Chapter 2
How much energy do we use? – Energy statistics

2.1 The history of energy use

The energy use in the world has been increasing over the whole history of mankind. In table 2.1 you see an estimation of the energy use per capita on different stages of the development of human society. The big leap is with industrial society when fossil energies started to be used on a larger scale. This also changed the society to a more advanced level as economy increased. The societies which entered the industrial civilisation left behind most of extreme poverty, starvation, bad housing and so on.

The increase in energy use per capita needs to be multiplied with population increase to get a total energy use. The period from about 1900 when use of fossil fuels started on a larger scale to year 2000 the global population increased from 1.5 billion to 6 billion, that is a factor of 4. During the same period the increase in energy use is about 16 times, that is the energy use per capita increased 4 times (J. McNeil, 2000).

During the same period the kinds of energy used and as well the purposes of energy use changed. In the earlier stages biomass, wood in particular but also everything else which was grown, was important. It is well illustrated by the changes in transportation. 100 years ago horses and other animals were providing transportation on land and sailing ships did the same on sea. Sources of energy were biomass for the horses and wind for the ships. These were replaced by cars and steamships, using either oil or coal as a source of energy.

Table 2.1 Estimated energy use per capita in different societies (Source: A Sustainable Baltic Region Book 5. Energy, Baltic University Programme, 1997).

Stage of development	Energy use/capita (kWh/day)
Biological	2.4
Gatherers, hunters	10
Agriculture	25-50
Industrial society	50-100
Contemporary	250

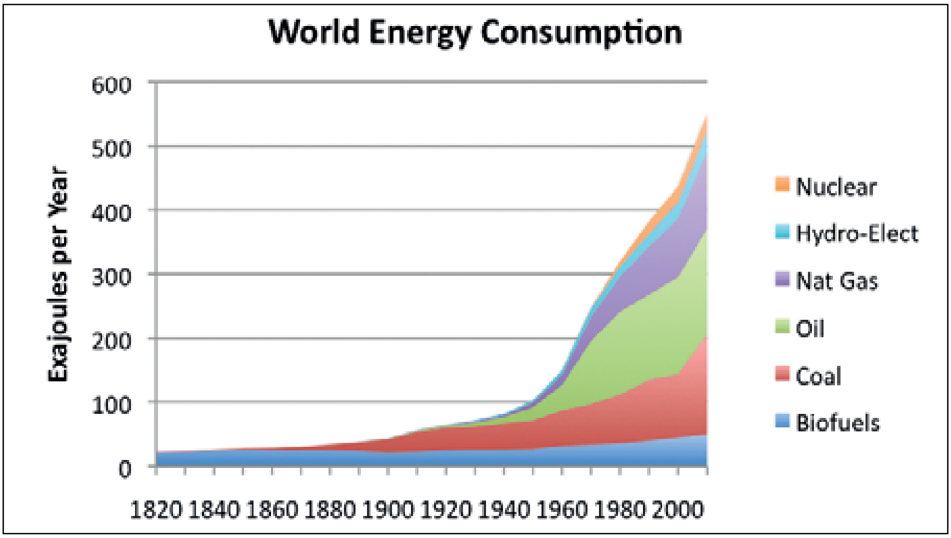


Figure 2.1 World Energy Consumption by Source. Based on Vaclav Smil estimates from Energy Transitions: History, Requirements and Prospects together with BP Statistical Data for 1965 and subsequent http://gailtheactuary.files.wordpress.com/2012/03/world-energy-consumption-by-source.png.

An estimation of the increase in global energy production and use and different kinds of energy is shown in Fig. 2.1. It is clear that biofuels is the original form of energy, followed by coal. Oil and natural gas became large parts of the energy budget from the 1920s. Hydro power as the first form of renewable energy after biomass is entering on a larger scale in the 1960s. Nuclear power is expending from the 1980s.

