of use. The useful heat output of an electric fire is almost 100% of the electrical input. Modern incandescent and fluorescent lamps give far more useful lumens per watt than their gas counterparts. We get far more useful *energy service* out of the delivered energy. The price we pay is the enormous energy losses at power stations.

Although looked at on the long term time perspective, UK delivered energy on a per capita basis hasn't changed much in a century; there have been ups and downs and shifts between the different sectors. Figure 3.13 and Table 3.4 below chart the changes in the sectors since 1970.

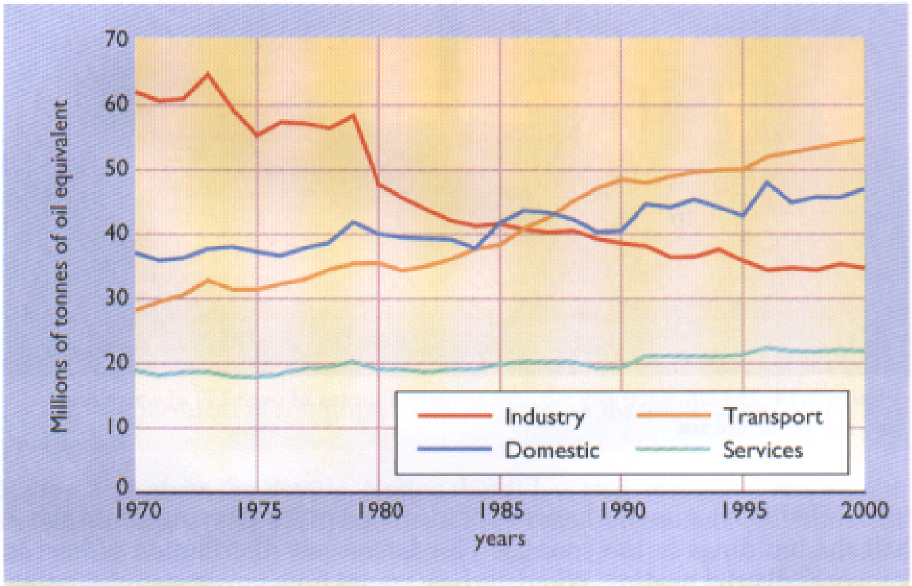


Figure 3.15 Sectoral changes in UK energy consumption 1970–2000 (source: DTI, 2001c). Remember 1 Mtoe = 42 PJ

Table 3.4 Trends in UK delivered energy

Sector	1970 delivered energy (PJ)	2000 delivered energy (PJ)	% change 1970–2000
Transport	1179	2311	+96%
Industry	2612	1515	–42%
Domestic	1544	1961	+27%
Service Sector	779	915	+18%
TOTAL	**6114**	**6702**	**+10%**

Sources: DTI, 1971; DTI, 2001a

Since 1970, total delivered energy consumption has been rising. Consumption in both the domestic and services sector has gone up. The increase in domestic heating energy consumption reflects the increasing standards of comfort in UK homes, spurred on by the availability of cheap North Sea Gas. In 1970 only 31% of homes had central heating. By 2000 this figure had risen to 89%. There has also been a continuing rise in domestic electricity consumption, feeding a whole host of new electrical appliances.

The rise in consumption in the services sector also reflects increased standards of heating. Lighting makes up a significant proportion of the electricity demand in this sector. There has also a continued increase in electricity consumption as offices are filled with computers and photocopiers. Indeed in many office buildings, especially those with large areas of glazing, the problem is that of dealing with the *surplus* of heat. Even in the UK, air conditioning is seen as essential by new office developers, much to the dismay of those interested in energy conservation.

The decline in industrial energy consumption reflects the 'dematerialization' of the economy, the shift away from heavy industry, such as steel making and car manufacturing, to lighter 'high value' industries such as electronics. The monetary value of industrial output has continued to rise, but the energy used in the process has been falling. This is part of a much longer trend (see below).

