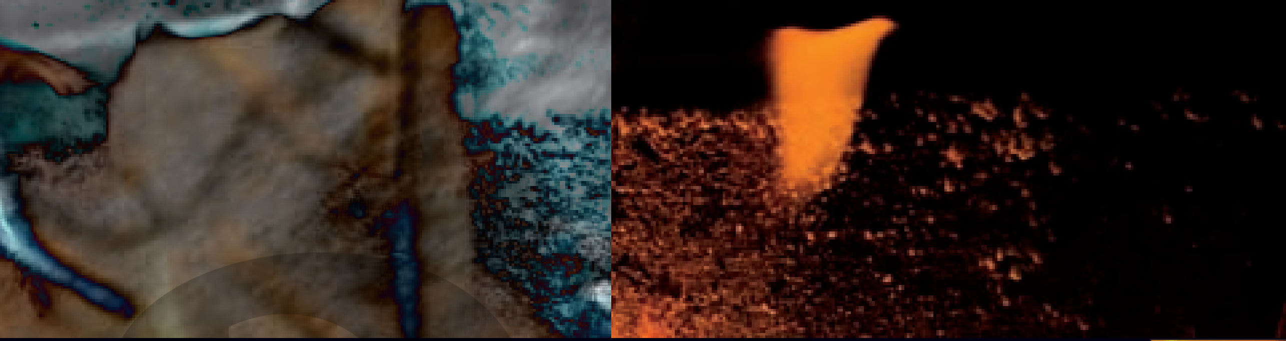

3: Energy use and heat production

3.1 Energy use

3.1.1 Factors influencing energy use trends

A country's energy use and material living conditions are normally closely related. Generally speaking, energy use rises with economic growth because the need for energy increases as more goods and services are produced. Increased value added means increased income for both the private and public sector. The increase in income is partly used on greater consumption, including energy.

The effect of economic growth on energy use will depend on which sectors of the Norwegian economy are in growth. Energy usage varies widely from one sector to another in terms of both energy mix and energy intensity in production.

The use of electrical equipment has increased significantly both in households and in industry, as electricity has become widely available. Falling product prices combined with rising disposable incomes have made new products available to everyone.

Demographic factors such as population size, age structure, settlement patterns and the number and size of households have an impact on energy demand. Population growth leads to an increase in energy use because more houses, schools and commercial buildings are built, and these need heating and lighting. Population growth also results in

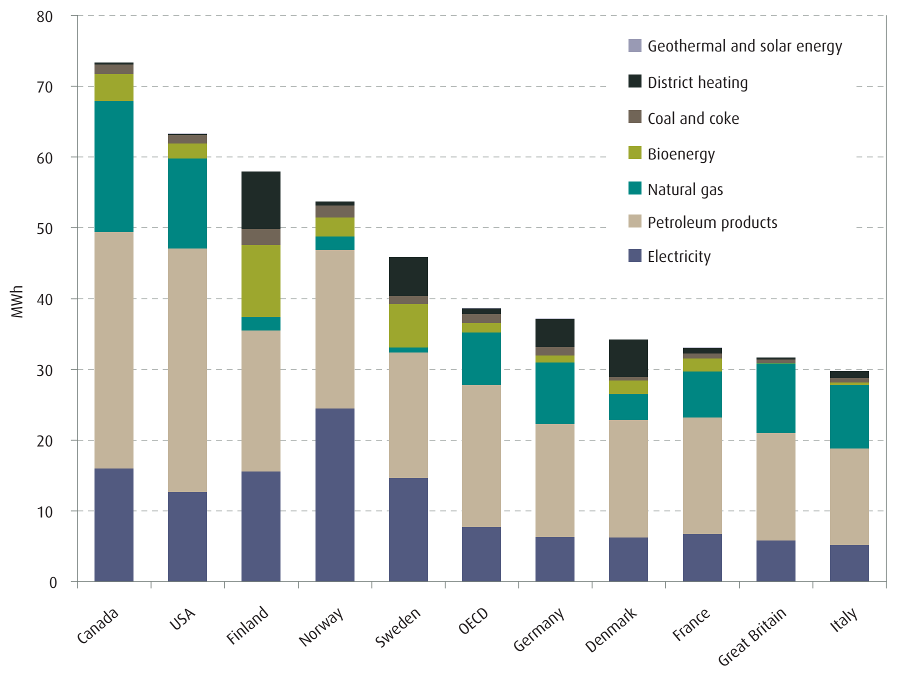

Figure 3.1 Per capita energy consumption in OECD countries, 2005.
Source: Energy balances of OECD Countries, IEA/OECD Paris

higher consumption of goods and services produced with the aid of energy.

Energy use will be higher for a given number of people living in many small households rather than large households. In Norway, the trend in recent years has been towards more households of fewer people.

Energy use also depends on energy prices. Higher energy prices boost production costs for industry as well as the cost to households of using electricity and other energy carriers. This usually constrains energy use.

3.1.2 Trends in energy use

Per capita energy use in Norway is somewhat higher than the OECD average (see figure 3.1). However, the proportion of energy use accounted for by electricity is considerably higher than in other countries. The main reason for high electricity consumption is that Norway has a large energy-intensive industrial sector. In addition, electricity is used to a much wider extent for heating buildings and water than in other countries.

Net domestic energy consumption in Norway in 2007 was 225 TWh. This is approximately the same as for the year before. Figure 3.2 shows energy use by carrier and consumer category in 2007.

Stationary energy use is defined as net domestic energy use minus energy utilised for transport purposes. In 2006, stationary energy use in Norway was 143.9 TWh. This was slightly lower than the year before. Figure 3.3 shows trends in stationary energy use by energy carrier from 1980 to 2006.

Electricity is the most used energy carrier. In 2006, stationary electricity consumption was around 107 TWh. Oil products, wood and waste (bioenergy) are also important stationary energy carriers in Norway. Stationary energy consumption of oil products was just over 10 TWh and the consumption of different types of gases was 10 TWh. Registered bioenergy use was 12.2 TWh. Use of district heating was 2.6 TWh. Coal and coke are also used. See Appendix 3.

A marked shift from oil products to electricity has taken place over the past 25 years.

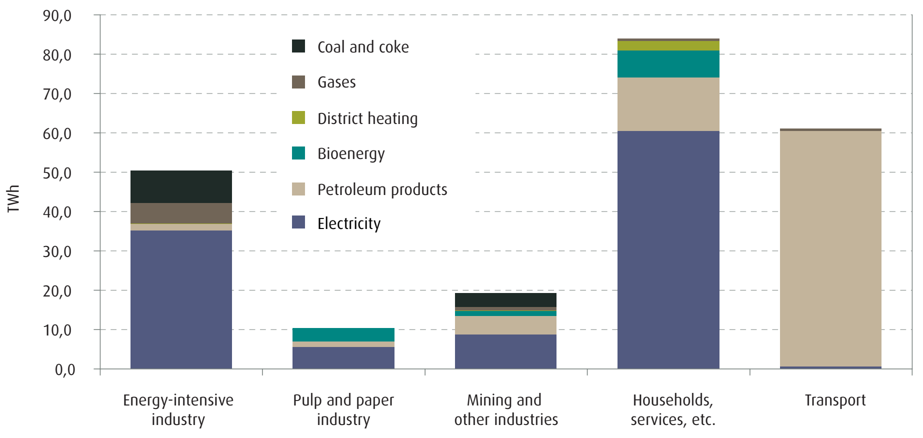

Figure 3.2 Energy consumption in 2007 by carrier and sector.
Source: Statistics Norway, Energy Balance

