2

Electricity generation

- Hydropower
- Wind power
- Gas-fired power
- Other forms of electricity generation
- Taxes and fees in the power sector
- The role of the electricity supply sector in the Norwegian economy

Electricity production in 2005 was 138 TWh, the highest since 2000 due to abnormally high levels of precipitation. Power production in a normal year in Norway is estimated to be 121 TWh, including wind, hydropower and thermal power. Hydropower accounts for around 99 per cent of production.

2.1 Hydropower

Norway's river systems are very important both for commercial interests and for public interest generally – in connection with outdoor recreation, for instance. Electricity generation is the most important commercial use of Norwegian river systems.

A river system comprises a river and all its tributaries from source to sea, including any lakes, snowfields and glaciers in the catchment area. There are about 4 000 river systems in Norway. In some counties, almost all the larger rivers have been developed. Seven of Norway's 10 highest waterfalls have been developed, and the remaining three are permanently protected against such developments. See table 2.1. To increase electricity output, water is commonly transferred from one part of a river system to another or even between neighbouring river systems. In many cases, several power stations have been built in the same river system.

Great variations in topography, precipitation and climate in Norway mean that its river systems include a wide range of types. Rivers in western Norway, Nordland county and parts of Troms county are generally short and steep, with many waterfalls, while eastern Norway, the Trøndelag region and Finnmark county have much longer systems which carry a large water volume but drop more gently to the sea.

Volume and head of water determine the potential energy of a waterfall. The head of water is the height difference between reservoir intake and power station outlet. Water is directed into pressure shafts leading down to a power station, where it strikes the turbine runner at high pressure. The kinetic energy of the water is transmitted via the propeller shaft to a generator, which converts it into electrical energy.

Low-head power stations often utilise a large water volume but have a small

Table 2.1 Norway's highest waterfalls (vertical head)

Waterfall	Height (m)	Phase	Licensed/protected
Tyssestrengen	300	Built	1964 Tyssefaldene A/S
Ringdalsfossen	300	Built	1964 Tyssefaldene A/S
Skykkjedalsfossen	300	Built	1973 Statkraft
Vettisfossen	275	Permanently protected	1923 Natural Environment Protection Act
Austerkrokfossen	256	Built	1966 Elektrokjemisk A/S
Søre Mardalsfossen	250	Built	1973 Statkraft
Storhoggfossen i Ulla	210	Built	1973 Statkraft
Vedalsfossen	200	Permanently protected	1980 Protection plan II
Feigefossen	200	Permanently protected	1986 Protection plan III
Glutrefossen	171	Partly built	1973 Statkraft

Source: Watercourse Act Committe

head, as in a run-of-river power station. Since regulating the flow of water is difficult, it is generally used as and when available. The amount of electricity generated therefore rises considerably when the river is carrying more water during the spring thaw or when precipitation is very high. Most run-of-river power stations are situated in lowland areas, particularly in eastern Norway and Trøndelag. Several run-of-river power stations stand along the Glomma river. Solbergfoss power station at Askim in Akershus county has the largest low-head turbine in Norway.

High-head power stations are generally constructed to utilise a large head but smaller volume of water than run-of-river installations. Many of this type of power stations store water in reservoirs and are referred to as power stations with reservoirs. The reservoirs allow water to be retained in flood periods and be released in drought periods, typically in the winter. Reservoirs allow a larger proportion of runoff to be used in power production. They usually have a larger installed capacity than run-of-river stations, but a shorter utilisation period. High-head power stations are often excavated near the reservoirs used to regulate the volume of its water supply. Power station and reservoirs are connected by tunnels through the rock or pipes down the mountainside.

Power stations with an installed capacity of up to 10 MW are designated as small, and usually sub-divided into the following categories:

- micro (installed capacity below 0.1 MW)
- mini (installed capacity from 0.1-1 MW)
- small (installed capacity from 1-10 MW)

Small power stations are often installed on streams and small rivers without regulation reservoirs. Their output will then vary with the level of water flow.

2.1.1 Water inflow

Water inflow is the volume of water flowing from the entire catchment area of a river system into the reservoirs. A catchment area is the geographical area which collects the precipitation which runs into a particular river system. Useful inflow is the amount of water which can be used for hydropower generation.

Precipitation levels vary from one

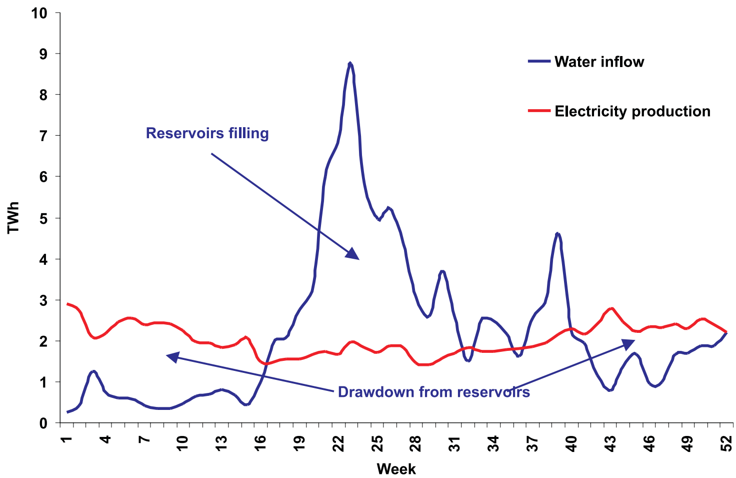

Figure 2.1 Variations in water inflow and electricity output during a year
Source: Nord Pool

part of the country to another, between seasons, and between years. Precipitation is highest in coastal and central parts of western Norway. There is also a clear tendency for precipitation to increase with elevation above sea level. Mean annual precipitation is lowest in the upper Otta valley (300 mm) and in inland parts of Finnmark county (mean annual precipitation 250- 300 mm). The mean annual precipitation in much of western Norway is 3,000-3,500 mm.