Energy utilisation in the welfare states towards the end of the twentieth century is at a level that has been reached rather recently. A study of energy growth in Scandinavia shows that commercial energy has grown by about 5% a year over a period of nearly 200 years. This corresponds, if the growth is exponential, to a doubling time of about 15 years. Indeed there are fluctuations – such as minor decreases during the world wars – but growth patterns have been remarkably constant over a long period. In the history to be written on human ecology this will be regarded as an important cause for the ensuing problems. Sustainability cannot be consistent with such a dramatic growth and not even with such a high level of energy use.

No nations exhibit today the extreme growth that characterised the first few decades after the World War. An estimate based on reasonable human ecological values is that whatever growth there will be in the global per capita use of energy

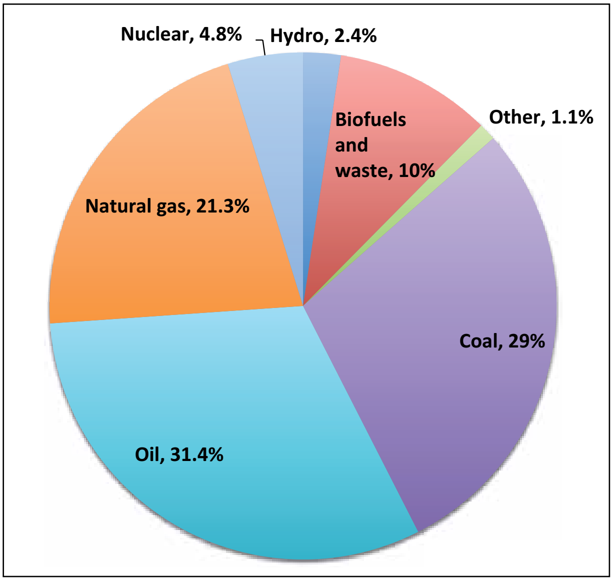


Figure 2.2 World Energy Production 2012 in Mega tonne of oil equivalents. Source: IEA.

in the future, it ought to be devoted to the poorer countries. Renewable resources will in the longer term have to replace the non-renewable ones. The replacement of fossil fuels and present nuclear technology are all-embracing projects for the near future in many modern societies. There are several alternatives. Biomass has great potential as an energy source, even for replacement of the petrol and diesel oil in cars with alcohol and biodiesel. Biogas is one further possibility. Solar technologies are developing. Most countries in Europe have a resource consumption, which is so high that it is technically no difficulties to save energy.

The question to be asked with this background is: how much energy consumption is possible in the world? How much energy do we need in the world? A simple answer is that the sun, which is our ultimate energy source, is still far from maximally exploited. An estimation is that human energy consumption is about 0.01% of the total energy coming from the sun. The problem from this point of view is not the total amount. It is the kind of energy used. Below we will look into prospects for much more efficient energy (exergy) management.

2.2 Oil production and consumption

Today some 85% of the global energy supply consists of coal, oil and gas. Studying the production and consumption of fossils fuels is thus very important when dealing with energy questions. Oil was extracted on a larger scale from about

1865. Then the first American Oil well was discovered in Pennsylvania. Almost at the same time the oil resources at Baku on the shore of the Caspian Sea were extracted. The amounts of oil produced worldwide have increased ever since, especially with the discoveries of large oil fields in the Middle East. The global production of fossil fuels is shown in figure 2.3

Oil turns out to be extremely practical for many reasons. It has a very high energy content. It is easy to transport. It can be used in all kinds of chemical productions, in particular plastics of all kinds. Oil is so good that the world has turned into oil addicts. It is thus a shock for countries that have relied on these sources of energy since even hundreds of years to learn that they cannot continue burning fossil carbon as it leads to emissions of carbon dioxide, which cause climate change.

