



Overview of Norway's Electricity History

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SUMMARY

Formative periods

Norway's electricity history, which goes back to the 1870s, is characterized by three formative periods:

| | |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1906-1945 | Introduction of a legal framework with main purpose to secure national control of hydropower resources. Facilitation and organization of municipal ownership and electrification in general |
| 1945-1990 | Expansion of the power system (generation, transmission, distribution) and significant increase in industry and household consumption. |
| 1990- | Market focus (system optimization). Deregulation of the sector and introduction of an electricity market based on full competition. |

Key messages

- Many stakeholders have contributed significantly to the Norway's electricity history.
- Before 1930, most larger hydropower plants had been developed by foreign investors for industrial purposes.
- In parallel, publicly owned utilities developed hydropower for general consumption.
- Gradually, also the government (state) took an active role in hydropower development.
- In 1906, time limited licences were introduced in order to secure national ownership.
- The state had a particular focus on providing cheap and reliable electricity to the industry.
- The industry was the dominant off-taker of electricity until 1980 and is still a large consumer.
- In general, the industry have payed considerably less for electricity than other electricity users.
- Household electrification had a decentralized approach.
- (Almost) 100% electricity access was achieved in 1960. Rural support schemes contributed.
- Power system expansion has mainly been financed via public budgets and loans.
- Cost reflective tariffs have always been emphasized.
- Norway has aimed at a power surplus, due to the higher socio-economic costs of a power deficit.
- Sector unbundling took place only after the system expansion period was over.
- Public ownership dominates the power sector, also after the 1991 unbundling.
- The first major cross-border transmission lines were commissioned in the early 1960s.
- The basis for Nordic power cooperation has been short to medium term optimization of power resources based on differences in the generation mix.
- The driver behind each cross-border transmission project has been cooperative incentives of the government owned utilities.

Impacts of electricity

Electricity has contributed significantly to the industrialization of Norway and economic development. In addition to the direct employment opportunities in the hydropower industry and in industrial end-users, this also facilitated a knowledge base that has benefitted other industries. At an early stage, electric equipment, such as irons and later washing machines reduced the drudgery for women. Today, taxes and dividends from the electricity industry makes a significant contribution to public budgets, indirectly providing employment opportunities for women.

Most hydropower plants are located in rural districts. Affected districts receive a considerable share of the generated values. This happens often through establishment of local business development funds, partly free power for affected municipalities, municipality property tax revenues of electricity infrastructure, etc.

1. ABOUT THE REPORT

The report has been prepared by a working group¹ from the Norwegian Water Resources and Energy Directorate (NVE, www.nve.no) and the Norwegian Agency for Development Cooperation (Norad, www.norad.no). Statistics Norway (www.ssb.no) has provided data for most of the figures.

The **purpose** is to give an overview of Norway's electricity history. Electricity has contributed significantly to the economic development of Norway for more than 100 years.

The **target group** is staff working with energy related development assistance in Norad and the Norwegian Ministry of Foreign Affairs, including embassies. Norway's own electricity history may provide a useful reference.

2. INTRODUCTION

Norway's electricity history goes back to the 1870s. In 1889, the first municipality-owned electricity utility was established with a 88 kW hydropower plant as its source. The electricity utility in the Norwegian capital Oslo was established in 1892. In 1898, the English company Kellner Partington Paper Pulp Co. Ltd commissioned a hydropower station in the Sarpefossen waterfall.

2.1 Legal framework

The introduction of electricity necessitated a legal framework. The first law, advocated by insurance companies, concerned safety of electric equipment.

In the beginning of the 1900s, a major political concern was to secure **national control** of waterfalls. The major legal framework was put in place between 1906 and 1917. It secured **public control** and also ensured that **third party interests**, such as fisheries, boat transport and timber floating, were addressed through the licensing process. Since then, licenses have been granted to public owned companies without time limits, while private license holders have been granted a limited license period, typically 60 years. When the license expires, generation and other assets have to be transferred free of costs to the state. After 1945, environmental and social issues gradually become more important in the licensing process, in particular after some controversial hydropower projects in the 1960s and 1970s.

2.2 Stakeholders

Many stakeholders were involved in the electrification of Norway. The main stakeholders were the large industries, cooperatives and utilities owned by municipalities as well as counties and the Central government. Other industries and educational institutions provide a human resource base.