The most important change has been the large rise in transport energy use. Figure 1.50 in Chapter 1 shows the rise in UK travel since 1952 in terms of passenger-kilometres. What is most noticeable is the massive increase in travel by car. Even this chart understates the overall increase in transport use since it only includes *internal* UK air travel. Figure 3.16 shows UK transport energy consumption from 1970 onwards, including road freight and the energy used in refuelling international aircraft. It can be seen that the bulk of the energy consumption is now in road and air transport. Railway energy use is just a thin line on the bottom of the chart. However, it is worth reflecting that in 1903 the UK railways used 13 million tonnes of coal (about 9 Mtoe). The large decrease in railway energy use reflects both the contraction of the railway network since then, and the switch from steam to diesel and electric traction that took place in the 1960s (see Chapter 9).

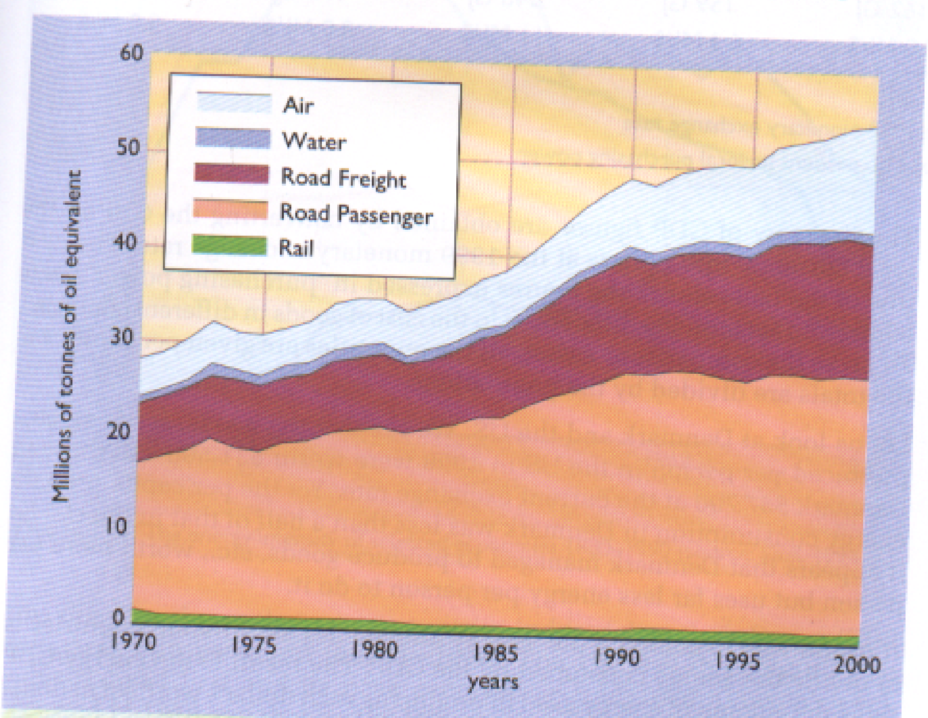


Figure 3.16 UK transport energy consumption 1970-2000. Source: DTI, 2001b

The growth in road transport energy consumption was greatest during the 1980s but has now slowed almost to a halt. However, air transport consumption continues to rise encouraged by air fares that are cheap in relation to earnings. In 1999 London's three airports alone dealt with 986 000 take-offs and landings.

International comparisons

Energy and GDP

The Gross Domestic Product (GDP) of a country is the monetary value of everything the country produces in a year. We would expect that energy consumption and GDP might be related and indeed it is generally true that the higher the GDP of a country, the higher its energy consumption (see Table 2.3 in Chapter 2). This has led energy forecasters in the past to assume that growth in GDP must automatically require more energy.

Table 3.5 shows the relation between energy consumption and GDP on a per capita basis for our five sample countries.

Table 3.5 Energy and GDP for five countries (1999 figures)

	UK	Denmark	US	France	India
Population (millions)	59.5	5.3	273	60.3	998
Annual per capita GDP:					
at current exchange rate[1]	$21 100	$37 700	$31 500	$28 200	$450
at local purchasing power[2]	$20 500	$25 100	$31 500	$21 800	$2173
Annual per capita energy consumption	162 GJ	159 GJ	348 GJ	177 GJ	21 GJ
Energy/GDP ratio[2]	8.0 MJ/$	6.3 MJ/$	11 MJ/$	8.0 MJ/$	9.0 MJ/$

Source: IEA (2001)

[1] GDP converted to US dollars at the 1999 monetary exchange rate

[2] GDP converted at a rate which takes into account its local purchasing power.