Inflow is high during the spring thaw, but normally decreases during summer. High rainfall generally results in an increase before the onset of winter, when inflow is normally very low. It also varies during the year, depending on local geographical and climatic conditions. The spring thaw is later in inland regions and in the mountains than near the coast and in lowland areas. In much of lowland eastern Norway, western Norway and Trøndelag, the rivers run highest during May. The highest water levels near the coast occur at the end of April, but are delayed until June or July in inland and upland regions. In northern Norway, discharge volumes reach a peak in June, or somewhat earlier in coastal areas.

Precipitation varies substantially from year to year and is more than twice as high in the wettest years as in the driest ones.

From 1980 and 1993, precipitation in several years was high and ensured high water inflow for power generation. There was relatively little precipitation in 1993 and 1994, while inflow in 1995 was very high. Inflow was considerably below normal levels in 1996. Inflow was relatively high in the period 1996-2000, particularly in 2000. Inflow in both 2002 and 2003 was below the normal level. However, variations through the year were considerable in 2002. From January-July, inflow was 89 TWh or 12 TWh above the normal level. However, the autumn was unusually dry with very low inflow. It was no more than 22 TWh, or 19 TWh below normal. Inflow was very high in 2005. Total utilisable inflow was around 140 TWh. This was 22 TWh more than the average for 1970–1999. Variations in actual power generation from year to year over the past decade can be attributed primarily to differences in inflow, as generating capacity increased very little.

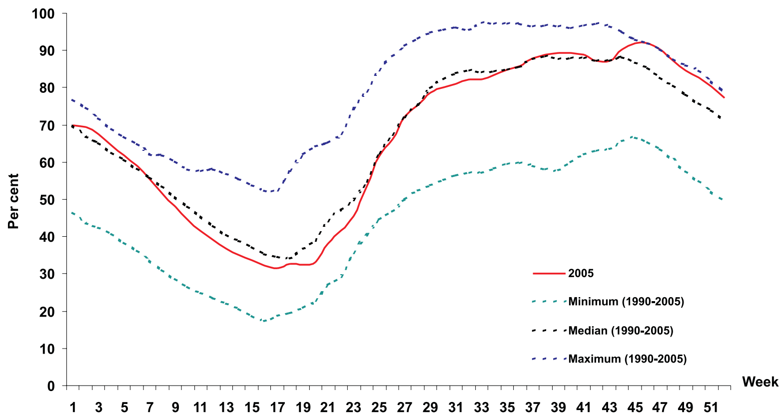

Figure 2.2 Reservoir filling 2005
Source: Norwegian Water Resources and Energy Directorate

In addition to variations in inflow, electricity demand fluctuates over the year and is much higher in winter than in summer. In fact, the pattern of demand – and thus the amount which must be generated – is generally the reverse of inflow variations. When inflow is high, output is often low – and vice versa. Figure 2.1 shows the relationship between mean output and useful inflow over a year. Consumption can also vary considerably between years because temperature changes affect the amount of electricity needed for heating.

2.1.2 Regulation reservoirs

The potential energy of water can be stored in regulation reservoirs constructed either in natural lakes or in artificial basins created by damming a river. Water is collected in the regulation reservoirs when inflow is high and consumption low. When inflow is low and consumption high, stored water can be drawn from the reservoirs and used to generate electricity. Regulation reservoirs are generally situated in sparsely populated areas, and usually at high altitudes in the mountains in order to make the fullest possible use of the head of water. The difference between the highest and lowest permitted water levels in a reservoir is stipulated in a watercourse regulation licence (rules for reservoir drawdown), which takes into account such factors as topography and environmental considerations.

Storing water in the summer for use in winter months, when the demand for power peaks, is known as seasonal regulation.

Dry- or multi-year regulation is made possible by large reservoirs which can store water in wet years for use in years when precipitation is low. Short-term regulation involves a daily or weekly filling and emptying cycle.

Power and capability balance

In a power market, there must always be a balance between the power supplied to the power grid (power availability) and the power withdrawn (consumption).

The domestic power balance is defined as being the relationship between annual production and total annual consumption of power. When evaluating the power balance, the relationship between consumption and normal year production (production in a year with normal precipitation) is often focussed on.

Where inflow to domestic hydropower plants is high, domestic production is often greater than consumption. The situation will be the reverse in years with low inflow. Transmission links with other countries reduces the dependence of consumption on domestic production.

The capability balance represents the balance between availability and utilisation of power at a specific point in time. The development of the power balance and the capability balance are interlinked. A gradual tightening of the power balance due to little new production capacity availability increases the risk of a short term over demand situation.

New power consumption (withdrawal) records have been continuously set in the last few years, without an increase in production and transmission capacity. This means that the power balance is developing tighter margins. The last record was set on the morning of 5 February 2001. The consumption maximum was 23,054 MW between 9 and 10 am.