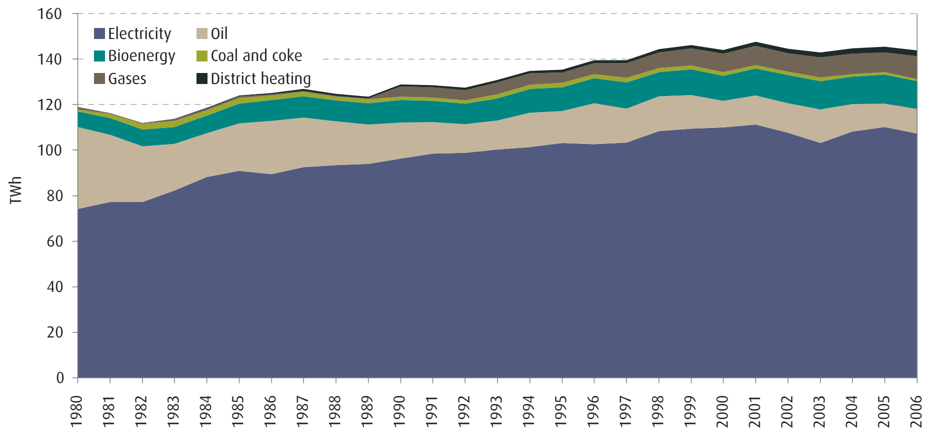

Figure 3.3 Trends in stationary energy consumption.
Source: Statistics Norway

Electricity consumption has increased by about 50 per cent since 1980. Stationary oil consumption has declined by about 70 per cent over the same period. The fall in water inflow to electricity supply and high electricity prices has partly resulted in higher use of heating oil than in 2002 and 2003.

The main switch from heating oils to elec-

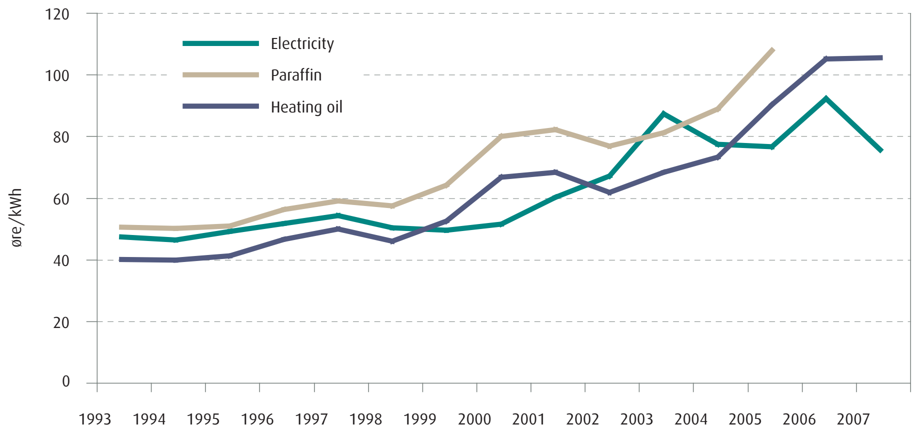

Figure 3.4 Price of electricity for households, and list prices for heating oil and heating paraffin converted to utilised energy. Annual average. Including all taxes.
Source: Statistics Norway

tricity took place before the early 1990s. Figure 3.4 shows price trends for heating oil and electricity to households.

3.1.3 Stationary energy use by sector

Studies of the distribution of stationary energy use among different consumer groups usually distinguish between manufacturing and mining, households and other consumers (in this context, primarily private and public service suppliers). Industry is usually subdivided into energy-intensive industry, the pulp and paper industry and mining and other industries.

Figure 3.5 shows trends in stationary energy use by sector. Stationary energy consumption has increased most in the group ‘other consumers’ in the period 1980 to 2006. Energy use increased by 47 per cent in the sector in this period. There has also been significant growth in energy consumption in other sectors. Growth in the period was 37 per cent for energy-intensive industry, 19 per cent for the pulp and paper industry, 19 per cent for households. Energy consumption in the sector ‘mining and other industries’ decreased by 26 per cent.

The figure shows that total energy consumption in Norway increased until the end of the 1990s. In recent years, consumption has levelled off and stabilised at around 145 TWh.

In 2006 energy consumption in the energy-intensive industries was 42.8 TWh, while the level for the paper and pulp industry was 10.9 TWh. Energy-intensive and pulp and paper production differ from other consumer categories in that their energy use is stable over 24 hours and over the year. Energy-intensive industry also differs by taking power from the grid at high voltages.

Statkraft SF has power contracts based on terms set by the Authorities for around 8.5 TWh per year with energy-intensive

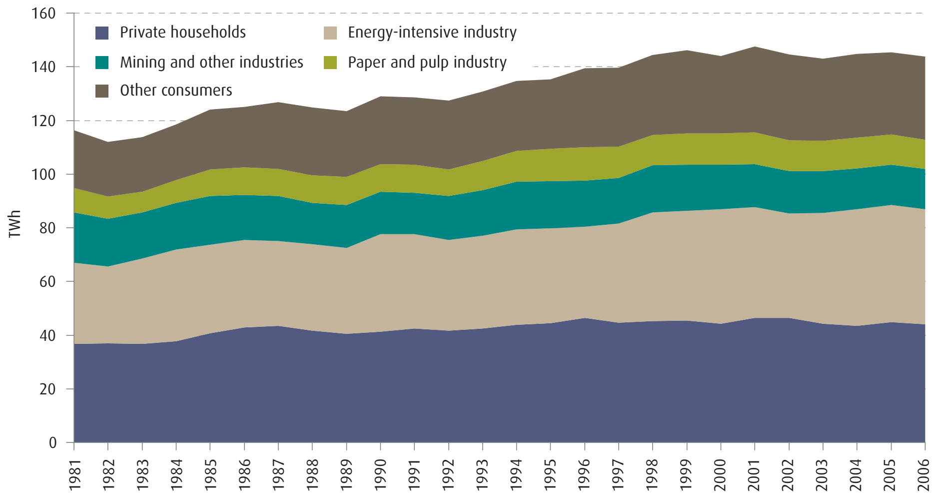

Figure 3.5 Stationary energy consumption by sector.
Source: Statistics Norway

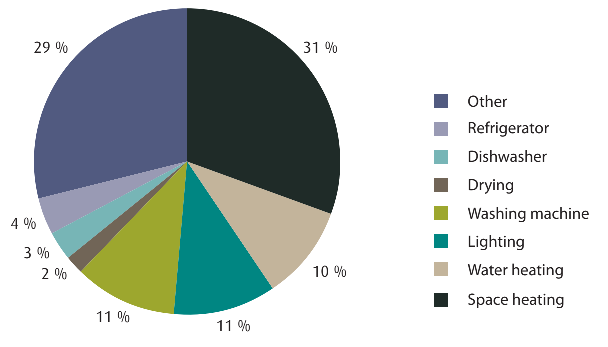

Figure 3.6 Electricity consumption in households by purpose in 2001.
Source: Statistics Norway

industries and the paper and pulp industry. Most of the power contracts based on terms set by the Authorities expire at the end of 2010. In addition, the industry uses around 4 TWh per year linked to so-called early reversion agreements, which run to 2030. This sector meets its remaining power requirements largely from its own power plants as well as from contracts with other power suppliers and purchases on the spot market.