The first row of GDP figures are obtained by converting the GDP in the local currency into dollars at the 1999 monetary exchange rate. The next row of the table shows the figures expressed in 'purchasing power' terms taking into account the differences in the cost of goods in different countries. To make the comparisons easier, all the quantities are given per capita, i.e. the totals are divided by the populations.

Let us look at Denmark and the US. We see that the goods, services, etc., produced per person in the US in 1999 were worth $31 500 and those in Denmark $37 700 at the current exchange rate. Yet the per capita primary energy consumption in Denmark was less than a half of that in the US. So it appears that Denmark managed to produce goods, etc., worth more per person but uses far less energy per person to do it.

A useful way to compare the 'energy efficiencies' of different countries is to divide the energy consumed by the GDP. The result is the **energy/GDP ratio**, the amount of energy used in producing each dollar's worth of national product expressed in MJ per dollar (MJ/$). The final line in the table shows this for our five countries. There are clearly considerable differences in this figure from country to country. Why? The following are just a few of many possible answers:

- They may obtain their primary energy in less wasteful forms than others (hydroelectric rather than fossil fuelled power-stations, for instance).
- They may earn their GDP by less energy-intensive types of activity than others: agriculture rather than heavy industry, or commercial rather than industrial activity, and so on.
- They may use less energy for the same purposes (greater industrial energy efficiency, better insulation of buildings, etc.)
- They may use more energy than others to support economically non-productive activities (watching TV, going for a drive, reading a book).

The historical picture is also interesting. Figure 3.17 shows the energy intensity of different countries from 1880 onwards, expressed in constant 1972 US$, i.e. corrected for inflation (see Chapter 12, Costing Energy for details of this).

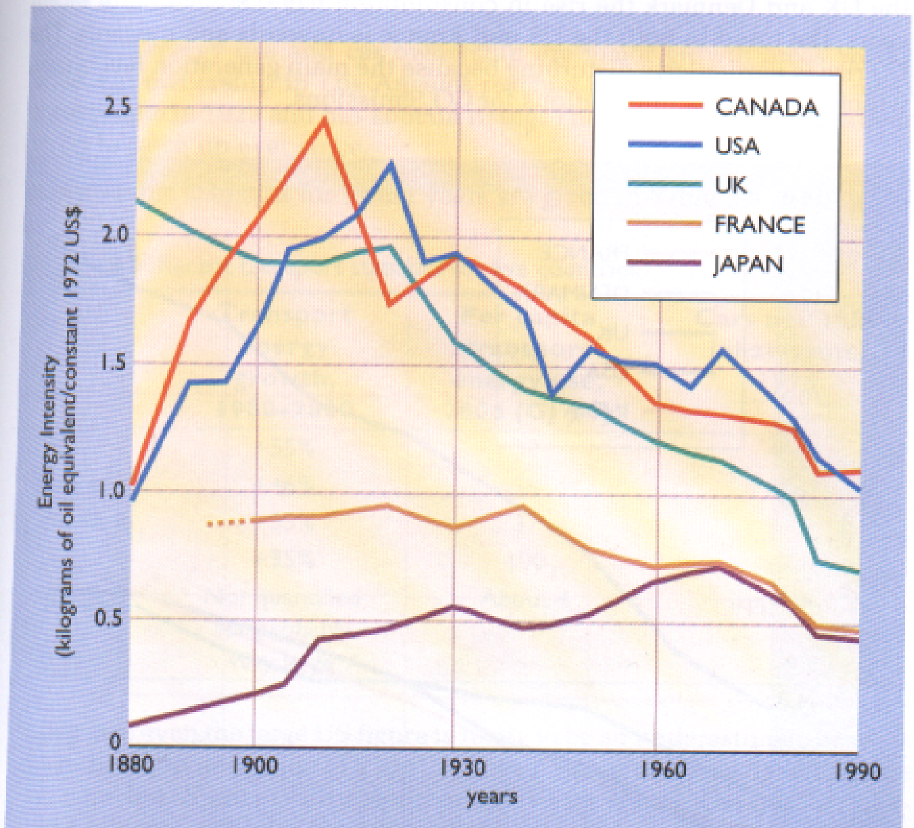


Figure 3.17 The energy intensity of selected economies 1880–1990 (source: Smil, 1994)

This diagram shows that when countries industrialize their Energy/GDP ratio rises to a peak and then declines. The UK was the country that industrialized first and its peak occurred around 1850. Canada's peak occurred in 1910 and that for the US occurred in 1920. As other countries such as Japan industrialized, they were able to do so in a more energy efficient manner by drawing on the past experience of the UK, US and Canada. Between 1880 and 1990 the UK's Energy/GDP ratio fell by a factor of three and is still continuing to fall. Put another way, modern UK citizens manage to produce goods and services of equivalent value with only one-third of the energy of their counterparts 120 years ago.

