Energy definitions, conversion factors and the theoretical energy content of various fuels

Energy units

Energy is defined as the capacity to do work.
The basic unit of energy is the joule (J).

1 MJ, megajoule	=	10^6 J	=	1 million J
1 GJ, gigajoule	=	10^9 J	=	1 billion J
1 TJ, terajoule	=	10^{12} J	=	1 1 000 billion J
1 PJ, petajoule	=	10^{15} J	=	1 million billion J
1 EJ, exajoule	=	10^{18} J	=	1 billion billion J

Other units used for electrical energy include:

1 kWh, kilowatt-hour	=	10^3 Wh	=	1 000 Wh
1 MWh, megawatt-hour	=	10^3 kWh	=	1 000 kWh
1 GWh, gigawatt-hour	=	10^6 kWh	=	1 million kWh
1 TWh, terawatt-hour	=	10^9 kWh	=	1 billion kWh

TWh can be converted to PJ by multiplying with 3.6.

One MWh is the approximate amount of electricity required to heat a detached Norwegian house with electrical heating for one week in winter.
One TWh is the approximate amount of electricity used by a Norwegian town of roughly 50 000 inhabitants in the course of a year.

Power is energy per unit of time

The basic unit of power is the watt, and the following units are used:

1 W,	watt	=	1 J/s
1 kW,	kilowatt	= 10^3 W	= 1 000 W
1 MW,	megawatt	= 10^3 kW	= 1 000 kW

Conversion factors and average theoretical energy content of various fuels:

	MJ	kWh	toe	scm natural gas	barrel of crude oil	cord of firewood*
1 MJ, megajoule	1	0.278	0.0000236	0.0281	0.000176	0.0000781
1 kWh, kilowatthour	3.6	1	0.000085	0.0927	0.000635	0.00028
1 toe, tonne oil equivalent	42 300	11 750	1	1 190	7.49	3.31
1 scm natural gas	35,54	9.87	0,00084	1	0,00629	0.00279
1 barrel of crude oil (159 litres)	5 650	1 569	0.134	159	1	0.44
1 cord of firewood (2.4 loose cu.m)*	12 800	3 556	0.302	359	2.25	1

**Depending on the moisture content.*

The market balance and the 2002–03 dry year – a brief description

In the power market, domestic output of electricity and imports in any given year will be equal to domestic consumption and exports. This correlation between demand and supply is called the market balance and applies for all time intervals. See the box on the market and power balances. Assessments of the market balance often look at the relationship between output in a normal year – one with normal inflow to the reservoirs – and domestic consumption.

The Norwegian power balance will show big variations in hydropower output from one year to another. To achieve a balance, imports, exports and consumption must adjust to output changes. Developments in the market balance during recent years have made the power supply system more vulnerable to dry years. That was evident under the tight supply position prevailing in the autumn and winter of 2002-03. Brief peaks in electricity consumption – the power balance – have also become more frequent, and the market comes under pressure at times.

Hydropower accounts for almost all Norwegian electricity output and half of Sweden's. Finland also generates some hydropower. This makes precipitation, and thereby inflow to the hydropower stations, important for electricity generation in the pan-Nordic power system. Reservoir inflow was unusually low in Norway, Sweden and Finland during the autumn of 2002. The biggest decline occurred just before the tapping season began. This gave the Nordic power supply system very little time to adjust to a substantial drop in the energy available from hydropower. The inflow decline meant that the Nordic electricity market became very tight in the winter of 2002–03.

Inflow was significantly below normal in all three countries during every month from August to December. Total inflow in Norway, Sweden and Denmark from July-December 2002 was no less than 35 TWh under the normal level. This decline corresponded to almost nine per cent of Nordic electricity consumption over a year.

The market and power balances

In a power market, electricity fed into the grid – input – and tapped from it – consumption – must always balance.

The domestic power balance is defined as the relationship between output and overall consumption of electricity over a year. When assessing the market balance, the relationship between consumption and output in a normal year – one with normal precipitation – is often considered.

Domestic electricity output will often exceed consumption in years with a high inflow to Norway's hydropower stations. This position will be reversed when inflow is low. Transmission links with other countries help to reduce the impact of swings in domestic output or consumption.