Households used 44.1 TWh in 2006, and this figure has remained at roughly the same level since the 1990s.

Mining and other industries used around 15 TWh in 2006. Other commercial total energy use was 31.1 TWh in 2006. Electricity was the dominant energy carrier in all sectors.

3.1.4 Stationary energy use by usage

Industry and mining used around 70 TWh in 2006. Electricity represented just under 50 TWh of this. Industry essentially uses energy as an input factor in industrial processes. There are no statistics on the distribution of industry's energy consumption by usage.

Based on Statistics Norway's household surveys, a study of energy consumption in Norwegian households was carried out in 2001. Total household energy consumption was around 45 TWh in 2001. Around 46 per cent of total energy consumption in households was used for space heating and 8 per cent for water heating, so called thermal use.

35 TWh of household consumption was electricity. 41 per cent of this was used for thermal purposes. The remaining use was electricity specific (appliances, etc). Figure 3.6 shows electricity consumption by usage for households.

The consumer can use various energy carriers for heating purposes. The possibility of alternating between different heating methods is crucial to the reliability of a supply system based on hydropower. To be able to change energy carrier at short notice, consumers must have installed several types of heating equipment. See also Section 3.2.

After 1970, there was a significant fall in the proportion of Norwegian households using paraffin or oil burners. These have largely been replaced by electric heating equipment. Statistics Norway's consumption survey

Examples of heating systems

Electricity-based heating systems

In electricity-based heating systems, electricity is converted to heat by being conducted through a resistance such as a filament. Common electricity-based heating systems are convectors, underfloor heating cables, portable fan heaters and radiators, and electrical hot water tanks.

Water-based central heating

In water-based heating systems, a central source is used to heat water, which then circulates through a piping system (radiators, convectors or underfloor pipes), releasing heat to the surroundings. A water-based heating system can use various sources of heat. Among the most common are oil, electricity, biomass, heat pumps and district heating, but gas, solar energy and geothermal energy can also be used.

Warm-air heating

Various solutions exist for distributing heat through the air. Warm air can circulate through a closed piping system, which then releases heat, or the warm air can be blown directly into the space to be heated. As in the water-based systems described above, a number of heat sources can be used to warm up the air in these systems.

Independent heating devices

Independent heating devices such as wood-burning stoves, fireplaces and paraffin stoves are widely used in Norway. The most commonly used are wood-burning stoves.

from 2006 shows that 98 per cent of households have electric heating equipment.

Around 26 per cent of households only have one heating source. This is usual in small houses or apartment blocks, where 71 per cent fall into this category. 20 per cent of households only use electricity for heating, and around 10 per cent have on site central heating or district heating. In dwellings with two or more sources of heat, a combination of electricity and wood is most common

In the survey, some 8 per cent of the households stated that they had a heat pump in 2006, which is double the figure in 2004. Heat pumps consume energy in the form of electricity, but also use heat from the surroundings and thus yield more energy than they consume. This results in lower electricity consumption. Heat pumps can also be used for cooling in summer, counteracting this effect. 25 per cent of the households stated that they used heat pumps for cooling. The study concludes that it is difficult to ascertain the effect on electricity consumption, and that a series of data for the same households over a period of time is necessary to provide a clearer answer.

According to earlier studies[1], energy consumption for operation of industrial buildings was 35 TWh, of which 85 per cent was electricity. Roughly 18 TWh was used for heating. 12.5 TWh of this was provided by electricity. The distribution of energy consumption for different usages in industrial buildings varied significantly between building categories and also between buildings in the same category. For example, the proportion of energy used for space heating was 5 per cent in grocery stores, compared with over 50 per cent in schools. Energy for fans and pumps varied from 5 per cent in hospitals to around 25 per cent in universities and colleges.

1 Enova's statistics from the construction network in 2001.

3.1.5 Measures to limit energy use

Measures to limit energy consumption have been a part of Norwegian energy policy since the 1970s. Several measures are financed today through Enova (see Section 3.4.4). Energy use is also influenced by the provisions of the Energy Act and the Planning and Building Act, labelling requirements and standards for electrical equipment, various grant schemes funded by other ministries and taxes.

A system of informative electricity bills has been introduced in Norway. All customers expected to consume more than 8,000 kWh per year receive bills from the grid company for actual consumption (see Section 7.2.4). Previously, customers paid on the basis of estimated consumption. In addition, the bill must show how the customer's electricity consumption compares with the year before and specifies where advice on energy saving can be obtained. The aim is to make customers more aware of their electricity consumption. A number of new measures to improve the position of consumers have been introduced, including reducing the time required to change supplier and regulation of waiting tariffs. Work is currently underway on introducing new electricity meters, scheduled to be installed by 2012/2013. The new technology will enable more types of contracts than are currently available on the market, will serve to raise awareness about individual electricity consumption, and will make it easier for consumers to see the impact of energy conservation measures.

The National Office of Building Technology and Administration is responsible for administering the building regulations. Technical regulations issued under the Planning and Building Act govern energy use in buildings. New requirements for energy consumption and a different method for calculating energy use in new buildings are being prepared. At the same time, an energy labelling system will be introduced for new buildings and for buildings that either are leased or are to be sold.

Through the EEA Agreement, Norway participates in international collaboration on energy labelling of a number of consumer products. Refrigerators, freezers, dishwashers, washing machines, tumble dryers and household lighting are all now labelled. The labelling allows consumers to be able to select the most energy efficient equipment. There are plans to also mark air conditioning equipment, cookers and hot water heaters.

Taxes and tax exemptions influence the relative price and cost of energy carriers, and in turn affect consumption. The most important taxes are the electricity tax and various taxes on heating oil (see Sections 2.6 and 3.3.2 respectively).

3.2 Heat production

Energy sources such as oil, natural gas and biomass are used in Norway primarily to produce heat energy. The energy can be transported in pipes as district heating or is produced on site. Heat energy is primarily used in households, commercial buildings and industry. In households and commercial buildings it is used for space heating and hot water; in industry it is used for a variety of processes that require heat.

In the current situation, oil and in some cases natural gas and bioenergy provide valuable flexibility in the Norwegian energy system, and can make it easier to adapt to dry years and peaks in consumption. It is possible to increase consumption of these energy sources both in industry and in private households when necessary. Rapid switching between different energy carriers is possible in systems

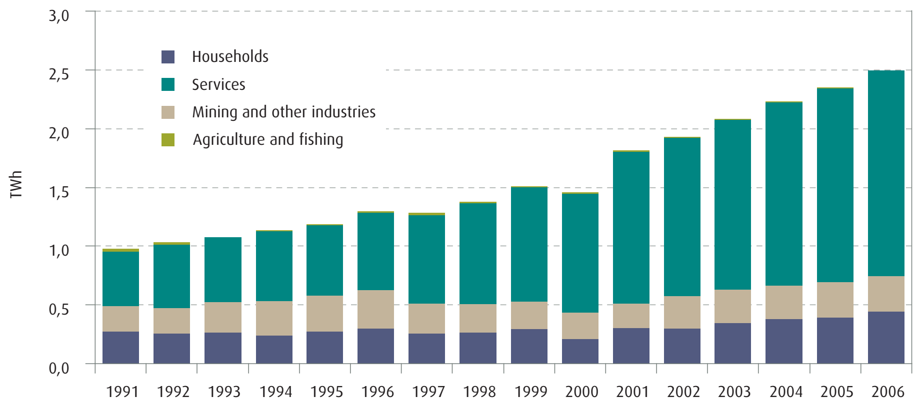

Figure 3.7 Consumption of district heating by various consumer groups.
Source: Statistics Norway

utilising combined oil/electric boilers, for instance.