The clearest example that increased GDP does not necessarily require increased energy is in the case of Denmark. In the 22 years from 1977 to 1999, GDP increased by nearly 50%, yet primary energy consumption did not increase at all (Dal and Jensen, 2000).

More and more electricity

It is perhaps extraordinary that although mains electricity was first deployed in the 1880s we still don't seem to be able to get enough of it. Figure 3.18 below shows how per capita electricity consumption has risen dramatically over the last 40 years, spurred on by falling prices and a host of new electric gadgets and applications. As might be expected, US per capita electricity consumption is the highest in our sample of five countries. Although in the UK and Denmark the rise in consumption has flattened off in recent years, the trend in both the US and France is onwards and upwards. The US rise is particularly disturbing because the main generation fuel is coal, which has serious implications for CO_2 emissions.

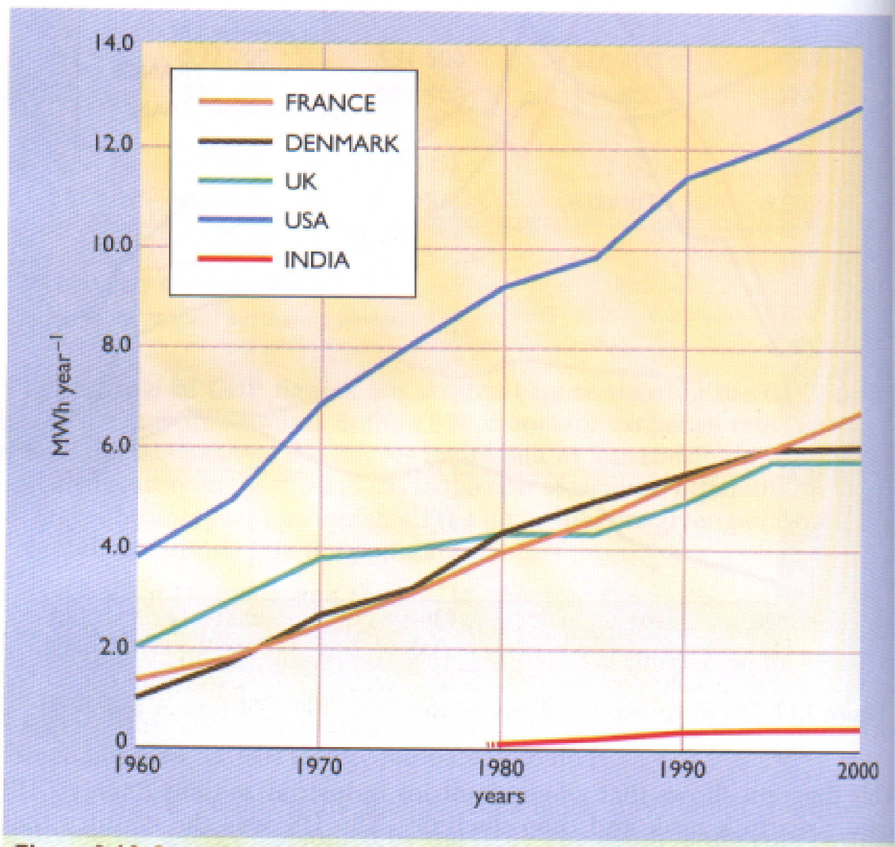


Figure 3.18 Per capita electricity consumption 1960–2000 for five countries

In France, since 1960, per capita consumption has risen by a factor of 5. The rise for the domestic and commercial sector of the economy is impressive. In 1960 it used 17.5 GWh; in 2000 it used 246 GWh – fourteen times as much! This, in part, has reflected the general improvement in housing conditions. A census of 1954 described the primitive state of French housing. Less than 60 percent of households had running water, only a quarter had an indoor toilet, and only one in ten had a bathroom and central heating. By 1990 all of these had become almost universal (Prost, 1991).