The development of production/consumption of oil from 1965 is shown on a more detailed level in Fig. 2.4. It is an ongoing increase. The increase was linear in the 1960s. In 1973 was the first so-called oil crisis when when the members of the Organization of Arab Petroleum Exporting Countries proclaimed an oil embargo. By the end of the embargo in March 1974 the price of oil had risen from

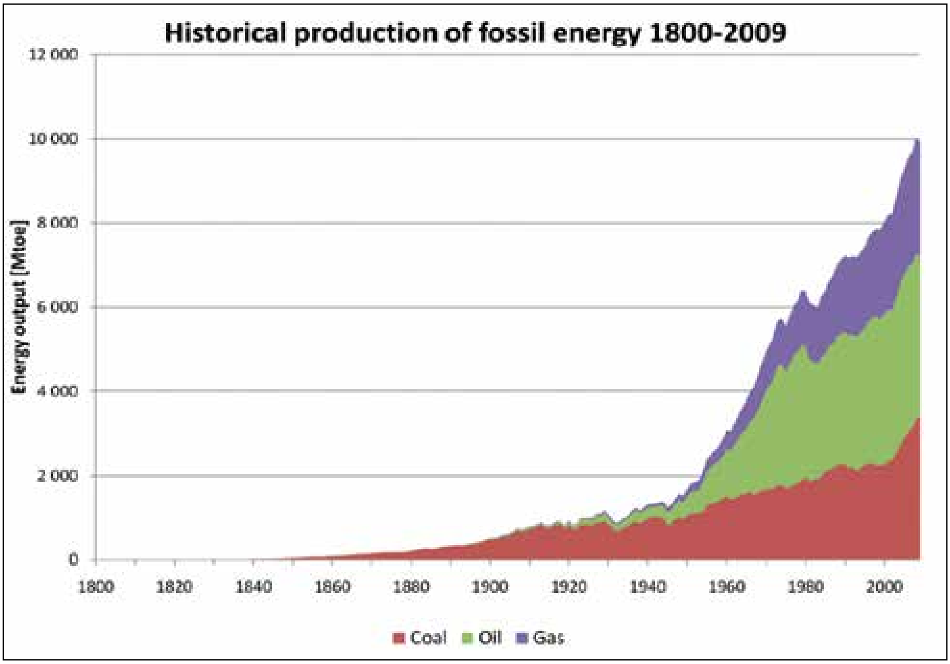


Figure 2.3 Global production of fossil energy from 1800 to 2010. Sources: adapted from M. Höök et al 2012.

Figure 2.4 Global oil production 1965-2010. Source: Kumhof & Muir (2012) Oil and the World Economy: Some Possible Futures. IMF Working Paper WP/12/256.

$3 per barrel to nearly $12, a 4-fold increase. From 1974 a new period of linear increase followed up to the next crisis period in 1979 when another quick change occurred raising this price once more, this time by a factor of three. Since then many countries have achieved a drastically reduced oil consumption as the higher price spurred technical innovations. From here followed a new period of slower but linear increase. This has in our time come to a standstill, a plateau, at a level of 85 million barrels of oil per day. A short dip occurred in 2008 because of the economic crisis but then it is back to the plateau level.

This needs to be understood in terms of production conditions. Up to the 2000s oil has been almost entirely so called *conventional oil*. This is oil pumped from oil wells without much difficulties. As these sources have been slowly emptied oil is produced from *non-conventional sources*. These includes oil pumped from *deep water*, e.g. from the Gulf of Mexico on a depth of 2,000-3,000 meters. It also includes oil produced from *tar sand* mostly in Canada. More recently *fracking of shale gas* has been used to produce oil. All these non-conventional production of oil is more expensive both in term of economic investments and energy needed to produce it. It is often expressed in terms of EROI, meaning Energy Return Of Energy Invested. EROI is very high for conventional oil, up to 100, but much lower for the non-conventional sources, perhaps 10 or 15. Obviously when a company invests more than what is earned by selling the oil they cannot continue, nor is it possible to do so if more energy is needed to produce the oil than what the oil itself contains.