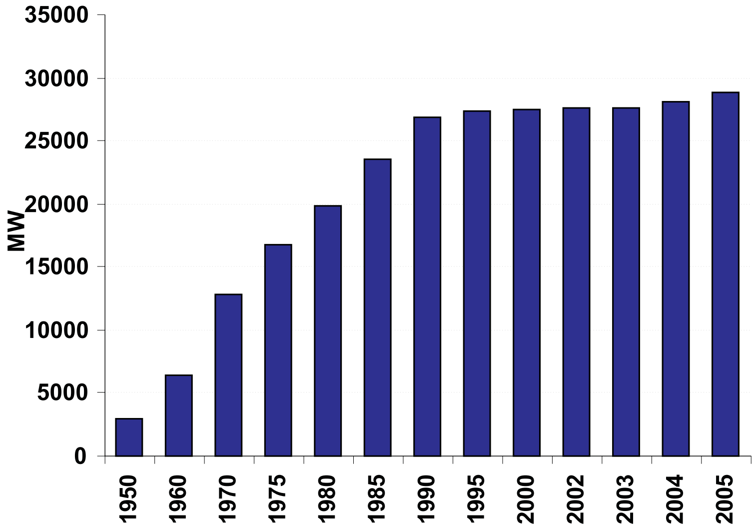

Figure 2.3 Installed capacity
Source: Norwegian Water Resources and Energy Directorate and Stastistics Norway

A reservoir's energy capability is the amount of power which can be generated when it is full. An upper and lower regulation limit is usually set for reservoirs. Since 1980, the energy capability of Norway's reservoirs has risen by just over 29 TWh. At the start of 2006, total energy capability was about 84.3 TWh, which is equivalent to around two-thirds of the annual electricity consumption. The degree of filling of the reservoirs is a measure of how much water (potential energy) they contain at any given time. Figure 2.2 shows changes in the degree of filling during 2005, and the minimum, median and maximum degree of filling in the 1990–2005 period, expressed as a percentage of the total energy capability of the reservoirs.

Table 2.2 The 10 largest power stations in Norway at 1 January 2006.

Power Station	County	Max capacity MW	Average annual production GWh/year
Kvilldal	Rogaland	1 240	3 517
Tonstad	Vest-Agder	960	4 169
Aurland I	Sogn og Fjordane	675	2 407
Saurdal*	Rogaland	640	1 291
Sy-Sima	Hordaland	620	2 075
Rana	Nordland	500	2 123
Lang-Sima	Hordaland	500	1 329
Tokke	Telemark	430	2 221
Tyin	Sogn og Fjordane	374	1 398
Svartisen	Nordland	350	1 996

** Pump fed power station*

Source: Norwegian Water Resources and Energy Directorate

Normally, water will be drawn off during the autumn and winter when electricity demand is highest. Demand reaches its lowest level in spring and summer, and the reservoirs refill. Changes in the degree of filling of the reservoirs reflect variations in electricity generation and water inflow during the year.

An economic gain can be obtained by pumping water uphill to a reservoir with a greater head of water, because the potential energy of water increases in proportion to its head. If electricity prices are low, it may be profitable for operators to use power to move water to a reservoir at a higher altitude, so that the water can be used for generation when prices rise again.

2.1.3 Electricity generation

Norway now has a total installed capacity of about 28 300 MW at 620 hydropower stations larger than 1 MW. In addition to this, 255 MW is supplied from thermal plants[2] and 280 MW from wind power stations. The mean annual generating capability of a hydropower station is calculated from its installed capacity and the expected annual inflow in a year of normal precipitation. Thirty years is the standard period used to calculate normal values for meteorological and hydrological variables. Generation from the Norwegian electricity system – hydro, wind and thermal power – in a normal year is now calculated to be about 121 TWh.

The largest hydropower development projects were carried out between 1970 and 1985, when installed capacity increased by 10 730 MW, or an average of 4.1 per cent per year. Towards the end of the 1980s, Norway's rate of hydropower development declined. Since the beginning of the 1990s, addition of new production capacity has been consistently low. Capacity increased by 800 MW from 1993 to 2005. The increase in the 1990s was primarily due to refurbishment and upgrading of old power stations, which resulted in better utilization of existing power stations. A large proportion of the capacity increase in recent years has come from refurbishment and upgrading of hydropower stations. We however see that new wind power plants now account for an increasing proportion of this increase. Figure 2.3 shows the growth in installed capacity.

The 10 largest power stations in Norway account for about a quarter of the country's generating capacity. Statkraft SF is Norway's largest power producer providing around 30 per cent of total production capacity. Table 2.2 lists the 10 largest power stations in Norway at 1 January 2006.

Kvilldal power station in Rogaland county is Norway's largest, with a maximum generating capacity of 1 240 MW. This corresponds to about 4.5 per cent of the Norwegian total. Table 2.3 shows the numbers and installed capacity of hydroelectric power stations in various size groups at 1 January 2006.

Electricity output in western and southern Norway and in Nordland county exceeds local consumption. In eastern Norway, on the other hand, electricity consumption is much higher than the amount generated in the region. This means that power must be transmitted from western and northern regions to the south and east of the country.

The flow of electric power between regions of Norway is also influenced by power exchange with Denmark, Sweden and Finland. Current transmission capacity from Norway to its neighbours is about 4 000 MW. The connections are used for both import and export of power (see Chapter 7).

[2] Thermal power station is a general term used for power stations which produce electricity from fossil fuels, biofuels or nuclear power.