Industry. Large electricity-intensive industry companies (metallurgy, aluminum, ferro-silica, pulp&paper), often owned by foreign investors, developed hydropower plants for their internal use. In some cases, these industry companies also provided electricity to the adjacent area. This expansion with foreign funding was at the highest level before 1930. Industry companies still own some hydropower plants, but today the industry's main role is as a large off-taker.

¹ NVE: Bjørnar Araberg Fladen and Gunn Oland. Norad: Knut Gakkestad, Svein Kroken and Inge Harald Vognild (editor).

Municipalities and cooperatives. Municipal autonomy was already well developed around year 1900. Many urban areas and even some rural districts had relatively strong financial and technical capacity. These factors were an important background for also a decentralized hydropower development and electrification. Cooperatives and utilities were established with the purpose of supplying local industries and homes with electricity. This could be the whole or part of a municipality, or several neighboring municipalities together. In the late 1930s, there were in the order of 3000 hydropower plants in Norway. While some of the hydropower plants supplied an interconnected grid in Eastern Norway, most plants were supplying small communities or isolated farms. In 2014, the number of distribution utilities had been reduced to 122.

Central government. NVE was established in 1920 as a government entity responsible for licensing, hydropower development and electrification. Already around 1895 the government started to buy water rights from landowners, but the first large government owned hydropower plan (developed by NVE) for general supply was commissioned only in 1928. After 1945 the government took an active role as producer² and supplier to the energy intensive industry and to the larger distribution utilities (bulk sales). This was motivated by the wish to provide reliable and cheap power to all kind of industries. The state utility was also the main entity for developing the transmission infrastructure. With some minor exceptions, the state has not been directly involved in electricity distribution.

Human resources and educational institutions. Many of the hydropower pioneers were educated abroad, in particular in Germany. However, other industries³ already had a knowledge base that the electricity industry could tap into. Norway's university⁴ and technical institutes⁵ already provided relevant academic and technical skills. In 1910, Norway's first technical university was established, among others with a hydraulic department. A turbine testing laboratory was established in 1917. The accumulated experience from undertaken hydropower and transmission projects was also an important contributor to the national knowledge base.

2.3 Electricity access

Already around year 1900 about 10% of Norway's population had electricity in their homes. In the early 1930s, the access rate had reached 70 %⁶. While the access rate was almost 100% in many urban areas, rural and northern areas were lagging behind. This started targeted efforts to "reach the last mile." Almost 100% of the population had access to electricity in 1960⁷.

Figure 1 shows development of the national electricity access rate⁸ as well as the access rate in the northernmost⁹ county. Electricity access tend to be correlated with economic development. Around year 1900, GDP per capita was somewhat higher than USD 3000¹⁰, while it had increased to more than USD 13 000 in 1960.

² NVE Statskraftverkene, from 1986 Statkraft (www.statkraft.com).

³ Such as timber and mining industries and the transport sector (road, railway, telegraph, canals).

⁴ The university, which was founded in 1811, also had technical subjects, such as geology, on the curriculum. Norw

⁵ The first institutes were founded in the 1870s (with roots back to a silver mining institute).

⁶ A mapping by NVE in 1936 showed that the national electricity access rate was 74%.

⁷ In 1965, less than 3000 persons did not have access to electricity (source: Kraftoverføringsens kulturminner, NVE, 2010.)

⁸ The dotted lines before 1946 indicate that data are not available for each year.

⁹ The reduction prior to 1946 were due to damages during World War 2.

¹⁰ Based on <https://www.ssb.no/a/histstat/aarbok/ht-0901-bnp.html> and an NOK/USD exchange rate of 8.5. Few countries have achieved 100% electricity access before GDP/capita has reached USD 3 000.