The consumption figures for oil, natural gas and bioenergy presented in the following sections show energy supplied. Efficiency varies with energy source and combustion process.

3.2.1 District heating

The technology used to supply hot water or steam to households, commercial buildings and other consumers from a central source is known as district heating. Heat is transported through insulated pipes and is mainly used for space heating and hot water.

District heating systems can utilise energy extracted from waste and sewage, or waste heat and gas from industrial sources that would otherwise be lost. Hot water or steam in district heating installations can also be produced using heat pumps, electricity, gas, oil, wood chippings or coal. Almost 40 per cent of Norway's net deliveries of district heating are derived from waste incineration plants.

Figures for 2006 show that consumption of district heating was 2.5 TWh (see figure 3.7). This is an increase of 6.2 per cent in relation to 2005. In 2006 around two thirds of consumption of district heating was within service sectors, while households used around 18 per cent and industry used around 12 per cent.

District heating is most widely used in the large towns and cities. In 2007, Norway had just under 50 district heating stations. Norway makes far less use of district heating for heating purposes than the other Scandinavian countries. Some district heating systems can also supply cooling.

District heating is regulated by the Energy Act (see Section 4.3.7). Suppliers of district heating from installations included in the system of mandatory connection to a grid are not permitted to charge a higher price than for the equivalent amount of electrical heating in the same area.

Since 1997, the authorities have provided support for the utilisation of bioenergy and other renewable energy sources to produce heat. Enova administers the financial support for district heating systems. See also Section 3.4 on Enova.

3.2.2 Oil for stationary consumption

The total stationary consumption of oil products in 2006 corresponded to 10.7 TWh. This is 0.4 TWh more than in 2005. However, the general trend is that stationary consumption of oil products is diminishing (see figures 3.3 and 3.8).

Oil is mainly used for space and water heating in buildings, and to generate heat for various applications in industry and elsewhere. In 2006, industry used 5 TWh of oil for stationary purposes: 1 TWh in energy-intensive industry, 1.6 TWh in the paper and pulp industry and 2.4 in mining and other industries. Households, service sectors, construction, agriculture and fisheries used 5.7 TWh of oil for stationary purposes.

Sales of oil for stationary consumption are split between paraffin, light heating oil, heavy distillates and heavy heating oil. They differ in density and sulphur content. Figure 3.8 shows trends in the consumption (sale) of heating oil for stationary purposes measured in millions of litres. As the figure shows, the products containing most sulphur have shown the greatest reduction in use. At the same time, the sulphur content of most oil products has been greatly reduced over the last ten years.

Paraffin is used mainly in stoves in private households. Light heating oil is used both in small heating systems in private households and in larger systems in commercial buildings and industry. Light heating oil is primarily used in water-based central heating systems. Heavy heating oils with a higher sulphur content are cheaper than light heating oils, and are used in larger combustion plants where stricter emission standards apply. The oil is also used to produce hot water or steam in

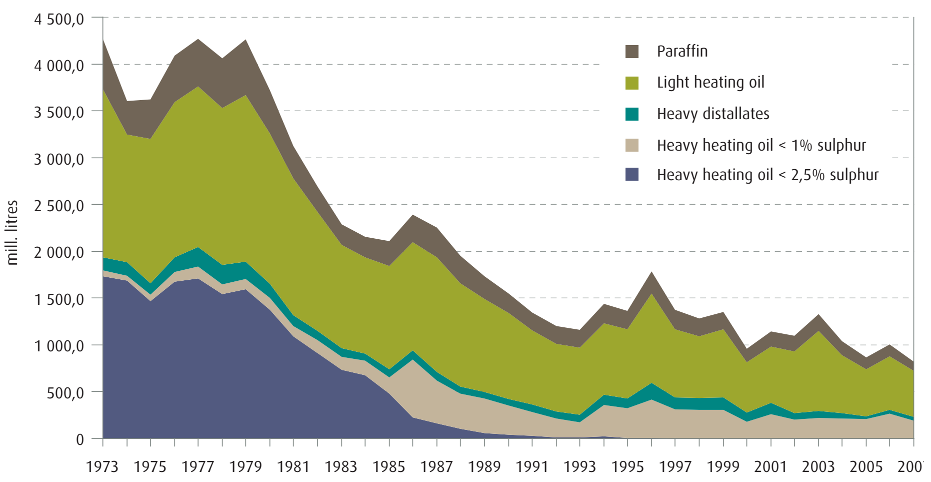

Figure 3.8 Consumption (sales) of heating oil for stationary purposes.
Source: Norwegian Petroleum Industry Association

these plants. Efficiency differences exist between old and new heating systems that use paraffin and oil. The efficiency of older installations averages about 80 per cent, whereas it may be as high as 95 per cent in new systems.

Oil is the principal fuel used in Norwegian water-based central heating systems. Renewable energy sources, heat pumps and waste heat can also be used in these systems.

3.2.3 Biomass

Bioenergy can be produced by incinerating or fermenting biomass or by treating it chemically. Biomass includes firewood, black liquor[2], bark and other forms of wood waste, and waste from households and industry used to provide district heating. Fuels such as gas, oil, pellets and briquettes can be produced from biomass.

The registered use of bioenergy was around 11.5 TWh in 2007. Industry accounted for more than a third of this, at 4.6 TWh. The remaining 6.9 TWh is primarily used by households. Biomass used to produce district heating is in addition to this.

The extent to which biofuel is used and its applications depend on factors such as available supplies and their quality and emission standards. Manufacturing of paper and pulp and the wood and wood products industry require large amounts of heat for various drying processes, meaning that the energy in wood waste such as bark and chippings can be used without further processing in large incineration plants. A proportion of the waste in large landfills can be incinerated, and the heat energy can be used directly or in thermal power generation. Biofuel used in households and in small incineration plants often requires more processing to be suitable for transport, storage and handling.

Processing of biofuel has increased in recent years. Biofuel in the form of pellets and briquettes is more suitable for storage, transport and use in automated incineration plants.

3.2.4 Domestic use of natural gas

Domestic use of natural gas for stationary energy supply in 2007 was 306 million Sm^3, equivalent to around 3.4 TWh supplied energy. This is up by 13.2 per cent from the year before. In addition, 1 TWh of natural gas was converted to other energy carriers in district heating and combined heat and power stations. Use of propane and butane is in addition to this.

Natural gas usage began in the last ten years and has primarily replaced heavier heating oils in industry. The chemicals industry used 1.1 TWh for energy purposes in 2007. The metals industry used 0.7 TWh, while the food and drinks industry used natural gas equivalent to 0.4 TWh for energy purposes. Household use of natural gas was equivalent to 46 GWh in 2007.

Natural gas consists mainly of methane and can be distributed by pipeline, or as compressed natural gas (CNG) or liquefied natural gas (LNG). See the box on natural gas on page 45 for an explanation of these terms. 60.3 per cent of domestic consumption of natural gas in 2007 was supplied by pipe, while LNG and CNG accounted for 36.8 and 2.9 per cent respectively.

Consumption is highest in the areas around the landfall terminals for gas pipelines. Norway currently has five pipeline terminals for natural gas: Kårstø, Kollsnes, Tjeldbergodden, Nyhamna and Melkøya.