The power balance expresses the relationships between supply and consumption of electricity at a specific moment in time. Development of the market and power balances is interrelated. A gradual tightening in the market balance because little new generating capacity is being installed also increases the risk that supply will come under pressure for brief periods.

New power offtake records have repeatedly been set in recent years without any significant expansion in generating and transmission capacity. This means that the power balance has become tighter. The most recent record was set on the morning of 5 February 2001, when consumption reached 23 054 MW between 09.00 and 10.00.

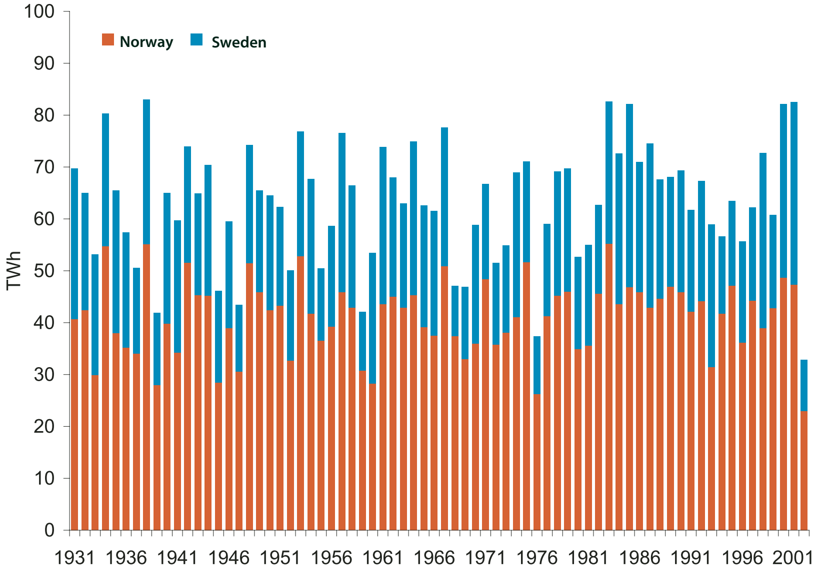

Figure 1 Inflow August–December 1931–2002

The drop in inflow led to a substantial decline in hydropower output. For the Nordic region as a whole, this was about 96 TWh in the second half of 2002 – roughly seven TWh lower than in the same period of the year before. Hydropower output in the first half of 2003 was only 84 TWh, about 26 TWh below the same period of 2002.

Big adjustments in the Nordic market helped to reduce the impact of the inflow decline. These occurred without government intervention to deal with the position.

Four factors in particular were significant:

- hydropower reservoirs were very important as buffers between output and consumption
- spare thermal generating capacity in other Nordic countries was eventually taken into use
- electricity imports from countries outside the Nordic region eventually became substantial
- consumption of electricity declined, particularly because of a shift to other energy carriers.

The loss of hydropower output was offset to a great extent by increasing thermal power generation. Nordic oil-, gas- and coal-fired electricity output in the second half of 2002 totalled 45 TWh, about nine TWh higher than in the same period of the year before. These power sources accounted for about 57 TWh in the first half of 2003, up by 18 TWh from the same period of 2002. Nuclear energy output in the autumn and winter of 2002-03 was roughly unchanged from the previous winter.

Net Nordic electricity imports increased gradually from the summer of 2002 until the end of the year, and totalled 4.6 TWh for the second half of 2002. This figure came to 10.2 TWh in the first half of 2003, as opposed to 0.8 TWh in the first half of the year before. Russia was a particular source of these Nordic imports.

Norway's net exports were high until the beginning of October 2002, when they began to decline gradually. But the country remained a net exporter until the beginning of December. Throughout the winter and spring of 2003, net Norwegian electricity imports were substantial. Purchases from abroad were particularly high from mid-