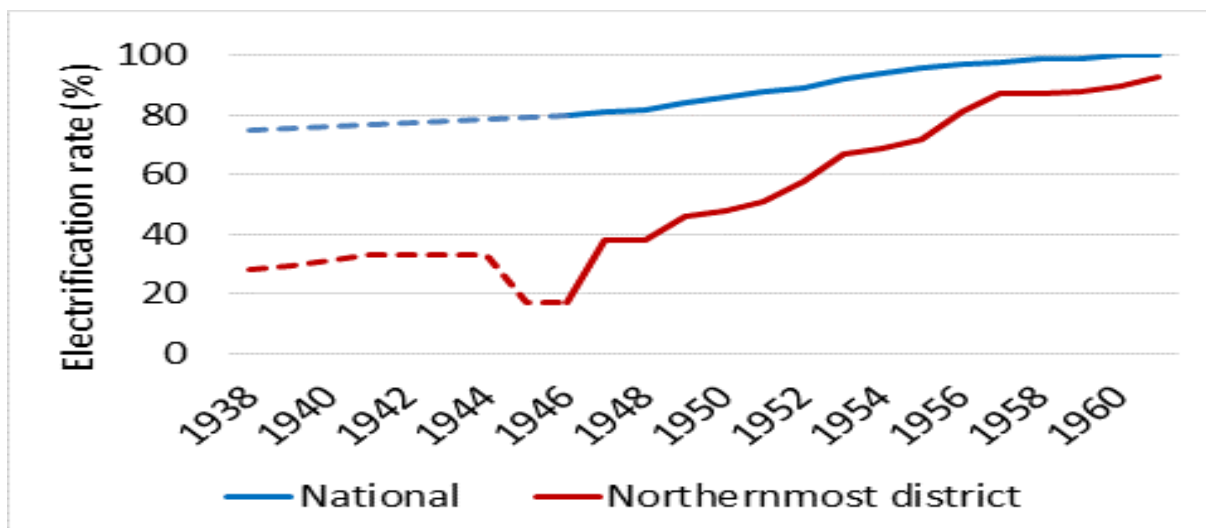


Figure 1. Development of household electrification rates (source: Statistics Norway).

Financing rural electrification

Around 1930 there was a growing recognition that electrified rural areas had higher economic welfare. This led to more targeted rural electrification. The main arrangements for increasing electricity access were subsidized loans, local financing and also government subsidies:

Loans. Often, loans were subsidized and issued with a certain guarantee from the municipality. The Norwegian Municipality Bank was established in 1926 with this purpose.

Local financing. Financial contribution was provided from the municipality, local industry and private persons.

Government subsidies. In 1938, the Norwegian Parliament started granting funds to promote rural electrification. A specific levy on electricity consumption was introduced in 1951 to finance rural electrification. The total grant between 1938 and 1990 was in the order of USD 100 million (NOK 883 million, 2014 value). The support was modest compared to the book value of physical assets of the distribution network in Norway, but very important in the targeted areas. NVE established a separate department for administration of this electrification fund with certain rules, terms and restrictions. Among others, NVE had to approve the tariff. In some cases, the fund also financed smaller hydropower plants. The support scheme proved successful for achieving 100% electricity access.

Today, a grant mechanism still subsidizes the network tariff in some specific sparsely populated areas with the highest distribution costs. The Parliament decides the grant level each year. The annual support is in the order of 4-6 million USD¹¹.

3. ENERGY AND ELECTRICITY USE

3.1 Primary energy consumption

The **stationary**¹² per capita energy consumption in Norway is at the same level¹³ as in neighboring countries. In Norway, however, electricity constitutes a much higher share, presently in

¹¹ The support was reduced to 20 million NOK in 2016, corresponding to about USD 3 million.

¹² Transport and offshore is excluded.

¹³ About 80 000 kWh in 2010 (Sources: Statistics Norway and International Energy Agency).

the order of 70%. Electricity has been the dominant energy carrier since 1980. In the early days, electricity was used for productive purposes in the industry and for lighting in homes. Wood, coal, coke and peat were used for heating. Today, cheap and easily available electricity is also the main source for space and water heating and for cooking.

Annual electricity consumption in Norway has doubled many times. Today, the net consumption is about 120 TWh¹⁴. Per capita electricity consumption is among the highest in the world. The main reason is the wide use of electricity for residential heating purposes. The industry was the dominant consumer of electricity until around 1980. Still, the industry consumes near 40% of all electricity.