2 Black liquor is a residual product from cellulose production and consists of wood pulp and sodium salts.

Natural gas

Natural gas from Norwegian offshore fields is called 'rich gas' and usually contains 60–95 per cent methane. This is separated into natural gas liquids (NGL) and dry gas (methane) at the landfall terminal. Also called wet gas, NGL comprises ethane, propane, butanes, natural gasoline and condensate. Liquefied petroleum gas (LPG) is a sub-group of wet gas. Methane is referred to as dry gas or natural gas. Propane and butane are shipped to customers in Norway and abroad by tanker, while most of the dry gas is piped to continental Europe. Gas is exported from Kårstø and Kollsnes through the major pipelines system Europipe, Statpipe, Zeepipe and Franpipe. Pipeline distribution of gas involves high investment costs. The larger the volume of gas transported through a pipeline system, the lower the cost per unit transported.

Compressed natural gas (CNG) is natural gas stored at a pressure of 250–300 bar (250–300 times atmospheric pressure). This makes it suitable for distributing relatively small gas volumes over short distances. Transport is by road or ship. Liquefied natural gas (LNG) is created by refrigerating natural gas to −162°C, when it liquefies. Stored in insulated vessels under atmospheric pressure, LNG occupies only about one-600th of its gaseous volume. Because its energy density is much higher than CNG, it can be transported over greater distances by road, sea or rail at lower cost. LNG can be stored or regasified for transport to end users as CNG or by pipeline.

Liquefied Petroleum Gas (LPG)

LPG is a mixture of propane and butane. LPG is liquid at moderate pressures and temperatures. It is part of the wet gas part of natural gas, or can be produced during the refining of crude oil. Propane is easier to store and transport than natural gas. Applications for LPG include heating or processing by industry or space and water heating in households.

The figures for LPG in the environmental accounts are comparable with those for natural gas, but CO_2 emissions from LPG are 10% higher.

Source: Norwegian Petroleum Industry Association

Gasnor is the market's largest supplier of domestic natural gas. In 2007, Gasnor supplied roughly 178 million Sm^3 of natural gas. Gasnor has constructed a pipeline network in the Haugesund area of south-west Norway to distribute natural gas. Gasnor has three production facilities for CNG and LNG. LNG is distributed by road and by a specially constructed coastal tanker ship.

Lyse Gass has constructed a high-pressure pipeline from Kårstø in northern Rogaland to Risavik in Sola municipality south of Stavanger. A distribution system has been constructed from Risavik, which covers large parts of the Jæren region.

Buses in several towns run on natural gas. The largest use is in the Bergen region where around 80 buses use natural gas. Supply ships serving oil installations in the North Sea and car ferries also run on natural gas. At Tjeldbergodden, 503,000 tonnes of wet gas was used to produce 855,000 tonnes of methanol in 2006. 15,200 tonnes of LNG a year is also produced at Tjeldbergodden, which corresponds to just under 21 million Sm^3 of natural gas.

Several small natural gas companies have been established in recent years, often in connection with the new landing sites and establishing new LNG reception terminals. At the end of 2005, there were around 20 LNG reception terminals in operation in Norway, and several new terminals are being planned and under construction.

3.3 Environmental impact of energy use

Due to the extensive use of hydropower to generate electricity, emissions to the air from stationary energy use in Norway are low. The environmental impact of stationary energy use relates largely to the combustion of energy commodities. In addition to emissions to the air from stationary combustion, there are also emissions to the air from mobile combustion and process emissions.

Stationary incineration is mainly in directly-fuelled furnaces burning energy commodities to provide heat for an industrial process, boilers using energy commodities to heat water for steam, and small stoves burning oil or wood to heat dwellings. After 2007, there will also be emissions of greenhouse gases from production at gas-fired power stations. The amount will depend on how much power the gas-fired power stations generate a year. Efforts to reduce emissions from gas-fired power stations by means of carbon capture and storage are described in Section 3.3.3.

Environmental impacts related to interventions in the landscape in connection with developing hydropower and wind power are discussed in Chapter 2, and the environmental impact of laying power cables is discussed in Chapter 6.

3.3.1 Emissions to air from stationary combustion

Emissions from stationary combustion derive from many different sources of energy in a wide variety of applications. Waste, heating oil, biomass and gas are all among the fuels used in district heating plants. Industry uses heavy and light heating oils, natural gas, coal and coke, while the paper and pulp industry uses a lot of wood waste and black liquor.

After electricity, the main energy carriers used for heating are biomass (wood, wood waste and black liquor) and different types of heating oil.

Combustion of biomass results in emissions of polycyclic aromatic hydrocarbons (PAH), particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO) and benzene. Biomass is primarily firewood, wood waste, bark and black liquor, plus waste from households and industry used to provide district heating. The size of these emissions and the damage they cause depends on a number of factors. The main factors are whether the fuel is wet or dry, the type of wood-burning appliance used, and the amount of air flow.

Since 2005, quarterly surveys have been conducted among households to map use of firewood, the type of fireplace and the age of the oven (see figure 3.9). This survey shows that 38 per cent of the wood is burnt in clean-burning stoves (stoves manufactured after 1998). This represents a 20 percentage point increase since 2002. New wood-burning stoves are more efficient than old ones, i.e. each kilo of wood produces more heat. The amount of wood burning varies widely from county to county, from less than 100 kg per capita in Oslo to more than 500 kg in Nord-Trøndelag, Hedmark and Oppland. On average, Norwegians burnt 300 kg of wood each in 2006.

Burning oil releases sulphur dioxide (SO_2), carbon dioxide (CO_2), nitrogen oxides (NOx) and some particulate matter (PM). The size of these emissions depends on the technologies and fuels used. Key factors are the size and age of the boiler and the quality of the fuel.

Heating oil was responsible for roughly 7 per cent of the total CO_2 emissions in 2006. Emissions of sulphur dioxide were 6 per cent lower in 2007 than the year before. This reduction is due primarily to reduced emis-

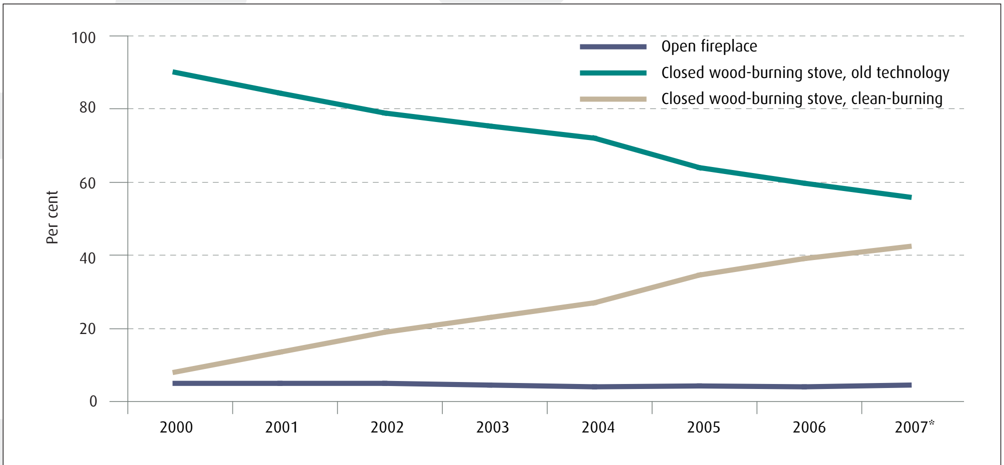

Figure 3.9 Wood consumption by type of wood-burning appliance.
Source: Statistics Norway

sions from burning oil and other stationary combustion, but a drop was also registered in emissions from industrial processes, according to preliminary calculations done by Statistics Norway (SSB) and the Norwegian Pollution Control Authority (SFT) in June 2008. Since 1990, emissions of SO_2 from stationary combustion have decreased by 55 per cent. This reduction can be ascribed to lower sulphur content in oil products and lower con-

