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Deregulation of electricity markets—The Norwegian experience[*]

Abstract:
In this paper, we describe the approach to, and experience of, the deregulation and liberalisation of
the Norwegian electricity sector from 1991. The Norwegian electricity market was subsequently
integrated with the Swedish, Finnish and Danish markets to become the Nordic electricity market: the
first common, integrated, intercountry electric power market in the world. We discuss the background
to electricity market reform, the analytical and legal foundations for reform, and the chosen market
and regulatory design. We find that the market has performed well in terms of economic efficiency
and market functionality, even when exposed to severe supply shocks because of water shortages
for a power system that relies heavily on hydropower. However, we also identify issues and
challenges that must be addressed to improve the performance of the Nordic electricity market and
its regulatory system.

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1. Introduction

Following the enactment of the new Energy Act in 1990, which laid the legal foundation for Norway's electricity market reform, Norway was one of the first countries to deregulate and liberalise its electricity sector. The main motivation for electricity market reform was an increasing dissatisfaction with the performance of the sector in terms of economic efficiency in resource utilisation, particularly with regard to investment behavior, which caused capacity to exceed demand considerably (see Section 2). Simultaneous market liberalisation initiatives in other pioneering countries, such as New Zealand and the UK, increased awareness of the need for electricity reform, and influenced its design and implementation. This was particularly the case within the Norwegian Ministry of Finance, which initiated the reform.

The market reform should be considered against the background of the structure and functioning of the electricity system before liberalisation (Hope et al. 1992) and (Hope 2000, chapter 7). The generation of electricity in Norway is almost exclusively based on hydropower. When the reform was launched, there were about 70 power-producing companies and 230 network owners in the system. There was some vertical integration between power generation and the network, particularly at the regional and local levels, but many power producers were not integrated. The largest of them, Statkraft, accounted for approximately one-third of total generation. About 85 per cent of the electricity system was publicly owned by local, regional and state-owned companies. The power production capacity of the energy-dimensioned hydro system in 1991 was approximately 108 TWh in a normal year, of which the energy-intensive industries consumed approximately one-third. Annual production could vary considerably from year to year because of the stochastic nature of water inflow to the hydro system.

On the consumption side, around 90 per cent of power was sold on long-term contracts, defined as contracts for 'firm power'. Those contracts were negotiated individually and were predominantly bilateral, nonstandardised contracts between buyers and sellers. Power producers were obliged to deliver power within their concessionary areas and to cover their firm power contract obligations through contracts with other power producers. However, the lack of an organised secondhand market for contracts made most of the electricity market inflexible. In addition, electricity prices and other contract terms were generally set by administrative or political decree. For example, the basic price charged by the state-owned company Statkraft, known as the Statkraft price, was an element of the annual regulation of the company determined by the Norwegian Parliament. The Statkraft price functioned as a price signal to the rest of the market.

Because of the stochastic nature of hydropower production, a market for occasional or interruptible power developed. In 1972, this market was formally organised as a spot market in a power exchange, or pool, among the power producers, known as 'Samkjøringen'. Spot market transactions were carried out at a market-clearing price on an hourly basis determined by bids sent in by the generators to the power pool based on expected demand and supply schedules. This wholesale, producer-based spot market, comprising approximately the remaining 10 per cent of annual power production, met its objectives efficiently. The market is interesting as a forerunner to the design of the organised market system produced by Norwegian electricity market reform. In addition, for almost 20 years before market reform took place in 1991, it represented a 'training ground' for market participants in market-based transactions. Thus, because of the market experience gained from the spot market for occasional power, the learning-by-doing curve for market-based operations was not as steep in Norway as in most other countries that implemented power market liberalisation.

The rest of the article is organised as follows: In Section 2, we provide a brief review of the relevant background to deregulation. In Section 3, we describe the main elements of market reform. In Section 4, we discuss market design issues. In Section 5, we describe market development following deregulation. In Section 6, we discuss how effectively the new market dealt with extreme supply-side shortages in 2002–2003. In Section 7, we discuss market and regulatory challenges. Section 8 concludes the article.

2. The background to deregulation

During the regulation period, all investments in production and transmission capacity were subject to cost reimbursement. This was implemented either through direct market prices, cross-subsidisation between utilities,[1] or direct public subsidies.[2] There was no direct link between market prices (since there was no functioning market) and investment or between market prices and operating cost efficiency. The government, when determining its budget, set the following year's prices in the electricity market.[3] The government equated prices to average costs until 1979, from when it set prices equal to long-run marginal costs (LRMC). It used LRMC as a price criterion rather than an investment

[1] This is made possible by the increasing marginal cost of expansion in firms.

[2] This is achieved through either capital subsidy or relaxed requirements on the rate of return on investment.

[3] In fact, the government set prices for state-owned companies. However, the municipalities and counties, which own almost all the rest of the power producing capacities, followed. Since the energy-intensive manufacturing industry had long-term contracts, they were exempted. See Bye et al. (1999).

criterion.[4] The market functioned as a cost reimbursement system and provided no incentives for utilities to be cost effective. Moreover, since the transmission network is a natural monopoly, regulation is required for welfare maximisation. During the regulation period, while cost minimisation (given output) was pursued, output maximisation was also used to ensure an adequate supply. In addition, the central government and municipality authorities set different prices for different consumers,[5] which created inefficiencies and welfare losses in the electricity market.