The Danish rise in electricity use is also remarkable, because since the mid 1970s it has been achieved without any increase in national primary energy consumption. A key ingredient of this success has been the increasing use of CHP, making sure that the waste heat from the power stations is put to good use.

Although electrification in India has also increased, it has barely kept pace with the booming population, so that the per capita consumption remains very low and has hardly increased over the past decade.

More and more travel

Transport energy use and car ownership are major growth areas worldwide. Car ownership in Los Angeles reached a level of one car to every three people in 1923 and has kept on rising. The rest of the world has been trying to catch up ever since.

Some sample statistics for recent years are given in Table 3.6.

Table 3.6 Recent transport statistics for five countries

	Transport energy growth, 1980–2000	Per capita transport energy use, 2000 (GJ y^{-1})	Cars per 1000 inhabitants, 1998
UK	+55%	39	404
France	+46%	38	456
Denmark	+35%	37	343
US	+35%	100	>500
India	Not quantified but probably very large	About 4	approx 4

In practice even the large US figure is likely to be an underestimate because of a rather tight definition of a 'car'. A large number of US road vehicles are not 'cars' but 'Sports Utility Vehicles' (SUVs for short). The number of 2-axle 4 wheeled vehicles per 1000 inhabitants is closer to 750, i.e. three to every four people. The problems of reducing pollution from car engines are discussed in Chapter 8.

Comparisons of delivered energy

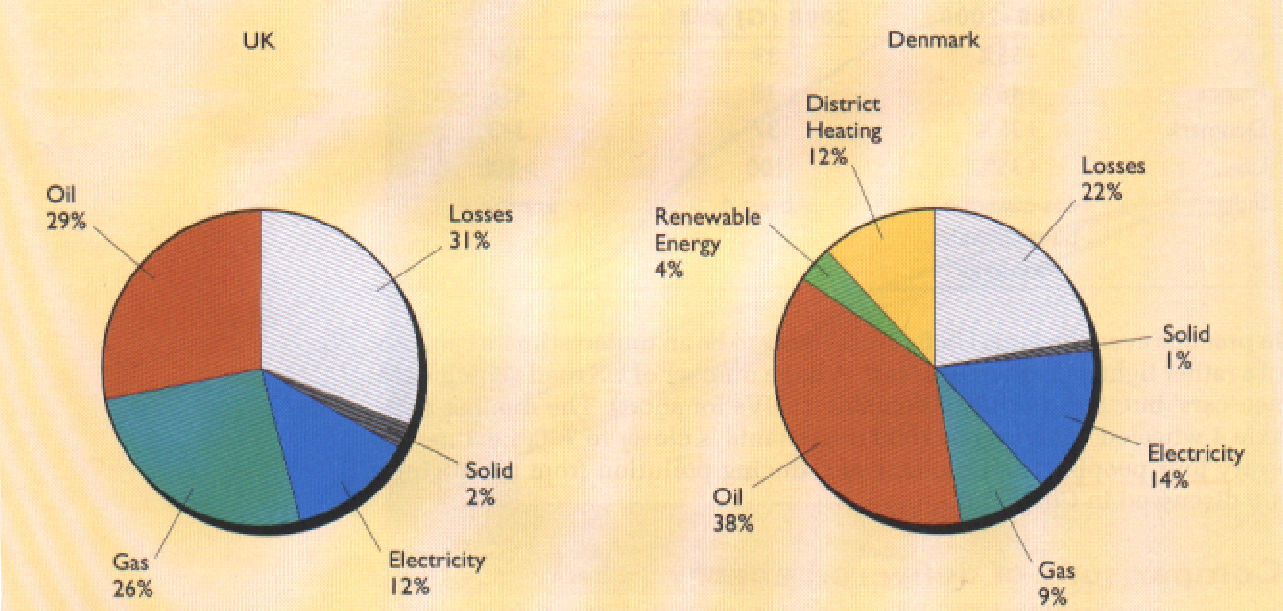
Broadly speaking, the pattern of energy use in the UK is not significantly different from that in Denmark, France, or the US. However, there are some differences that are worth pointing out.