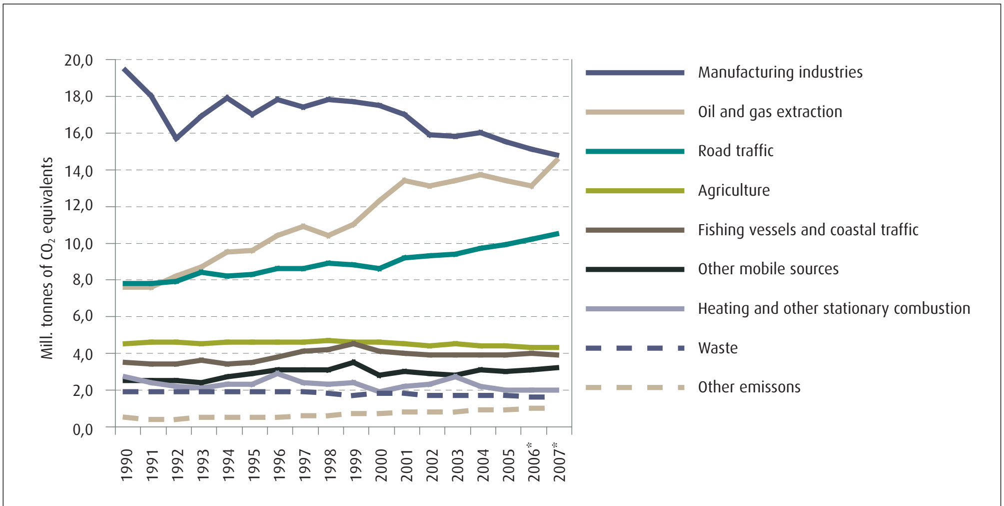

Figure 3.10 Emissions of greenhouse gases by source.
Source: Emissions accounts by Statistics Norway and the Norwegian Pollution Control Authority

Table 3-1 Emissions of CO_2, NO_x and SO_2 in 2006.
Source: Statistics Norway

	CO_2 1000 tonnes	SO_2 tonnes	NO_x tonnes
Emissions to air	43278	20939	190755
Stationary combustion	19140	5772	54178
Process emissions	7610	10863	8400
Mobile combustion	16527	4304	128177

sumption of oil. Figures from the emissions accounts compiled by Statistics Norway and the Norwegian Pollution Control Authority show that 54,600 tonnes of sulphur dust (PM10) were emitted in 2006. 62 per cent, or 33,700 tonnes, of this come from wood burning, including in holiday homes.

The total emission of greenhouse gases from heating and other stationary combustion was just under 2 million tonnes of CO_2 equivalents in 2007, and has remained at roughly the same level since 1990 (see figure 3.10). This corresponds to approximately 3 per cent of Norway's total emission of greenhouse gases in 2007.

Norway has undertaken a number of international commitments to reduce emissions of CO_2, NO_x, nmVOC and SO_2.

Global climate pollution is regulated internationally by the UN Climate Convention. Norway has committed itself to an emission cap whereby average emissions for the years 2008–2012 shall not increase by more than 1 per cent compared to the emission level in 1990. Relative to current levels, this implies a reduction of approximately 8 per cent. The obligation can be met through national reductions and in other countries by the use of the Kyoto mechanisms (international emissions trading, the clean developement mechanism and joint implementation). Norwegian climate policy is discussed in more detail in Report no. 34 (2006–2007) to the Storting on Norwegian Climate Policy.

Emissions that result in regional environmental consequences are regulated in various protocols under the Convention on Long-range Transboundary Air Pollution (LRTAP Convention 1979). Together with the US, Canada and other European countries, Norway signed the Gothenburg Protocol in 1999, which aims to solve the environmental problems of acidification, eutrophication and ground-level ozone. The Gothenburg protocol came into effect on 17 May 2005 and is currently the latest protocol under the LRTAP Convention. The Protocol is discussed in more detail in Report no. 26 (2006–2007) to the Storting on environmental policy and the state of the environment).

3.3.2 Instruments to limit emissions of pollutants and greenhouse gases

Extensive measures have been initiated to limit emissions of pollutants and greenhouse gases. At present, taxes are levied on about 68 per cent of Norway's CO_2 emissions. Mineral oils (including paraffin, light and heavy heating oil and autodiesel), petrol and coke are subject to CO_2 tax. The different mineral products are taxed at different rates. The CO_2 tax on mineral oil in 2008 is NOK 0.55 per litre, corresponding to NOK 207 per tonne of

CO_2 for light heating oil, and NOK 175 per tonne of CO_2 for heavy heating oils. CO_2 tax on domestic consumption of natural gas was NOK 0.47 per Sm^3 for natural gas and NOK 0.60 kroner per kilogram for LPG in 2007. This is equivalent to roughly NOK 200 per tonne of CO_2.

To reduce emissions of greenhouse gases, a national carbon quota trading system has been introduced, in addition to the CO_2 tax. The purpose of the law is to limit emissions of greenhouse gases in a cost-efficient way, through a system of quotas for the emission of CO_2 and freely tradable emissions quotas. From 2008, the Norwegian quota trading system includes emissions of CO_2 that are subject to the mandatory quotas pursuant to the European quota directive, (see Proposition no. 66 (2006–2007) to the Odelsting on the Act to amend the Greenhouse Gas Emission Trading Act, etc). The Norwegian quota trading system is being linked up to the EU quota system, and the quota directive has been included in the EEA Agreement, and is thus more extensive than the quota system that was in use in the period 2005 to 2007. The extended quota system entails that sources of emissions that are currently subject to CO_2 tax will be subject to quota trading. These are the use of mineral oils in the pulp and paper industry and in energy plants larger than 20 MW, and emissions in the oil and gas sector. For a more detailed presentation of the CO_2 tax, see Proposition no. 1 (2008–2009) to the Storting 'Decisions on taxes and customs'.

The sulphur tax on mineral products was introduced in 1970. This environmental tax is intended to help reduce sulphur emissions. The sulphur tax is levied on mineral oil. Mineral oil includes paraffin, heating paraffin, gas oil, diesel oil and heating oil. Sulphur tax was NOK 0.07 per litre for each 0.25 per cent of sulphur content by weight in oil with a sulphur content of 0.05 per cent by weight in 2007. This corresponds to about NOK 17 per kilogram of SO_2. Sulphur tax is not levied on oil with a sulphur content of 0.05 per cent by weight or less. The scheme has resulted in the sulphur content of a number of product categories being reduced to less than 0.05 per cent by weight in order to avoid the tax. Sulphur tax can also be wholly or partly refunded if it can be documented that the sulphur has been wholly or partly removed.

NO_x emissions vary widely with combustion technology and fuel. Large emission sources must have a discharge permit under the Pollution Control Act. In autumn 2006, the Storting decided to introduce a tax on NO_x emissions from 1 January 2007, at a rate of NOK 15 kroner per kilogramme of NO_x. It applies to ships, fishing vessels, aviation and diesel-powered trains, and engines, boilers and turbines in industrial power stations. Only large units (defined as having a capacity of more than 10 MW for heating boilers) are subject to this tax. Enterprises subject to this tax that enter into an agreement with the State on concrete targets for NO_x reductions are exempt from this tax.