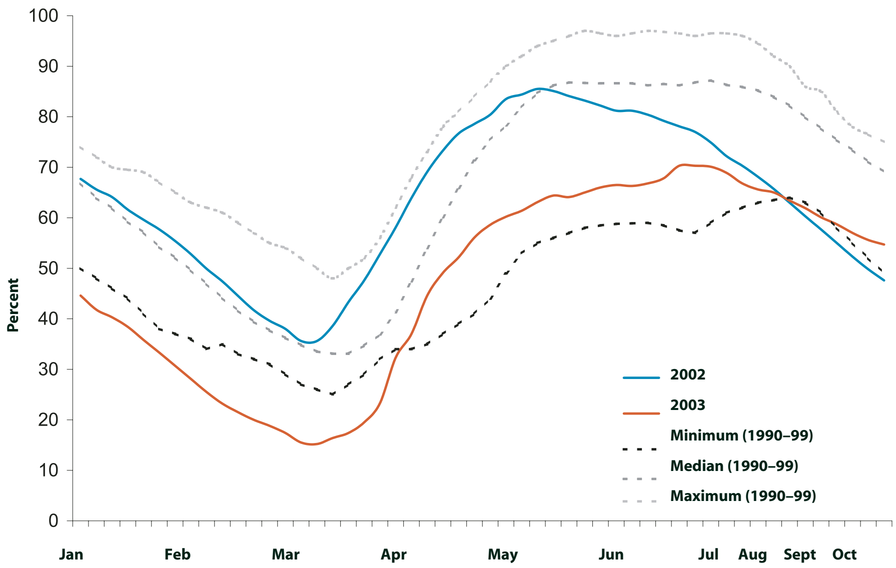

Figure 2 Reservoir levels, Nordic region

March until the beginning of May. The power exchange fluctuated between net imports and exports during the summer of 2003. Taken as a whole, Norway had high net exports of more than six TWh in the second half of 2002. This was reversed to net imports on a corresponding scale during the first half of 2003.

Electricity prices reached very high levels as a result of the tightness of the power market, adding to costs for Norwegian industry and householders in the winter of 2002-03. Electricity bills became a very burdensome expense for some.

The spot price for electricity in 2002 averaged NOK 0.201 per kWh, but varied considerably over the year. Power prices were low during the first half, but the gradual tightening of supply during the second six months eventually yielded substantial increases. Towards the end of the year, prices rose sharply over a very short period. From 30 November 2002 to 31 January 2003, the Nordic power market was characterised by high and fluctuating electricity prices. The average daily spot price ranged in this period from about NOK 0.5 per kWh to roughly NOK 0.8 per kWh. At its peak, the average daily price reached NOK 0.831 per kWh. Prices also remained high during January 2003, when the electricity spot price averaged NOK 0.524 per kWh. And prices in the rest of the winter and spring of 2003 remained far above the normal level for recent years. The average price in the first half of 2003 was NOK 0.317 per kWh.

Nordic electricity consumption was two per cent higher in the second half of 2002 than in the same period of the year before. During the first half of 2003, it was 0.5 per cent lower than in the first six months of 2002. Total Nordic consumption from July 2002 to June 2003 came to 388 TWh, an increase of 0.7 per cent from the preceding 12-month period. The growth in consumption was highest in Finland, while Sweden and Denmark experienced a modest increase and Norway showed a decline.

Total electricity consumption in the second half of 2002 was roughly on a par with the same period of the year before. During the first half of 2003, it was lower than in January-June 2002. A particular decline in consumption compared with the

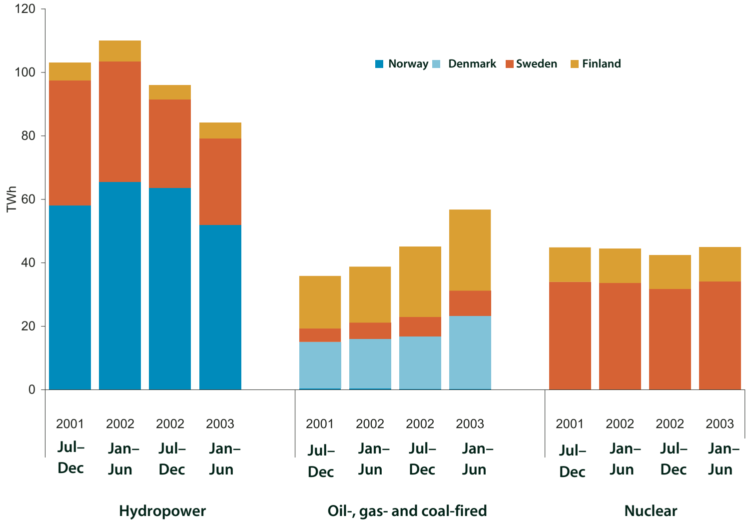

Figure 3 Composition of Nordic power generation, July 2001–June 2003

previous year was recorded from January to April 2003. Total consumption for the first half of 2003 was about four TWh lower than in the same period of 2002. A particular decline was recorded for power-intensive industry and electrical boilers.