UK and Denmark

While the UK has had a history of relative fuel security, with plenty of coal, and, since the 1970s, an abundance of oil and gas, Denmark has been in a very different position. As pointed out in the previous chapter, in 1972, Denmark was almost 95% reliant on imported oil (see Figure 2.11). The world price of this rose by a factor of 7 between 1973 and 1980 (see Figure 2.5), making a large dent in the Danish national budget. Drastic measures had to be taken. Initially there was a lot of belt-tightening – at one point the driving of cars on Sundays was banned. Subsequently, a number of more medium- to long-term policy decisions were implemented:

- Switching power stations from oil to coal
- Expanding the use of combined heat and power generation (CHP)
- Phasing out individual oil-fired central heating units, many of which had poor thermal efficiencies by expanding the district heating networks.
- Implementing new insulation standards in Building Regulations.
- Expanding renewable energy supplies, especially biomass and wind power.

The results were quite impressive. The rapid growth in national primary energy consumption halted and consumption has remained almost stable at about 800 PJ per year ever since (see Figure 2.10). Between 1975 and 1985 domestic energy consumption for space heating was reduced by 50%. Since 1985 it has been held constant by continuing the expansion of the district heating networks and replacing even more oil-fired boilers with new gas-fired ones, using the country's new-found gas supplies (Dal and Jensen, 2000). By 2000 well over a half of Danish homes used district heating. The results of this attention to energy efficiency and renewable energy can be seen in a comparison of the breakdowns in delivered energy for the year 2000 between the UK and Denmark (see Figure 3.19).



Figures 3.19 Comparison of UK and Danish delivered energy breakdowns, 2000. Electricity in Denmark includes renewable electricity

In Denmark district heating made up 12% of the delivered energy supply and the extensive use of CHP kept the national figure for losses down to 22% compared to the UK figure of 31%. Although Denmark is still heavily reliant on imported oil, its energy mix is very varied with a 4% contribution from renewable energy.

One other point is that Danish agriculture uses 7% of the country's delivered energy as opposed to 0.8% for the UK.

United States

US energy use is high – and is still increasing. Primary energy consumption increased by over 40% between 1970 and 2000. This growth was shared between all sectors of the economy. Energy use in the commercial sector doubled over this period. As in the UK, natural gas is widely used as a heating fuel, but as pointed out above, electricity use is a major growth area. About a half of US electricity comes from coal-fired power stations; coal consumption for electricity generation increased by almost a factor of three between 1970 and 2000.

Since, naturally, everything is bigger in the US, it is no surprise that the conversion losses in their electricity industry are 22 EJ, i.e. more than twice the total UK primary energy demand!

Transport energy use in the US is another major growth area. In 2000 it made up 36% of US delivered energy use and of this 97% was oil. The 35% increase in transport energy use between 1980 and 2000 amounted to 7.3 EJ per year, i.e. more than the whole of UK delivered energy use. This growth has contributed to the widening import gap between US oil consumption and production (shown in the last chapter in Figure 2.14) which stood at 23 EJ in 2000. At $25 a barrel, 23 EJ represents an import bill of approximately $100 billion per year.

France

French energy use has also been steadily increasing. Their primary energy consumption increased by 70% between 1970 and 2000. As in the US this growth has been shared across all sectors of the economy. The key factor has, of course, been their increasing use of nuclear power. In 2000 almost 80% of their electricity came from this source. As for delivered fuels, the mix is similar to the UK, though there is less use of natural gas and more use of oil, coal, wood and electricity.

India

India is a large country with a population of a billion people, of whom only about 25% live in cities or large towns. As pointed out in Chapter 2, about a half of the country's energy supply consists of biofuel in the form of wood, crop wastes, dung, etc. Since these materials are never 'traded', the precise amounts used don't enter the normal energy statistics. Although average Indian per capita energy and electricity use is very low, it is not uniformly so. The major cities are highly industrialized, with an increasing demand for electricity, cars and transport fuel.

The figures for the use of commercially traded fuels are straightforward enough and are shown in Table 3.7.

Table 3.7 India: percentages of commercially traded energy used by different sectors

Sector	Percentage	Breakdown
Industry	49%	73% coal, 14% petroleum, 2% gas, 11% electricity
Transport	22%	98.5% petroleum, 1.5% electricity for railways
Agriculture	5%	10% petroleum, 1% gas, 89% electricity for irrigation
Residential	10%	71% petroleum, 28% electricity, 1% gas
Others	14%	61% petroleum, 34% gas, 5% electricity

Source: TERI, 2002

Indian industry has much the same mix of iron and steel, chemical and manufacturing components as other countries. Coal being an indigenous fuel is widely used. The transport sector uses the same mix of petrol and diesel as other countries, and the railways consume a modest amount of electricity.