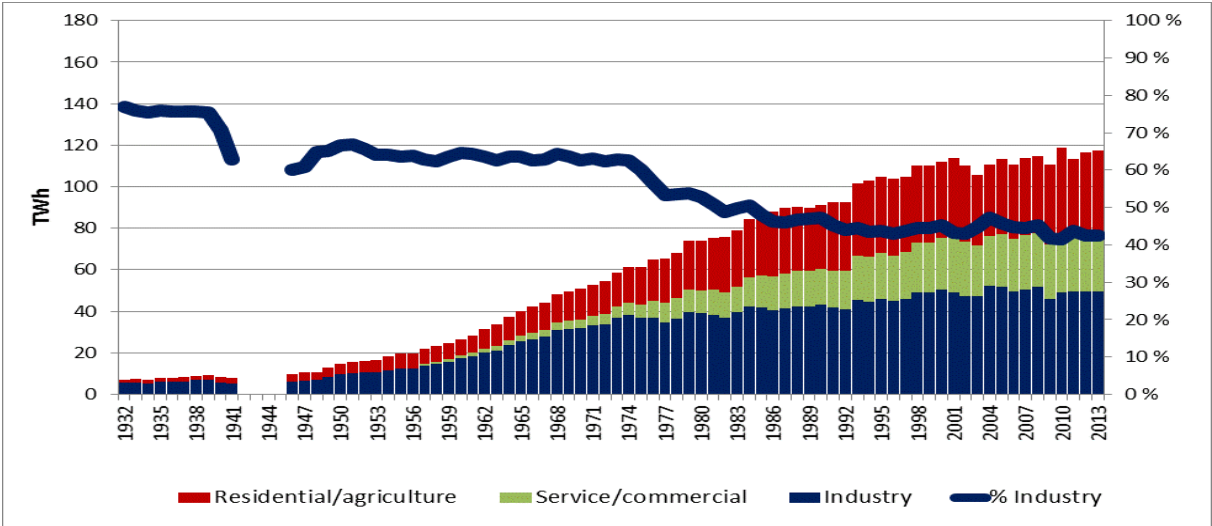


Figure 2. Historic use (billed) electricity consumption (source: Statistics Norway).

Today, an average Norwegian household consumes around 16 000 kWh annually. Electricity consumption is higher in cold years. Already in the early 1930s, an electrified Norwegian household¹⁵ in average consumed more than 2000 kWh per year.

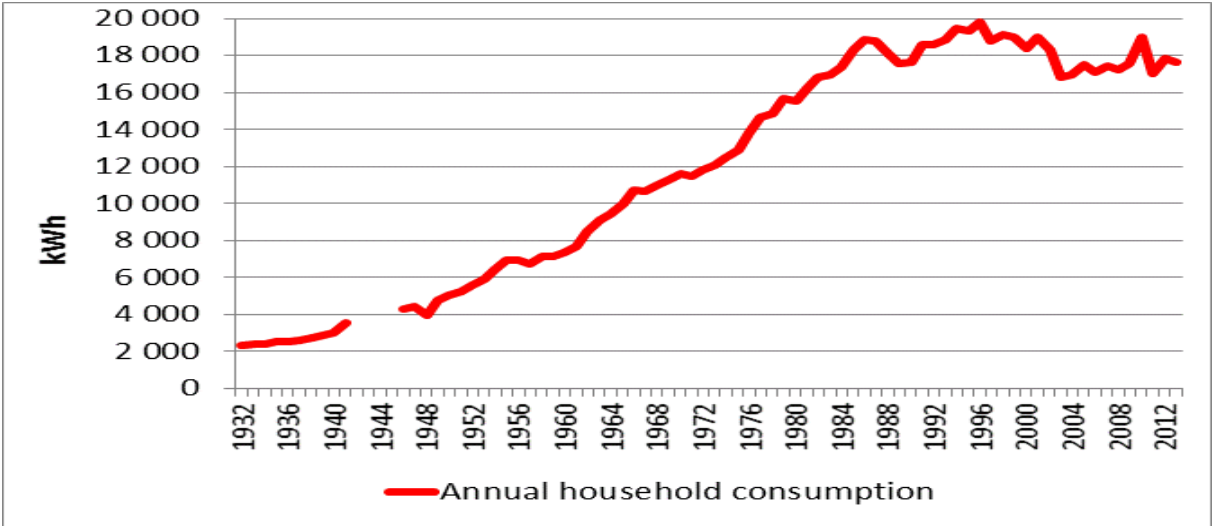


Figure 3. Historic household consumption (source: Statistics Norway).