Gross domestic consumption of electricity over the 12 months from July 2002 to June 2003 totalled 117 TWh, a decline of 3.8 TWh or roughly three per cent from the previous 12-month period.

The inflow decline put the Nordic power market to a hard test. A well-functioning power market helped Norway to emerge from the winter of 2002–03 without a supply crisis. The power system accordingly managed to cover an unusually dry autumn. Estimates indicate that conditions of this kind will recur every 100-200 years in Norway, 50–100 years in Sweden and 100–200 years for these two countries combined.

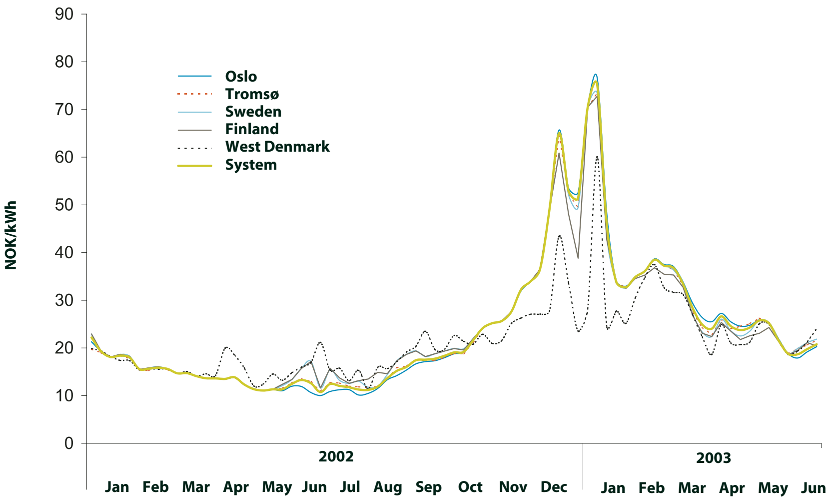

Figure 4 Spot prices for electricity, Nord Pool

Transmission capacity in the Nordic region (MW)

Useful internet addresses:

Ministry of Petroleum and Energy	www.odin.dep.no/oed/

Other players	**internet addresses**
Barents Energy Working Group	www.barentsenergy.org
Baltic Sea Region Energy Cooperation (BASREC)	www.cbss.st
EU Community Research & Development Information Service (CORDIS)	www.cordis.lu
Norwegian National Committee on Large Dams (NNCOLD)	www.nve.no/nncold
UN Economic Commission for Europe (ECE)	www.unece.org
International Energy Agency (IEA)	www.iea.org
Norwegian Electricity Industry Association (EBL)	www.ebl.no
Energy Charter	www.encharter.org
Swedish Energy Agency	www.stem.se
Danish Energy Authority	www.ens.dk
Enova SF	www.enova.no
EU Directorate-General for Energy and Transport (DG Tren)	http://europa.eu.int/comm/dgs/energy_transport
Forum for Regional Energy-Saving Centres (Fres)	www.enok.no
International Centre for Hydropower	www.ntnu.no/ich
Labro School, Norway	www.labroskolen.no
Lågdals Museum and Watercourse Museum Labro	http://kongsberg.net/laagdalsmuseet
Ministry of the Environment	www.md.dep.no
Norad	www.norad.no
Nordel	www.nordel.org
Nordic Energy Research (NEFP)	www.nordisk.energiforskning.org
Nordic Council of Ministers	www.norden.org
Nord Pool	www.nordpool.no
Research Council of Norway	www.forskningsradet.no
Norwegian Water Resources and Energy Directorate	www.nve.no
Norwegian Petroleum Institute	www.np.no
Statistics Norway	www.ssb.no
Statkraft SF	www.statkraft.no
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