This means that at some point in time the production will peak and then decline. The time of maximum production and consumption is called *peak oil.*

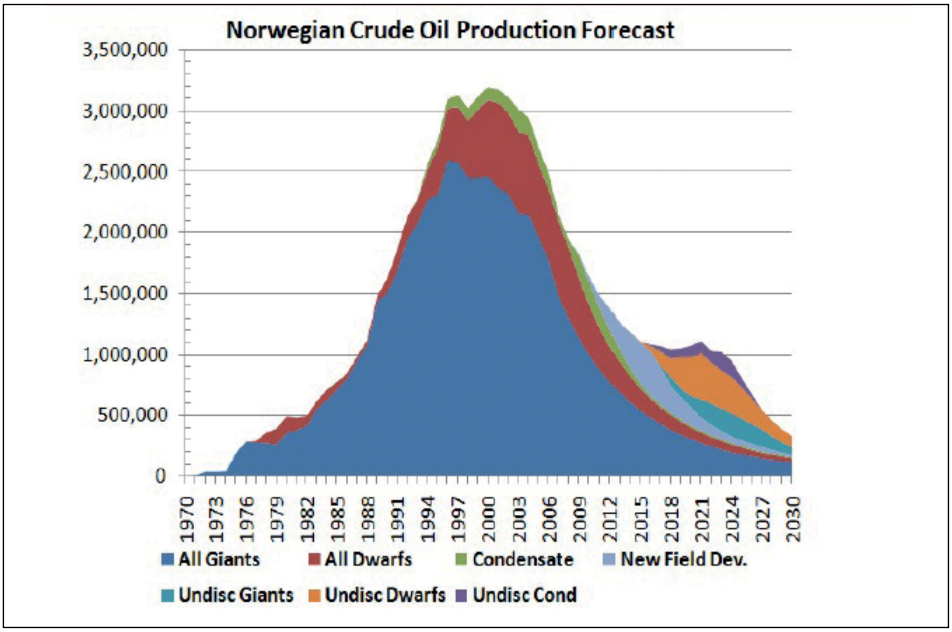


Figure 2.5 Norwegian oil. The production of oil and predicted future production. The Norwegian peak oil occurred in about 1999. A field by field analysis with maximum discovery potential. As Norway uses 0.2 Mbpd the export in 2030 will be around 0.2 Mbpd. (Source Kjell Aleklett et al, Uppsala University)

It is much studied but difficult to predict as much data are hidden. For specific countries and fields it is, however, well known. Thus US peak oil occurred in 1970 and the Norwegian peak oil was 1996-1999 (Fig.2.5). Global peak oil occurs right now as a plateau, not really as a peak. Conventional oil peaked at about 2005. The decline in the production of conventional oil has thus been replaced by unconventional oil since then. At some time this will not suffice and we will see a decline in production.

Box 2.1 Energy statistics

World energy statistics as well as statistics for individual countries is collected by several institutions. The International Energy Agency (IEA) is perhaps the best source for detailed statistics. It is available at http://www.iea.org/statistics/statisticssearch/

Another source is World Energy Council (WEC) http://www.worldenergy.org/data/resources/

BP Statistical Review of World Energy is another standard publication used widely for energy statistics. http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy-2013.html