Installed capacity, mean output and utilisation period

The maximum power output (MW) of a hydroelectric power station increases in proportion to the product of the head of water and the water volume per unit time, but is limited by the installed machine capacity. The amount of electricity generated (MWh) in a given time period is equal to the product of the average power output and the time. For example, a power station which operates on average at an installed capacity of one MW for one year (8 760 hours) will generate 8 760 MWh (8.76 GWh).

Variations in water inflow and electricity consumption mean that a hydropower station does not operate continuously at maximum capacity. The average utilisation period for a power station is defined as the number of hours required to generate electricity equivalent to mean annual output when operating at maximum capacity. Thus, a power station with a mean annual inflow equivalent to 200 GWh and an installed capacity of 50 MW has a utilisation period of 4 000 hours. The average utilisation period for most Norwegian power stations is between 3 500 and 5 000 hours per year.

Power output was generally above average in the second half of the 1980s and the beginning of the 1990s because inflow was high. It was below the mean level in both 1996 and 1997. In the period 1998–2001, hydropower output was generally relatively high. Precipitation was above normal for several years in a row, with hydropower output high as a result. A new production record was set in 2000 at 143 TWh. Production in 2005 was almost 137 TWh. Figure 2.4 shows trends in mean annual generating capability and actual hydropower output in Norway from 1980 to 2005.

2.1.4 Hydropower potential

Norway's hydropower potential is the amount of energy in its river systems which is technically and financially available to generate electricity, and was calculated to be 205 TWh/year at 1 January 2006. These calculations are based on the 1970–99 reference period. Figure 2.5 shows hydropower production potential as at 1 January 2006.

Around 44.2 TWh/year of the total hydropower potential is located in protected watercourses. This potential is therefore not available for development. A potential of around 41.3 TWh/year is not protected and is available for development.

Table 2.3 Hydropower stations in operation as at 1 January 2006 by size and total installation*)

MW	Quantity	Total power, MW	Average annual production GWh/year
0 – 0.1	164	6	29
0.1 – 1	192	91	375
1 – 10	293	1 035	4 850
10 – 100	250	9 256	41 419
100 -	77	17 977	73 455

**) Power station less than 1 MW based on SKM's survey from 2000 with update from 2005. Quality control work is on going.*

Source: Norwegian Water Resources and Energy Directorate

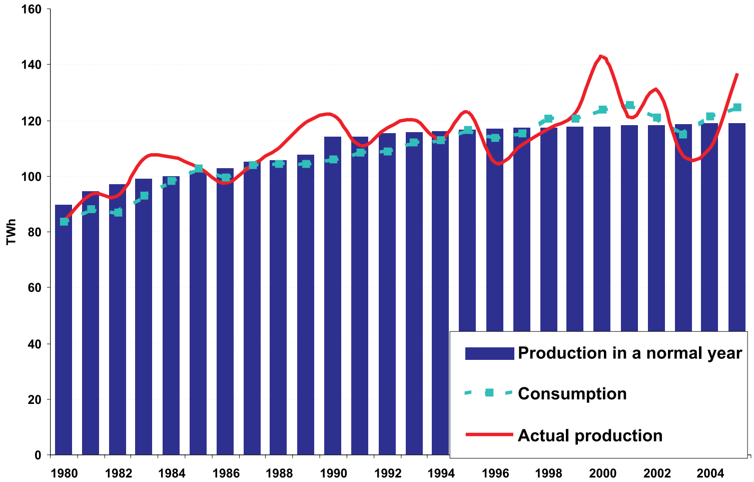

Figure 2.4 Trends in hydropower output and mean annual generating capability
Source: Norwegian Water Resources and Energy Directorate

As at 1 January 2006, the developed mean annual generating capability was 119.7 TWh. In addition, projects with a capacity of 1.3 TWh were under construction, and the development of a further 1 TWh had been licensed.

Most large hydropower projects were classified in the White Paper on a Management Plan for Water Resources. The various categories used in this Management Plan indicate the order in which river systems should be developed. Giving priority to the lowest-cost projects and those with the fewest conflicts of interest is considered important. The Management Plan is further discussed in Chapter 4.2.1.

Refurbishment of hydropower stations involves modernising them to use more of the potential energy of the water. In addition, operating costs can be reduced and operating reliability improved. The head loss can be reduced by widening water channels and increasing tunnel cross section, for instance. Utilisation rates can also be improved by using more modern turbine and generator technology.

Examples of upgrading are the transfer of water from other catchment areas, enlarging existing regulation reservoirs or constructing new ones, increasing the head of water or expanding technical installations to increase the available power output. Refurbishment combined with upgrading generally yields a bigger increase in electricity generation and better profitability than refurbishment alone.

Most refurbishment and upgrading projects are classified as category I in the Master Plan for Water Resources. Some fall into category II, while others are not dealt with in the Management Plan or were exempted from it.

Developers themselves take the initiative on new projects, and also bear the economic risk. The latter can be particularly high for hydropower developments because projects are very capital-intensive, the future price of electricity is uncertain, and their costs vary widely.