¹⁴ Billed consumption, i.e. excluding electrical losses.
¹⁵ While there were four persons per household in 1930 in Norway, the average size of a Norwegian household in 2011 were 2.2 persons.

3.2 Electrical losses

Detailed data and in particular analysis of electrical losses before 1970 are scarce¹⁶. In the early 1970s total electrical losses were about 10%¹⁷. However, some rural utilities had electrical losses higher than 20%. Network refurbishment and voltage and conductor upgrading have contributed to loss reductions. Today, losses are in the order of 8%. Utilities have regulatory incentives to keep losses low. In Norway, commercial losses (theft) are very small.

4. ELECTRICITY GENERATION

4.1 Almost entirely hydropower

Already from the early days, most of the generation capacity was hydropower. Availability of water is the constraint factor in hydropower systems. Hydropower generation varies due to both seasonal and annual variations in precipitation. Much of the precipitation comes as snow and is not available for electricity generation in the winter season, when the demand is highest.

Thus, in order to secure high reliability of electricity supply all through the year, Norway has developed many storage hydropower plants. The storage capacity corresponds to more than 60% of the annual hydrological inflow. The state took a particular responsibility in developing expensive multi-year reservoir projects. Today, this large storage capacity together with a considerable cross-border transmission capacity is facilitating integration of intermittent renewable energy generation in both Norway and neighboring countries. Because installed capacity is high in hydropower plants in order to make optimal use of the water, the available capacity in hydropower systems normally is higher than the domestic needs.

Norway has experienced periods with a power surplus as well as power deficits. The first large government owned power plant was commissioned only a few years before the global economic recession in the 1930s. Due to lower than anticipated sales revenues the government utility faced a financially challenging decade. On the other hand, between 1945 and 1960, the power balance was tight, with frequent periods of load shedding, despite rapid hydropower development. The socio-economic costs of a power shortage are much higher than the costs of a power surplus. Thus, a power surplus in nine out of ten years was aimed at. This gave incentives to cross-border power exchange (see paragraph 5) and later also paved the way for deregulation of the electricity sector (see paragraph 6).

Between 1950 and 1985, a massive national expansion of the hydropower sector took place, as can be seen in figure 4. In 2013, the installed capacity in Norway was about 33 000 MW, of which more than 30 000 is hydro. Annual average electricity generation is now around 130 TWh, with significant annual variations.

¹⁶ Statistical Yearbooks (Statistics Norway) provides information on gross and net electricity consumption.

¹⁷ Source: NVE report 1/2004 Opprustning av kraftnettet for å redusere energitapet. The losses are expressed as a percentage of gross production. Note that exports/imports of electricity also affect electrical losses.