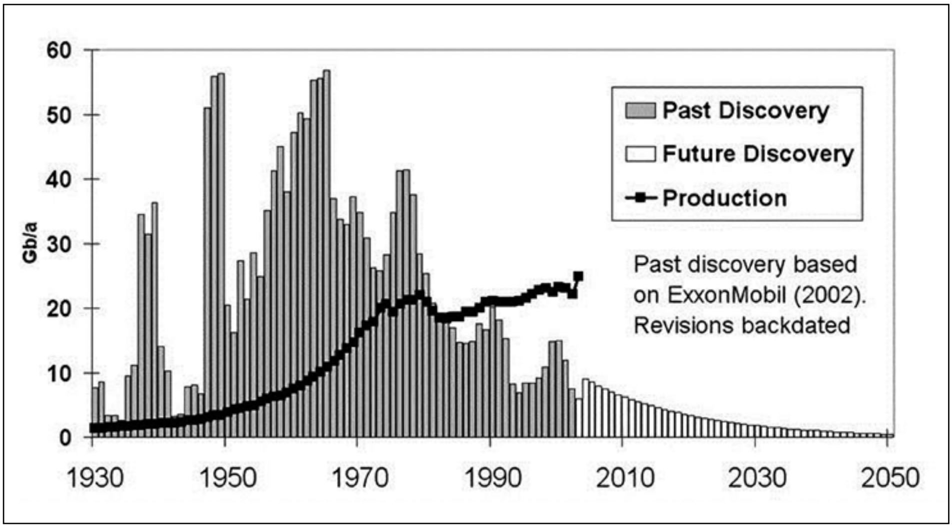


Figure 2.6 Oil discoveries. The growing gap between discoveries of oil fields and the production of oil, the global situation. (Source: ASPO; Association for the Study of Peak Oil, http://www.hydrex.be/case-story/81).

It is not realistic to believe that this situation will change because of discovery of new oil fields. The discovery of oil fields have been declining since the 1960s (Fig. 2.6). The typical time from discovery to maximum production is about 30 years. Now globally we are 50 years after the peak of discoveries and it is expected that we have a peak of oil production.

Of course the price of coal, oil and gas will increase when less is produced after the peak, if demand continues. Today we see a declining price because oil has been replaced by other means of energy. We will come back to that.

It is important here to ask what kind of energy supply we find in Uzbekistan. The data provided by the International Energy Agency (IEA) (Fig 2.7) tells that the total amount is around 50,000 ktoe per year, that is about 580 TWh. This is completely dominated by gas. Oil and coal has the second and third place. It seems that the energy budget of Uzbekistan is close to 100% fossil fuel.

The more detailed figures for recent years can be found at International Energy Agency on http://www.iea.org/statistics/statisticssearch/ or at World Energy Council (WEC) http://www.worldenergy.org/data/resources/. The data for gas in Uzbekistan from IEA was extracted from IEA and is shown in Table 2.2. Here we can see that conventional Power plants and CHP each provide 50% of electricity production in the country. Households use almost 50% of the final consumption, while industry uses about 24%. Agriculture is minimal probably because they are

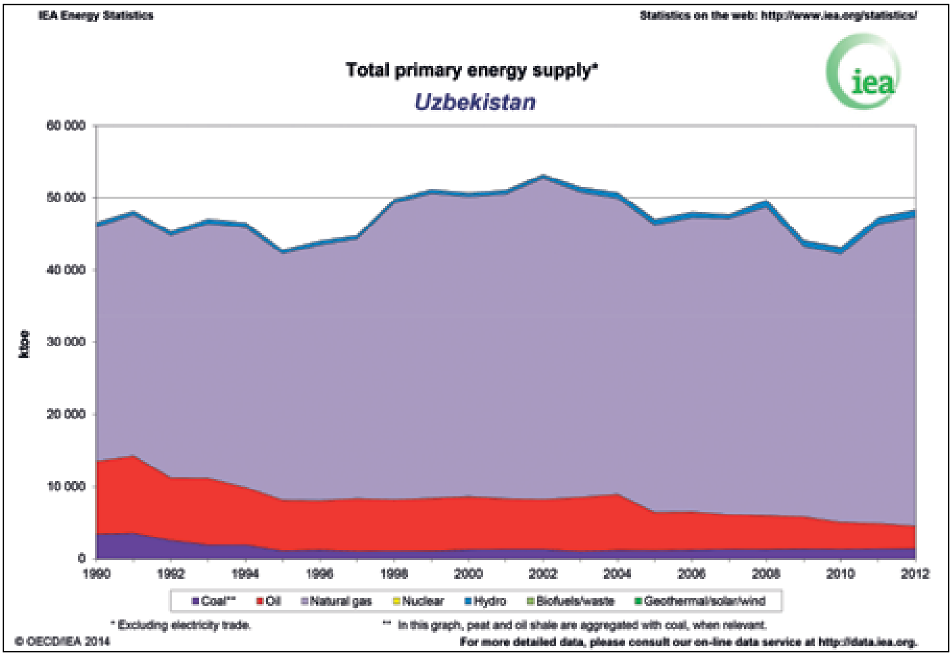


Figure 2.7 Energy in Uzbekistan. Total primary energy supply. (Source: http://www.iea.org/stats/WebGraphs/UZBEKISTAN5.pdf)

completely dependent on electricity. There are no data on biomass in the statistics of Uzbekistan, although one would expect at least on the country side some biomass would be used.