2.1.5 Small hydropower plants

Small hydropower plants include power plants with installed capabilities of up to 10 MW. These can in turn be subdivided into the following sub groups: micro power stations (installed capability up to 0.1 MW), mini power stations

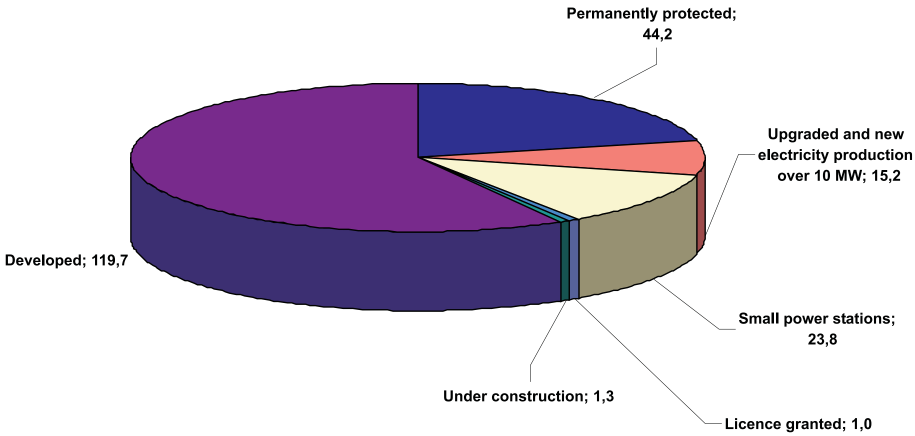

Figure 2.5 Norway's hydropower potential at 1 januar 2006, TWh/year
Source: Norwegian Water Resources and Energy Directorate

(installed power output up to 1 MW) and small power stations (installed capability up to 10 MW).

Conventional small power stations are not regulated and are therefore only handled in accordance with the Water Resources Act. Micro and mini power stations can have so little impact that they do not require a licence. The competence to issue licences to develop up to 10 MW installed capability has now been delegated to NVE, if the undertaking is only subject to the Water Resources Act. A power station with an installed capability of up to 10 MW is also exempted from the Management Plan for Water Resources. Parliament's processing of Royal Proposition no. 75 (2003-2004) on supplementing the protection plan for watercourses opened the possibility for licensing micro and mini power stations in protected watercourses.

NVE has mapped the nationwide small hydropower station resources and found that the potential is around 25 TWh. It is stressed that this is a theoretical potential. Environmental impact and other factors which reduce development opportunities are not taken into consideration. Licences were issued for 34 small hydropower stations in 2005, with a total production of around 490 GWh per year. A resolution on licence exemption for 70 smaller power stations with a total production of around 200 GWh was also passed.

The Ministry of Petroleum and Energy has prepared a strategy for increased small hydropower station development. This can be found on the ministry's webs site.

2.1.6 Environmental impact of hydropower development

Converting hydropower to electricity is a clean process. Hydropower in Norway accounts for 99 per cent of generated electricity. However, the development of river systems does have an environmental impact, directly in the form of land use and more indirectly in the fragmentation of areas of the natural environment and in the regulation of lakes. In addition to the actual generating installations, facilities such as access roads, quarries and rock tips are generally needed. Access roads tend to increase traffic and may result in changes to land use.

The interventions can reduce the experience of being in the countryside. At the same time, several of the older power stations are considered to be important cultural and industrial historical monuments.

Hydropower development and generation can have various impacts on the flora and fauna in and around river systems. Rapid changes in generation and therefore in water volumes discharged are characteristic outcomes. Changes in discharge volume can affect fish stocks and other freshwater organisms.

The environmental disadvantages, both the aesthetic impact on the landscape and the impact on biological diversity, are the main reasons why many watercourses are protected from power development as specified in chapter 4.2.1.

An application for a licence for power development in watercourses must pass through a comprehensive process. This includes a thorough review of the environmental impact. An application may be refused on environmental grounds. The authorities may also require measures to mitigate the impact of a development project to be implemented. Examples include requirements to establish a fund for stock enhancement or rules on the minimum permitted rate of flow if regulation harms fish and other flora or fauna in and around the watercourse. The legislative framework for hydropower developments is described in more detail in Chapter 4.

A licence to develop a watercourse which is protected by the protection plan can only be granted where the protected object is not harmed. Where the watercourse's unspoilt nature is the aspect being protected, a licence will not normally be granted. In general, only very careful development with limited water withdrawal will be permitted.

2.1.7 Norwegian expertise in the hydropower sector

Norway is the sixth largest hydropower generator in the world and the biggest in Europe. The Norwegian hydropower industry is more than a century old. During this period, Norway has developed expertise covering all stages of hydropower development, from planning and design to the delivery and installation of technical equipment. The authorities have in addition through almost 100 years of development, accumulated expertise in regulating and managing hydropower resources.

The companies within the supply industry, except contractors (construction), have a total annual sales of around NOK 8 billion. There are around 3,500 employed in these companies.

Norway has already developed a large proportion of the available hydropower potential. Norwegian industry has therefore and to an increasing extent competed for assignments in other countries. These include consultancy services within planning, design and engineering and the supply of turbines and electro-mechanical products. In addition, demand for Norwegian expertise in system operation and power market development is growing.

2.2 Wind power

A wind power station comprises one or more wind turbines and the necessary electrical installations. When several turbines are installed, it is often called a wind farm.

The wind turbine consists of tower, rotor and blades, and a turbine head containing a generator and control system. The turbine blades are driven by the wind in the same way as an aircraft

wing in motion provides lift to an aircraft. Energy is transmitted from the turbine via the propeller shaft to a generator inside the turbine head. The generator converts kinetic energy to electrical energy, which is then transmitted to transformers out on the network.