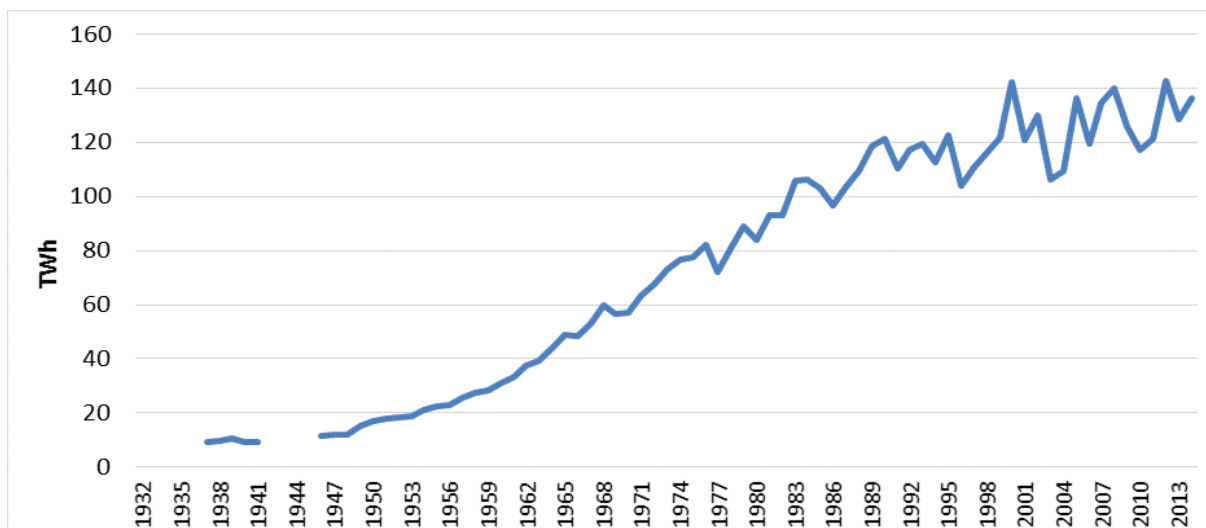


Figure 4. Annual electricity generation from hydropower¹⁸ (TWh) (source: Statistics Norway).

4.2 Transmission Development

Local and regional electricity networks gradually expanded and merged, as indicated in figure 5. The drivers were benefits in pooling generation resources¹⁹ and development of new hydropower projects further away from the load centres. In parallel, the technology for long-distance, large-scale transmission²⁰ of electricity improved. The process towards a nation-wide transmission grid took many decades and was completed only in 1994.



Figure 5. From decentralized systems to a national grid. (source: White Paper 14 (2011-12) Norwegian Ministry of Petroleum and Energy²¹)

4.3 Ownership

Public entities (state, counties, municipalities) own about 90% of the generation capacity through their positions in hydropower companies. The share of state ownership has increased due to expiry of time limited generation licenses. Today, the government utility owns about 1/3 of installed generation capacity through direct ownership of Statkraft (www.statkraft.com) and considerably more through indirect ownership. Many companies have several owners. There is also a significant level of cross-ownership. Most of the transmission infrastructure (> 132 kV) is owned by the government owned transmission system operator, Statnett (www.statnett.no).

¹⁸ Data before 1960 also includes (some) thermal generation.

¹⁹ Starting in 1913.

²⁰ Point of time when the following voltage levels were introduced: 20 kV: 1903, 60 kV: 1913, 132 kV: 1928, 220 kV: 1949, 300 kV: 1961, 420 kV: 1963.

²¹ Based on an illustration from a book by Skjold and Thue.

4.4 Financing

Financing of the state hydro power plants and transmission infrastructure came mainly through the state budget and in some cases with commercial loans. One large project was also co-financed with bonds. In the 1950s and 1960s some large hydropower projects were co-financed with World Bank loans. Other utilities have developed hydropower projects with a large share of debt financing, including foreign loans.

5. CROSS-BORDER ELECTRICITY COOPERATION

While hydropower storage projects were developed mainly in Norway and Northern Sweden, the electricity generation system in the rest of the Nordic region mainly relied on thermal generation (coal and nuclear)²². This different electricity generation mix is the physical basis for cross-border exchange²³ of electricity. The hydro based system will provide flexibility and regulation capacity to the thermal based system and the thermal/intermittant system will provide the hydro system with energy in dry years. The first cross-border lines to Sweden were commissioned in the early 1960s²⁴. By and large, each Nordic country has been self-sufficient with electricity. Cross-border exchange contributes to short and medium term optimization of the power resources.

The Nordic/North European governments have created a legally enabling environment for cross-border electricity trade. However, the driver behind each cross-border project has been corporate incentives of the government owned utilities. The Norwegian state utility²⁵ has been responsible for costs in Norway, and vice-versa. In recent years also EU has taken an active role in promoting cross-border projects.

As can be seen from figures 6 and 7, the development of cross-border (and national) transmission lines in the Nordic countries have taken many decades. Figure 7 also illustrates an increasing North European perspective.

²² In the last decades, intermittent renewable energy generation, in particular wind power, as well as biomass power plants have been developed in Denmark, Finland and Sweden.

²³ While cross-border **exchange** is the most appropriate term before the deregulation, today it may be more relevant to use the term cross-border **trade**.

²⁴ The first submarine cable between Sweden and Denmark was commissioned already in 1913.

²⁵ The Norwegian transmission system operator (Statnett) since 1992.