2.3 Use of energy

Main users of energy in our societies are

Residential/households. The largest energy consumption in households is due to heating/cooling. It may be either fuels incinerated in local boilers in the homes or from district heating when fuels is burnt in heat plants or CHPs. Other means of heating is using electricity or heat pumps. Cooling is using electricity for air conditioning and is in some countries a very large user of electricity. Electricity is used for all kinds of purposes in households. Lighting is typically using about 25-30% of electricity. Commercial and public services have very similar uses of energy.

Industry. The industry sector is a large consumer of energy, mostly in the form of electricity. This depends entirely on the kind of industries in the country.

Table 2.2 Natural gas data for Uzbekistan for 2012 (Source: International Energy Agency, http://www.iea.org/statistics/statisticssearch/report/?country=UZBEKISTAN&product=natural-gas&year=2012)

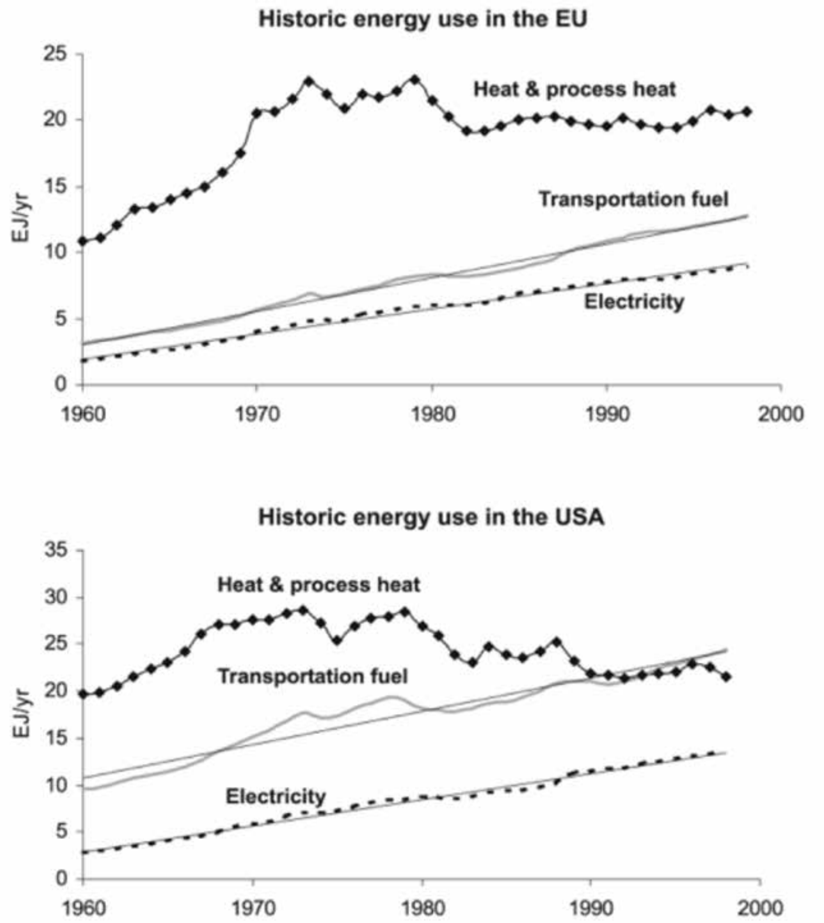
Category	Amount (TJ)
Production	
Total production	2,377,306
Domestic supply	1,991,858
Export	-385,448
Energy industry own use	77,443
Consumption	
Electricity plants	272,050
CHP plants	278,132
Heat plants	81,383
Industry	288,528
Transport	63,407
Residential	653,089
Commercial/ public services	130,626
Agriculture/Forestry	6,981
Non-energy use	67,569
Final consumption	1,210,200
Transformation	631,565

In Sweden big users of electricity includes the pulp and paper industry, the steel mills and the forestry industry such as saw mills. The building and construction industry, included here, is as well as large consumer of electricity.