A modern wind turbine generates electricity when the wind speed at hub height reaches four to 25 metres per second (m/s) – from gentle breeze to storm. At wind speeds exceeding 25 m/s, the blades lock and the turbine shuts down. The available wind power is proportional to the cube of the wind speed. Energy production is therefore very dependent on wind conditions. In practice, a wind turbine utilises up to 40 per cent of the kinetic energy of the wind which passes across the blades. The maximum theoretical energy utilisation rate is about 60 per cent. Wind power is a variable energy source and unlike hydropower, cannot be regulated. Since such facilities necessarily operate when the wind is blowing, they can only cover part of electricity requirements.

The annual utilisation period for a wind turbine in Norway is expected to exceed 3 000 hours at favourable sites. In many places, the average annual wind speed over a year period is six to eight m/s at a height of 10 m above ground. The wind speed will typically be 10-20 per cent higher at the relevant operating height for wind turbines, depending on the local topography. See the box in section 2.1.3 for a more detailed explanation of the utilisation period.

At the beginning of 2006, 280 MW of wind power was installed in Norway, distributed across 138 turbines. This represents a production capacity of around 0.85 TWh, which is equivalent to the electricity consumption of around 40,000 households. NVE has, in addition, awarded licences to a further 10 projects, with a total installed capacity of around 840 MW. If all these projects come to fruition, total production capacity will be just over 3 TWh/year. 507 GWh was generated during 2005. This is almost a doubling on the previous year.

In Europe, significant investment is being made in wind power and other renewable energy, to reduce releases from electricity production and from non-renewable energy sources. The wind power industry has experienced significant growth. Global installed power has increased from 2,500 MW in 1992 to over 40,000 MW in 2004, which represents an annual growth of around 30 %. More than 75% of this capacity is installed in Europe.

Technology development and industrialisation within wind power production has increased unit performance and a reduction in investment costs per MW. Production costs are estimated to currently lie around NOK 0.30/kWh at sites with good wind conditions and where costs linked to the construction of the plant and associated infrastructure are moderate. Wind power development is today not commercially viable, and therefore continues to require some form of financial support.

Development of wind power plants and associated infrastructure can come into conflict with other business interests, such as tourism, reindeer husbandry and other interests such as military radar installations. These conflicts are evaluated in NVE's licence processing.

In Report No. 29 (1998-1999) to the parliament on Norwegian energy policy, a target of building wind power stations with a generating capacity of three TWh by 2010 was set. Refer also to chapter 3.4 on Enova SF.

2.2.1 Environmental impact of wind power developments

Wind power is a renewable energy source which does not result in the release of pollutants such as greenhouse gases or particles. Development of wind power and associated infrastructures however lead to land use changes and environmental impact. The environmental impact primarily

Table 2.4 Wind power production which as at 1 January 2006 is licensed but not on line.

	Power MW	Annual production GWh/year	Licence
Bessakerfjellet, Sør-Trøndelag	51	150	November 2004
Harbaksfjellet, Sør-Trøndelag	90	200	November 2004
Valsneset, Sør-Trøndelag	12	30	November 2004
Skallhalsen, Finmark	65	190	October 2004
Ytre Vikna, Nord-Trøndelag	249	870	October 2004
Høg-Jæren, Rogaland	80	260	September 2004
Gartefjellet, Finnmark	40	120	August 2003
Hundhammerfjellet 3, Nord-Trøndelag	45	160	February 2002
Kvitfjell, Troms	200	660	February 2001
Valsneset Teststasjon, Sør-Trøndelag	5,75	16	August 2001
TOTAL	837.75	2656	

Source: Norwegian Water Resources and Energy Directorate

relates to visual effects, changes to the landscape, animal life and flora. A wind power plant is often located in an open landscape near the coast, where wind resources are best. This position makes wind farms well exposed and visible in the landscape. A licence to build and operate a wind farm is granted for a period of 25 years. Wind park construction is a highly reversible intervention in the landscape.

The environmental consequences, which are revealed by a consequence report and associated consultative statements, will be included in the licence process. If the total environmental impact is shown to be considerable, the likelihood that the wind farm is granted a licence is reduced. Through the licence process, the intention is to arrive at counter measures which can reduce the negative impacts of wind farm construction.

2.3 Gas-fired power

The term 'gas-fired power station' is often used as a general designation for all facilities which use natural gas to generate electricity and possibly heat. Several types exist. One in which gas turbines generate all the electricity is known as a simple-cycle gas turbine station. Such facilities can be started up and closed down at short notice, and are therefore suitable for providing peak-load power. Running costs are relatively high. Plants of this type are currently found on fixed installations in the North Sea.

Electricity generation using gas turbines also produces heat. Combined-cycle gas turbine stations (CCGT) and cogeneration (combined heat and power – CHP) stations exploit this heat, making them considerably more efficient than simple-cycle gas turbine units. In CCGT stations, steam turbines are used to generate electricity from the waste heat given off by the gas turbines. Where used together, these turbines can give a net efficiency for electricity generation of up to 60 per cent.

A cogeneration facility produces both electricity and heat – for space heating, for example. Surplus heat from steam turbines or in gas turbine exhaust fumes is carried to a heat distribution system. A cogeneration plant produces less electricity than a CCGT plant for the same level of gas consumption. However, it converts a larger proportion of the energy content of the gas to usable energy (more than 80 per cent) in the form of both electricity and heat.

Norway generally has a limited potential for using heat from electricity generation. The district heating infrastructure is not as well developed in the large cities than in other European countries. A high concentration of users is required to make a district heating network or industrial utilisation of the heat profitable. However, cogeneration stations could be relevant for industrial applications in Norway.