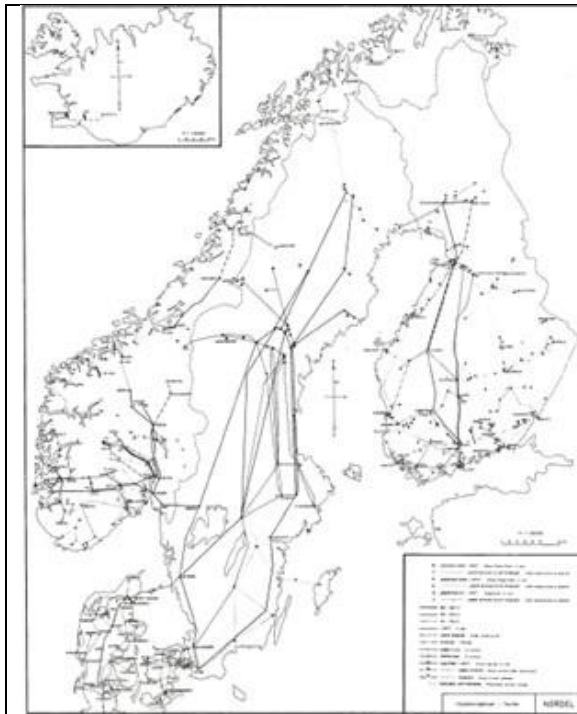


Figure 6. Map of the Nordic power system in 1963²⁶.



Figure 7. Map of the Nordic power system in 2008.

6. ELECTRICITY PRICING

6.1 Before the 1991 deregulation

Locally owned utilities companies were run as non-profit organizations. Their operations were regarded as a contribution to the business and industrial development in the district as well as securing favorable conditions for the local inhabitants. However, the tariffs were to a large extent cost reflective. The local utilities were able to develop new hydro power plants and expand the distribution network through financial contributions from the owners and commercial loans and the support schemes described in paragraph 2.3.

Before 1990, all investments in production and transmission capacity were subject to cost reimbursements. The end-user price was decided by the respective utilities, taking own costs (distribution network and own generation) and power purchase as well as local policy into account. Power purchase costs were decided by the terms of bilateral contracts between utilities. The price offered by the state utility often served as a reference.

The Parliament approved the state utility price as part of the annual state budget. However, between 1950 and 1965 only three price adjustments took place. The price reflected the average costs of generation. From 1979, the price related to the long-run marginal cost of new generation. The cost reimbursement system worked well as long as there was a steady growth in electricity consumption. However, it did not always provide cost efficiency incentives.

6.2 After the 1991 deregulation

In the late 1980s, the pricing regime and sector organization came under pressure. Low conjunctures reduced electricity demand. Combined with milder and wetter winters, this resulted in a considerable surplus. In some cases, a decentralized rather than a national focus on security

²⁶ Source: Nordel 1998 (25 anniversary book).

of supply had encouraged development of less cost efficient hydropower projects. As a consequence, some utilities faced economic problems. All these factors paved the way for the 1991 sector unbundling. The unbundling did not alter public ownership, however. In many ways, the unbundling illustrates the shift from power system expansion to power system optimization.

A national wholesale and retail market for electricity trading was established. The wholesale market gradually developed into a Nordic and North European market.

Distribution companies are natural monopolies due to economics of scale and environmental considerations. These companies are subject to tight regulations, including a maximum allowed profit margin. This includes the duty to physical provision of electricity with acceptable quality of supply to all customers in the respective geographical area. The regulator also decides a maximum allowed income based on utility efficiency benchmarking. The Norwegian regulator has a close cooperation with other European regulators in order to harmonize the framework conditions for the electricity industry as well as for electricity customers.

Today, the electricity bill is split between energy costs and network costs. After the deregulation, electricity prices have become more volatile.

6.3 Taxes and levies

Gradually, the electricity sector has been more and more taxed. Today, taxes and levies amount to more than one third of the electricity bill for a household consumer. The 1951 electricity levy referred to in paragraph 2.3 is now a fiscal levy, and has been considerably increased during the years²⁷. However, the northernmost parts of Norway and many industries are exempt from this tax or pay a considerably lower electricity tax than other consumption. In 2002, an additional levy was introduced with the purpose of financing energy efficiency measures and promoting renewable energy. Electricity users also pay ordinary value added tax (VAT) of 25%. Electricity utilities pay profit and property taxes. Hydropower companies also pay a resource rent.

²⁷ Corresponding to about 0.02 US cent per kWh in 2016.



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