Emissions of particulate matter can be reduced by treating flue gases. At present, only large incineration plants are required to reduce emissions of PM_{10} under the Pollution Control Act.

No such requirements apply to emissions from small heating systems, but their users can be held financially responsible under the regulations on local air quality for their contribution to poor air quality. Nowadays, all newly installed wood-burning furnaces/stoves in dwellings must be clean-burning. Problems related to high concentrations of particulate matter in the air are greatest in cities.

Various methods of capturing CO_2

CO_2 can be removed in three different ways: CO_2 is captured after combustion in the power station (post-combustion, illustrated in figure 3.11); CO_2 is captured before combustion in the power station (pre-combustion); or natural gas burns in the gas turbine in an atmosphere of pure oxygen (oxy-fuel). Post-combustion is the easiest method, it can be done independently from the power station. A post-combustion capturing facility takes up a lot of space; for example, a carbon capture facility for a gas-fired power plant of 420 MW would cover 10–12,000 m^2. The pre-combustion method converts the natural gas or coal into a synthesis gas consisting of carbon monoxide and hydrogen. CO is then transformed into CO_2 using steam and heat, which is then captured by means of absorption, while the hydrogen is fired in the gas turbine. This kind of facility would be smaller and cheaper than a post-combustion unit, but burning hydrogen at high temperatures is always challenging. This method is pertinent when the operator wants to produce power *and* hydrogen, for example, for transport purposes. The third method (the oxy-fuel method) separates oxygen from the air mixed in with the natural gas in the gas turbines. This results in nearly clean combustion, where the flue gas comprises CO_2 and water vapour. However, this process is energy-intensive and expensive. The oxy-fuel method is also currently a very immature technology and will not be ready for the market for several years.

3.3.3 Carbon capture and storage as a means of reducing CO_2 emissions

Power generation and other uses of fossil energy are the main source of emissions of greenhouse gases globally. Development of technology for carbon capture and storage (CCS), especially from coal-fired power stations, stands out as an important means of reducing global emissions and has been the focus of much international attention for many years now. Norway, the EU, the US and Japan are all working on plans for carbon management projects of various types and sizes. The International Energy Agency claims in its report 'Energy Technology Perspectives' (2008) that storing CO_2 may provide between 10 and 19 per cent of the emissions reductions in 2025. However, the CCS technology still requires further development, and we have little experience with capturing carbon from large coal-fired and gas fired power stations. Norwegian research and development has been a forerunner in this area for a number of years , and the State has given high priority to work on establishing CCS as an acceptable and attractive measure to curb climate change.

Capture, transport and storage of CO_2

Carbon capture is the process of removing carbon dioxide from exhaust or fuel. There are three ways of capturing CO_2 based on different principles (see box 3. 1). In all cases, carbon capture requires a lot of energy. The Intergovernmental Panel on Climate Change (IPCC) estimates in its report 'Carbon Dioxide Capture and Storage' (2005) that if 90 per cent of the CO_2 from a power station is captured, electricity consumption will increase by 11–40 per cent, depending on the technology and fuel. At the same time, the costs of power generation with carbon processing would increase by somewhere between 20 and 85 per cent. However, the climate report also claims that if the current level of research and development is maintained, the costs of capturing carbon may well be reduced by 20–30 per cent over the next ten years. Norway's

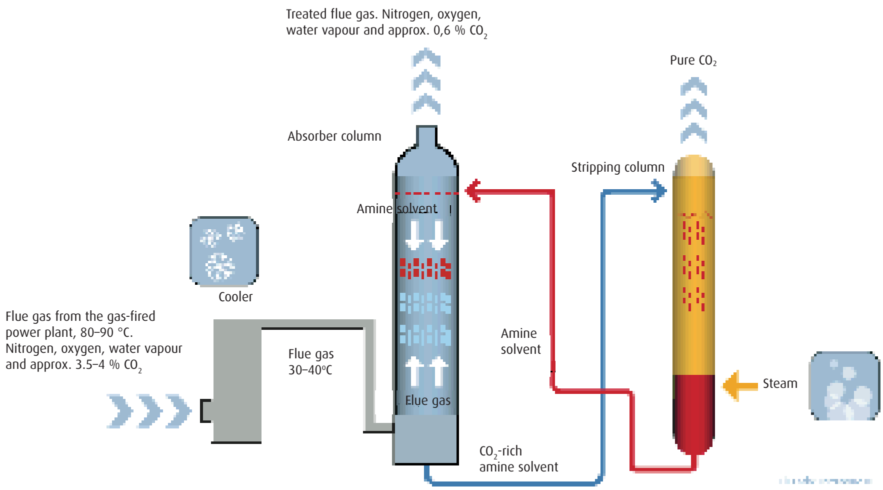

Figure 3.11 Illustration of post-combustion.
Source: Gassnova

projects may therefore contribute to technological developments that result in more energy-efficient and cost-effective facilities.

Once it has been captured, the CO_2 must be transported from the source to a geological structure for storage. The carbon dioxide can be transported by pipeline or ship. The method of transportation depends on the needs and circumstances in the individual case, including the number of sources of emissions, the size of the emissions from each source, the distance from the source to the storage site and the volume of CO_2 being transported. Transportation by pipeline is usually the simplest option, with clear economies of scale.

Norway has long experience with CO_2 storage in geological structures. Since 1996, approximately 1 million tonnes of CO_2 a year have been separated out during gas production at Sleipner Vest in the North Sea and stored at Utsira in a geological formation 1,000 metres below the seabed. $C0_2$ storage was also started at Melkøya in Hammerfest in spring 2008, in connection with the production of liquefied natural gas (LNG). The plan is that 700,000 tonnes CO_2 will be separated out and stored in a reservoir 2,600 metres below the seabed. There is vast technical potential for storing CO_2 in geological formations around the world. Current and old oil and gas fields, and other formations are suitable for such storage. Storage in abandoned reservoirs is a geologically sound solution because the structures are most probably impervious, since they have already held oil and gas for millions of years. Other formations may also be deemed safe for storage of CO_2. The international SACS project (Saline Aquifer CO_2 Storage) has documented that that there has been no leak of CO_2 from the Sleipner field that was pumped down into the enormous Utsira formation. The probability of a leak from geological storage is deemed to be very small. The IPCC report concludes that if storage is effec-

tuated in a proper manner, it is highly probable (90–99 per cent probability) that more than 99 per cent of the stored CO_2 will still be present 100 years later. After 1,000 years, it is probable (66–90 per cent probability) that more than 90 per cent will still be present.

CCS projects

The Government has initiated several projects to realise the deployment of CCS technology in Norway: The test center project at Mongstad and the full-scale CO_2 capture facilities at Kårstø and Mongstad. Also, the Government is working at establishing a CO_2 transport and storage solution from the two power plants.

In 2006, the State and StatoilHydro entered into an agreement on development of CCS at Mongstad as a two-part undertaking: A test centre for CO_2 capture (Test Centre Mongstad (TCM)), scheduled to start up around 2011, and full-scale CCS in connection with the combined heat and power plant at Mongstad by the end of 2014. The purpose of the CO_2 capture test centre is to develop and test new CCS technology that may be able to reduce costs and risks linked to building and operating full-scale CO_2 capture facilities and also encourage widespread use of this kind of technology. The results of the work at TCM will be important internationally for future carbon capture facilities. The State's involvement in the test centre for CO_2 capture at Mongstad was approved by the EFTA Surveillance Authority (ESA) in summer 2008.