A number of plans currently exist for building gas-fired power stations in Norway, and five projects have so far been licensed. Naturkraft AS has received licences for two gas fired facilities, Industrikraft Midt-Norge AS has received one licence and Statoil has received one licence in accordance with the Energy Act for an integrated gas-fired power plant at its Snøhvit gas liquefaction plant in northern Norway and a gas fired power plant at Tjeldbergodden. Both plants at Snøhvit LNG and Kårstø are under construction. The gas fired power plant CCGT at Kårstø is planned to have an installed capacity of about 420 MW, corresponding to an annual output of about 3.5 TWh. The plant is planned to come on line in the second half year of 2007. An application has also been submitted for a gas fired power plant at Mongstad and one in Hammerfest. NVE has in addition received an advance notification of two gas fired power projects in Grenland and Elnesvågen.

Energy requirements for the Snøhvit gas liquefaction project are to be met by an integrated gas-fired power station providing 215 MW of electricity and 167 MW of heat, which was licensed in 2003. An annual output of about 1.5 TWh is planned. The gas-fired power station is due to be completed before the Snøhvit gas liquefaction plant comes on stream in 2006, and is specially adapted to the energy requirements of the Snøhvit facility.

In accordance with the new Climate Quota Act, compulsory quotas apply to gas fired power stations. The three planned gas fired power stations which have been granted licences (Kollsnes, Kårstø and Skogn) will be allocated a quota if they are built before 2008. A CO_2 tax will be levied on the Snøhvit energy plant for the period under the previous Norwegian quota system.

Small quantities of electricity are generated by gas turbines at petroleum plants along the Norwegian coast. Some sites also produce small amounts of electricity using gas turbines and gas engines. Gas from the Grønmo landfill in Oslo is used to generate electricity, for instance.

2.3.1 Sequestration of CO_2

Research into separation and deposition (sequestration) of CO_2 from power stations is currently being pursued in the USA, Japan and Europe. CO_2 can be separated out either before or after being burnt for electricity generation, and several different technological concepts have been presented in recent years. The maturity of the various solutions varies. In some cases, substantial development work remains to be done, not least in relation to turbines. However, a common feature of these technologies is that the CO_2 reduction process is energy-intensive, and will therefore be expensive in comparison with other forms of power generation.

In the winter of 2006 the government implemented comprehensive work on establishing a value chain for CO_2. Appendix 2 reviews the government's work on the CO_2 chain and the challenges associated with this work.

2.4 Other forms of electricity generation

Production processes in many industrial companies generate waste heat which can be used to generate electricity. The opportunities for and costs of this vary from company to company, depending on process technologies and location.

A proportion of the heat generated in district heating plants can be used for power production, so called co-generation. About 155 GWh was generated in this way in 2004.

Total heating production was just over 1 TWh in 2005.

2.5 Taxes and fees in the power sector

Electricity consumption is subject to a consumption tax which is currently NOK 0.1005/kWh in 2006. This tax was NOK 0.0988/kWh in 2005 and NOK 0.0967 in 2004. The consumption tax added NOK 5.6 billion to the national treasury in 2005. Consumers in the county of Finnmark and some municipalities in the county of Nord-Troms are exempted from this tax. With effect

Just Catch

Gassnova has, in cooperation with Aker Kværner Engineering & Technology launched the Just Catch project for CO_2 capture technology from gas fired power stations. Gassnova provides financial support to the project. Aker Kværner Engineering & Technology is joined by the following leading Norwegian and international companies within the energy industry: Gassco, Fortum, Hydro, Lyse Energi, Petoro, Shell, Skagerak Energi, Statkraft, Statoil and Østfold Energi. GassTEK is involved as main supplier. The project's goal is to:

- Reduce technical and financial risk by building a full scale plant for CO_2 capture from gas fired power stations.
- Establish a cost efficient design for a demonstration plant for CO_2 capture based on technology which will be available in 2010.
- Develop descriptions, technical specifications and cost estimates for the recommended plant. The quality level and level of detail should be sufficient to form a basis for a decision on whether the project and the building of a demonstration plant should proceed.

The project should run for two years, have two phases and a total budget of NOK 32 million. Phase 1 consists of theoretical calculations, qualifications and verifications, development of technology and laboratory scale tests. These test can be carried out at research institutes such as Sintef or equivalent. The budget for phase 1 is NOK 18.5 million. Phase 2 includes testing of equipment and chemicals in a pilot plant, probably in the existing rig at Kårstø.

The selected technology in Just Catch is based on the absorption of CO_2 from gas fired power station exhaust in a chemical solution (amine). This is called post combustion technology.

The selected capture method in the Just Catch project has the following characteristics.

- Completely new technology elements are not required. The technology must however be developed to become cost efficient.
- The technology can be used and installed in the near future (2010).
- The method can be used in conventional gas fired power stations and can also be retro fitted to existing power stations and for industrial releases.
- Power production is not affected of the capture system.
- The biggest challenge are the exhaust's low CO_2 concentrations (3-4%), which requires the processing of large volumes of exhaust.
- Similar technology is in use to separate naturally occurring CO_2 from natural gas. This method is use by facilities such as the Sleipner platform, to clean and produce sales quality natural gas for the export market. The CO_2 cleaning process is also used industrially in the pre-treatment of LNG production.
- The method can also be adapted to coal fired power stations.

from 1 January 2004, the grid companies took over responsibility for collecting the tax. This job was previously discharged by the electricity suppliers via their invoicing. A new consumption tax system for industry was introduced on 1 July 2004 This system levies a tax on part of electricity consumption. The electricity tax is structured so that it follows the EU directive on tax on energy products (the Monti directive), in which power intensive industries are exempted from electricity taxes.