It is when we come to agriculture that the curious nature of the Indian energy economy shows itself. The bulk of agricultural electricity, indeed a third of all Indian electricity, is sold at subsidized rates for irrigation and water pumping. Indian agriculture uses nine times more energy as electricity than it does in petroleum for farm machinery. This can perhaps be explained by a 1991/2 survey which showed that the 1.3 million tractors on Indian farms were far outnumbered by the 84 million draught animals.

Although the 'residential' sector is shown as consuming 10% of the commercially traded energy, this is only a part of the story. There are really three groups of people. The richer city dwellers are likely to cook with LPG or kerosene stoves and have access to electric light. Poorer city dwellers are likely to use LPG or kerosene lamps for lighting and firewood for cooking. At the bottom of the league are the rural poor, who are likely to use firewood or cow dung for cooking and, if they are lucky, have LPG or kerosene lighting. According to the Tata Energy Research Institute (TERI, 2002), overall 40% of India's household energy needs are met by traditional biofuels and 90% of rural households depend primarily on them. The poor efficiencies of fuel-based lighting have been already discussed. The efficiencies of cooking stoves using firewood and dung are also very low, less than 10%, compared to figures of 50% or more using kerosene or LPG stoves.

Although there is a policy of national electrification, by 1991 only 76% of urban households and 31% of rural households had an electricity connection. This is about the level of connection in the UK in 1930.

3.4 Conclusions

In the few pages of this chapter we have covered over 10 000 years and spanned the economies of a number of different countries.

There are a number of basic trends. As we have risen from the culture of hunter-gatherer through to subsistence farmer and then to modern industrial society, energy sources have been tapped:

(a) to allow the basic tedious tasks of life to be carried out with less human labour,

(b) to allow human activities to carry on into the hours of darkness,

(c) to enable new products to be manufactured and distributed, and

(d) to allow new activities to take place, such as mass travel and communication.

The process of growing food, which even in the fourteenth century occupied the full-time labour of most of the population, is now carried out in Europe and the US by a relatively few people and machines, aided by artificial fertilizers. This has allowed the bulk of the population to concentrate on manufacturing and service activities, and to have time for 'leisure'.

The efficiency of basic activities, such as the heating of houses and cooking of food, has been improved by the development of better chimneys and stoves. New fuels such as town gas, oil, electricity and natural gas have been developed and deployed so that life at the point of use is much cleaner and more pleasant. Artificial lighting, which 150 years ago would have been considered very expensive, is now so cheap that it hardly merits thinking about.

The process of industrialization, especially in the UK, has involved the use of a massive amount of fossil fuels. As other countries industrialized they did so in a more energy efficient manner, leading to falling ratios of energy use per unit of GDP.

Over the last 40 years there has been a very large growth in electricity consumption. Electricity appears to be the clean, controllable, end-use fuel of choice, even though its generation may mean the production of considerable pollution at the power station (and out of sight of the consumer) and the disposal of large amounts of waste heat.

The current main growth area in energy use is in transport. Following in the footsteps of the US, there has been a large growth in car ownership and use in Europe, leading to pollution problems and congested cities. In the UK the rise in road transport energy consumption has levelled off since the 1990s, but the energy consumption of air transport continues to rise.

However, the majority of the world's population are still living in societies without the benefits of all these energy services. In India a large proportion of the urban and rural poor still live in conditions equivalent in energy terms to those in China in 100 BC.

Overall, looking back in time we would probably not wish to go back to an earlier era. Indeed there may be an underlying fear that if energy supplies were to run short we would automatically be propelled back to a 14th century lifestyle. However, when we look at Victorian society in the 1880s, we can see a culture furiously manufacturing products and inventing exciting new ones, but doing so by using large amounts of energy in what we would see now as an inefficient manner, and living in a pall of urban air pollution that we are no longer prepared to tolerate.

It is worth asking whether the future inhabitants of the year 2120 might look back to us here in the first decade of the 21st century with similar feelings.

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