The next step is for the State and StatoilHydro to work together on full-scale CCS at Mongstad. StatoilHydro has committed to developing a general plan for future carbon capture at Mongstad. It is expected that full scale carbon capture at Mongstad may have a major long-term impact on reducing CO_2 emissions from Norway's largest emission source. It will also create an arena for bespoke testing and development of technology for carbon capture and help create a stronger supplier market.

The Government has also decided to build a full-scale carbon capture facility at the gas-fired power plant at Kårstø. This facility will capture around 1 million tonnes CO_2 a year, which will then be transported for safe storage in geological formation under the seabed. The basis for the investment decision is due to be presented to the Ministry of Petroleum and Energy in autumn 2009. Prior to this, strategic choices concerning the fundamental technology will be made and the technology must be qualified. The carbon capture facility at Kårstø will be ten times larger than what exists in the world today.

The State is also responsible for establishing a transport and storage solution for CO_2 from Mongstad and Kårstø. To this end, the Ministry of Petroleum and Energy has initiated a project to assess possible transport and storage solutions for CO_2 from Mongstad and other sources of emissions in terms of storage and injection volume. Gassnova is collaborating with Gassco and the Norwegian Petroleum Directorate to identify and map the transport and storage options for CO_2 from Kårstø and Mongstad. In 2008, seismic surveys and studies of the reservoirs' suitability are being carried out.

See Chapter 8 for an overview of Norway's participation in international collaboration on CCS.

3.4 More on Enova SF and management of the Energy Fund

Enova was set up by the Royal Decree of 1 June 2001, and came into effect on 22 June 2001. The Royal Decree is based on the Storting's decision of 5 April 2001 to adopt the Government's proposal for a new financing model and reorganisation of the work on restructuring energy use and energy production as specified in Report no. 29 (1998–1999) to the Storting on Norwegian energy policy. In its processing of the report, the Storting expressed a wish for more efficient management of the funds and more measurable results than previously. It resulted in amendment of the Energy Act (see Proposition to the Odelsting no. 35 (2000–2001)), where the Ministry of Petroleum and Energy established an energy fund and a new state-owned company (Enova) to manage the funds.

From 1 January 2002, responsibility for allocation of financial support to new renewable energy production was moved from the Norwegian Water Resources and Energy Directorate (NVE) to Enova. At the same time, the grid companies' statutory energy conservation activities were terminated, and responsibility for a nationwide information and advice service was transferred to Enova.

Enova's responsibilities are specified in the agreement between the Ministry of Petroleum and Energy and Enova SF. The agreement defines the goals for Enova's activity, its responsibilities, system requirements and reporting requirements. The current agreement is valid from 1 June 2008 to 31 December 2011.

The Ministry of Petroleum and Energy emphasises that Enova is to find practical solutions and manage the funds in a way that ensures that the energy policy goals are achieved in the most cost-efficient way possible.

The Energy Fund is currently financed by a grid tariff supplement of NOK 0.01/kWh and by the yield from the Basic Fund for Renewable Energy and Energy Efficiency (the Basic Fund). The Basic Fund was established in 2007 with an investment of NOK 10 billion. In 2008, the fund will also have a grant authorisation of NOK 400 million and an allocation in the national budget of NOK 200 million. This means the Energy Fund will receive a total income in of roughly NOK 1,450 million.

In addition to the Energy fund, Enova has managed grants for the construction of a natural gas infrastructure since 2004. The grants are structured as PSO contracts (Public Service Obligations). Funds are granted via the national budget. In 2007, contracts were signed for four projects that together can provide the foundation for gas sales of 970 GWh per year, once the facilities are in full operation. A total of NOK 57 million was allocated, which represented the entire framework sum.

3.4.1 Goals for Enova's activities

The goals for the management of the Energy Fund are defined as follows in the agreement between the Ministry of Petroleum and Energy and Enova:

The funds should contribute to increased generation of heat and energy from renewable sources and more energy saving equivalent to minimum 18 TWh by the end of 2011. Use of the funds must be considered in a long-term perspective with a working target of 40 TWh by the end of 2020. By the end of 2010:

- minimum 3 TWh must be from increased production of wind power, and
- minimum 4 TWh must be from increased access to water-borne heat based on new renewable energy sources, heat pumps and waste heat.

Based on this goal structure, Enova has directed its activity towards the following main areas: energy use and generation. Within these two areas, Enova operates with the subareas housing, construction, industry and households, children and young people, and heating, natural gas, renewable energy and new technology. Enova is also responsible for administering Norway's participation in the European programme 'Intelligent Energy – Europe' for the Ministry of Petroleum and Energy.

3.4.2 Heating

Enova works to establish new heating plants, distribution systems for heating and stable supplies of biofuel. Enova provides economic support to projects within development of heating plants and distribution systems.

In 2007, Enova commissioned a study of the potential of expected developments of district heating and bio-based local heating plants until 2020 (Xrgia). Given that in the future all new buildings are built with water-borne heating systems, it may be possible to establish 7.5 TWh of renewable heating by 2020 without government funding. On the basis of this report, Enova has developed three new support programmes for heating: establishment of local energy systems, development of new district heating and development of infrastructure for district heating. The purpose of these programmes is to tap into the potential identified in the study.

3.4.3 Wind power

Wind power is the renewable energy source that has received most investment and the one closest to becoming commercially viable. Investment grants represent the most important policy instrument in this context. Investment grants for wind power stations are only awarded to facilities that have been granted a licence. The grant from Enova is allocated after being applied for by the developer and an individual profitability evaluation of the project.

3.4.4 Energy conservation

Energy conservation provided 1.2 TWh of the energy result in 2007, of which 814 GWh was generated through Enova's industry programme and 365 GWh was generated through the housing and construction programme.

Enova's work on energy-saving measures and increasing energy efficiency are linked to its information and advice activities and to ordinary support measures within central industries where the potential and motivation for improving energy efficiency is large. Support from Enova obliges grant recipients to carry out activities (analyses, mapping savings potential, etc.) or introduce new efficient energy technologies.

More information on the project can be found on Enova's web site at www.enova.no. Enova has also established a telephone service that provides free information on energy conservation and consumption: 800 49 003.

3.4.5 Results from Enova's work

Enova reports results from the allocation of grants to projects in the form of contractual or realised energy results. The results are prepared by adding up the energy amounts in the contracts Enova enters into with players who have been allocated funds for projects. The projects included in the result reporting are therefore not necessarily completed in the course of the year in which they are reported in. Several of the projects are so big that they run over several years.

Since its establishment in 2001, Enova has supported projects with contractual reductions of 10.1 TWh. Improvements in energy efficiency in buildings and industry account for roughly 50 per cent of the results so far. The result for 2007 was 2.4 TWh in saved and generated new renewable energy. The results are distributed among the main areas as shown in table 3.2.

Table 3-2 Enova's contractual energy results (corrected for reported actual results) by areas.
Source: Enova

Area	Energy results 2001–2007. GWh.
Wind power	1 553
Renewable thermal energy	2 552
Biofuel refinement	978
Buildings, housing and construction	2 064
Industry	2 835
New technology	80
Households	10
TOTAL	**10 072**