Transport. The transport sector is a large consumer of fossil fuels, mostly as oil based products, such as diesel and petrol. This sector is for that reason one of the most difficult to work with for increasing sustainability.

Agriculture/forestry. This sector is very dependent on transport and machinery. In a situation when fuels are getting scarce this sector will be the first to be seriously affected, which of course will be a difficulty for the entire society.

Looking at the development in the EU and the USA (Fig. 2.8) it is clear that energy use for heat and process heat has been more or less constant since the 1970s, while electricity and transport fuel has been increasing in a linear way almost the whole period studied. This is still the case both in EU and the USA. The source of energy is changing much more than the use of energy.



Note: For the EU, the future electricity and transportation fuel demand is assumed to follow the linear historic extrapolation (the correlation coefficient r^2 is 0.99 for both electricity and transport fuel) while the heat demand is assumed to be constant, 18.5 EJ yr^{-1}, in the reference demand scenario. For the USA, the future electricity and transportation fuel demand is assumed to follow the linear historic extrapolation (the correlation coefficient r^2 is 0.99 for electricity and 0.93 for transport fuel) while the heat demand is assumed to be constant, 20.5 EJ yr^{-1}, in the reference demand scenario

Figure 2.8 Historic energy use in the EU and the USA. Source: ?????????????

2.4 Energy sufficiency and efficiency

When discussing energy management it is crucial to ask if there are possibilities to reduce the energy intensity of the sectors mentioned. This is the question of *energy sufficiency*. Even if energy is necessary it may be used more efficiently. *Energy efficiency* is as well a key task in energy management.

The residential sector has been very successful in reducing energy needs. Insulation of buildings, better construction of windows and doors, as well as more effective heat exchangers are part of the technical solutions. Today *low energy house* become more common in northern Europe. These use much less energy (15-25%) for heating and sometimes even have their own supplies of electricity and hot water. *Passive houses* have efficient insulation, heat exchanger for ventilation, and use heat from persons and machinery. Even if passive houses are not common low energy houses start to be so. These are slightly more expensive to build but much less expensive to use. Also retrofitting of present buildings is possible and profitable. As an example energy use in the building sector in Sweden could, according to the sector, be reduced by 20% with profitable investments. This figure is probably large also in other countries in the region.

The agriculture sector has several shortcomings which lead to energy wasting.

Food waste is large (some 20-30% of edible food) in many places. This can be reduced by simple means, such as better planned shopping, proper storage and taking care of leftovers. This refers both to producers, retailers and households/restaurants. Different food has very different carbon footprints. Meat production is by far most energy consuming while vegetables are much less so. But the trend in our societies is that meat consumption is increasing; 80% of the crops on farmland in the EU are used for animal feed. Denmark has five times more pigs than people. Less meat consumption is an important step to reduce energy needs.

Figure 2.9 A German ICE high-speed trains leaves the Schellenberg-tunnel at the Nuremberg-Munich high-speed track

The *transport sector* is by far the most difficult to improve. It is also the only sector where energy consumption is increasing and fossil fuels dominate. The first concern is to reduce travelling. For example many meetings may be replaced by video conferencing. Secondly improving public transport is a main concern especially in cities, to reduce the role of the private car. Here we also see an important technical development. New bio fuels, such as biogas, biodiesel and bio ethanol are introduced. But in the longer term electricity should be introduced since the electric motor is at least 4 times better than the combustion engine for mechanical work; train and tram is even better since rail requires less energy than tyres. Finally air traffic increases much; at present the environmental impacts of air traffic, including emissions, are not paid by the sector and there is a need for economic reforms. In the end lifestyle changes are needed. We simply have to travel differently and less.

Chapter 2 sources:

Main text Lars Rydén The Sustainable development course of the Baltic University Programme; Energy use and *supply http://www.balticuniv.uu.se/index.php/2a-energy-supply-and-use*.

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