Activities at the state-owned Enova company are financed through an energy fund. The fund receives income from a grid tariff supplement of NOK 0.01 per kWh in 2006. Enova should take the initiative to promote more efficient energy consumption, the production of new renewable energy and the environmental use of natural gas as stated in the description of Enova in chapter 3.4.

VAT is charged on electricity at the standard rate of 25 per cent that is levied on other goods and services subject to this tax. Household customers in the Nordland, Troms and Finnmark counties are exempt from VAT on electricity.

As for other industries, a tax of 28 per cent is levied and paid to the state on profits earned by all power companies. A profitability independent natural resources tax of NOK 0.013/kWh paid to the municipality and county municipality is in addition levied on hydropower producers. Of this, NOK 0.011 is allocated to the local authority and NOK 0.002 to the county council. This ensures that local authorities and county councils have a minimum tax income level. The calculation base for the tax on natural resource extraction is determined for each power station, and is the average of the plant's total output of electricity in the income year and the six preceding years. The natural resource tax does not represent an additional financial burden to the companies, as it can be deducted from income tax and, in the event of a difference, can be carried forward with interest. A basic interest tax of 27 per cent is levied on hydropower producers that achieve returns that are greater than the normal return. As for other taxes, the basic interest tax contributes to a large proportion of the potential basic interest being included as public income. The municipality can also levy a property tax on the production plant. This is calculated primarily on a profitability basis intended to reflect the market value of the property. Property tax can also be levied on the distribution system. About NOK 3.8 billion was raised from natural resource and basic interest taxes in 2004.

Licence fees represent compensation for damage caused to districts in which water resources are exploited. They are also an instrument for allowing these districts to share in the financial return on hydropower development. Within specified maximum and minimum limits, fees are determined by assessment. This evaluation gives weight to such factors as the degree of environmental disturbance and the profitability of the development. As the licensing authority, NVE is entitled to adjust the licence fee every five years. Licence fees provided NOK 515 million to local authorities and NOK 125 million to central government in 2005.

Local authorities affected by hydroelectric development are also entitled to buy a proportion of the power generated. The licensee can be required to sell up to 10 per cent of the electricity generated to the local authorities concerned. If this exceeds general power consumption in the local authority, the county council is entitled to buy the surplus. The licensee can also be required to sell five per cent of the power generated to the central government, but the latter has not exercised this right so far. The price paid by the power recipient must correspond roughly to generating costs or the full cost of delivery. Today, there are two price setting regulations. For licences issued before 1959, the price is negotiated between the licensee and the municipality, limited to a maximum price. For licences issued after 1959, the price is set by the Ministry of Petroleum and Energy in accordance with full costs for a representative selection of power stations. The financial significance of the obligatory sale of power is equivalent to the difference between the price for the power in the market and the price for obligatory power including the input tax. Deliveries under these provisions total about 8.5 TWh/year.

2.6 The role of the electricity supply sector in the Norwegian economy

The gross product in the electricity supply sector in 2005 was NOK 37.7 billion, or roughly three per cent of gross domestic product for mainland Norway.

Real capital in the electricity supply system amounted to NOK 190 billion in 2005, corresponding to 5.3 per cent of fixed real capital in mainland Norway.

Investment in the power supply sector totalled about NOK 9 billion in 2005. Figure 2.6 shows the development of gross investment in electricity supply since 1980. Net investment in the sector fell towards 2000, but has increased in recent years. Employment in the electricity supply sector rose steadily during the 1980s and stabilised after 1989. The number of people employed has declined in recent years. About 13 000 people worked in the electricity supply sector in 2005.

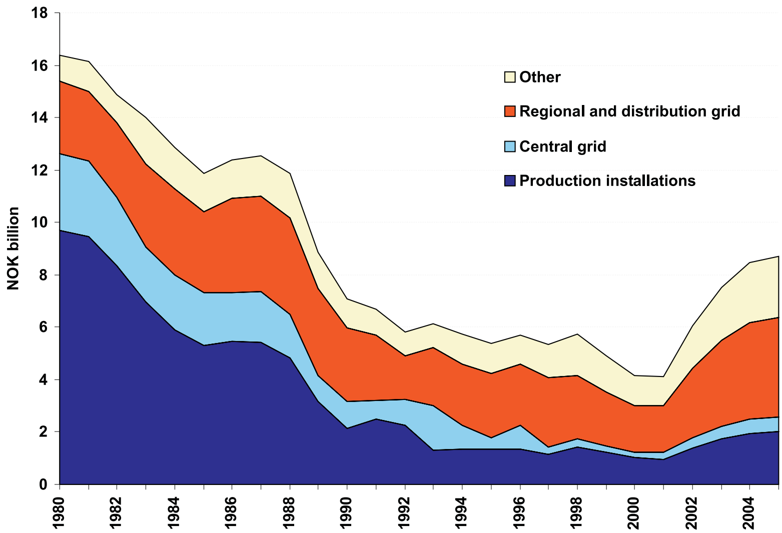

Figure 2.6 Gross investment in the electricity supply system. Fixed 2005 NOK
Source: Norwegian Water Resources and Energy Directorate and Ministry of Petroleum and Energy