2.1. Inefficiencies in production

There was no systematic evaluation of potential inefficiencies in production before deregulation of the electricity market, except that imbalances between capacity and demand were evaluated. Statistics illustrate excess capacity problems. During the late 1980s, between 5 and 6 per cent of the inflow of water to the reservoirs was spilt annually (even in normal inflow years). The prices set by the central government restricted demand relative to the capacity of primary energy supply (water inflow). To eliminate excess primary energy supply, producers accepted overflow from the reservoirs despite sufficient generator capacity. In a free competitive market, generators would produce sufficient water because prices would exceed variable cost and would fall to equate supply and demand. Prices would eventually be too low to stimulate further investment.

Midttun (1987, pages 102–109) outlines the political discussion of investment and pricing that took place in Norway from the 1960s to the 1980s. His main conclusions include the following. (i) Production capacity in state-owned companies has not increased following increases in marginal cost. (ii) The power price has never been high enough to cover the marginal cost of expansion. (iii) The expansion of capacity has led to excessive investments. According to Midttun, the bureaucracy wanted to equate prices and long-term marginal costs as an investment rule in the early 1960s. However, politicians resisted this until 1979. Then arguments about low electricity prices were replaced by debate over the discount rate. Politicians simply proposed a lower discount rate on investment projects to secure lower prices. Midttun also documents substantial cost overruns in state-owned companies that were because of weak financial management. However, some of the blame must be assigned to increasing environmental concerns, political intervention, changes to plans and development delays.

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[4] In 1979, the government, in a green paper, St. meld nr 54 (1979–1980) decided that the electricity price level in the long run should reflect long-run marginal cost. The escalation period continued until 1985.

[5] The purpose was to distribute some of the local natural resource value to local consumers or to support energy-intensive industries and the local labor market.

Costs overran by 57 per cent on average. Project planning focused on technical issues rather than economic issues.

2.2. Inefficiencies in transmission and distribution

Transmission networks are regional natural monopolies. Moreover, electricity distribution incurs large fixed costs and exhibits decreasing marginal operating costs. This suggests the following socioeconomic challenges. (a) The optimal private business price exceeds the optimal socioeconomic price. This produces suboptimal demand for transmission services. (b) The private price mark-up may cause profitability to exceed the normal rate of return on capital.[6] (c) The mark-up may cause technical or economic inefficiency in resource utilisation. Although public regulation is important, regulation appeared inefficient.

Kittelsen (1993, 1994) and Førsund and Kittelsen (1998) used production frontier analysis to test for inefficiencies in network distribution companies. They estimated total annual efficiency losses to be between 1.1 and 1.8 billion Norwegian kroner (approximately 300 million USD). This amount constitutes 25 per cent of the resources used for distribution per year. They found no evidence that mark-ups exceeded those necessary to cover cost inefficiencies. That is, they found no evidence of monopoly profits. Hence, distribution networks used their monopoly power to be cost inefficient rather than profitable.

There is no documented research on inefficiencies in the central grid.

2.3. Inefficiencies in the market

In a perfectly competitive market, one would expect different consumers to pay approximately the same price for a homogenous good. Power at the wholesale level at a specific time is close to being a homogenous good. Average reported prices for different consumers may be based on different types of contract (incorporating factors such as risk, security of supply, time of use, power and energy). However, during the regulation period, there was little risk of power shortages because a primary objective of the power suppliers was to ensure deliveries at any time.[7]

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[6] For ease of exposition, we assume the same risk in all alternative projects. However, in practice it is necessary to adjust for uncertainty differences.

[7] There was a compulsory delivery standard in each region.

Bye and Strøm (1987) did a backward calculation of prices at the power plant (a homogenous good) from statistics on purchaser prices (including transmission and taxes) for different consumers. Their results are reported in the table 1. Calculated prices for the energy-intensive manufacturing industry were between one-third and one-half of the prices for services and households. This indicates substantial discrimination, which reduces social welfare. Differences in prices between households and services were less substantial. The averages disguise large differences between regions for the same consumer group. In the power plant regions, (net exporting) prices were kept low for local customers at the expense of those in net importing regions, where prices were high.

Table 1. Power prices—net of taxes and transmission fees. Current prices. øre (kWh) [1]

	1978	1979	1980	1981	1982	1983
Households	12.2	13.7	15.2	17.3	20.0	26.0
Services	14.2	15.2	16.9	19.2	22.3	28.1
Other Manufacturing	12.4	13.4	14.5	16.8	19.9	25.4
Pulp and paper	6.6	7.0	8.2	9.0	10.9	11.0
Power-intensive industries	4.3	4.5	5.3	5.8	6.2	7.7
Weighted average	9.5	10.3	11.6	13.4	15.6	19.8

Source (Bye and Strøm, 1987)

1. In 2004, 1USD=6.7 NOK; i.e. 20 øre/kWh= 3 cents/kWh

Bye and Strøm (1987), Bye and Johnsen (1991) and (Bye 1991) estimated the implicit annual efficiency losses because of this price discrimination at between 3.7 and 4.5 billion Norwegian kroner. This represents three times the loss in the distribution network described above. Since the calculations assume identical firms within a sector, the calculated efficiency gains are biased downwards.

3. The main elements of Norwegian market reform

Based on the Energy Act of 1990, the main elements of the Norwegian electricity market reform were as follows.

- With regard to market design, it was decided to build on the established spot market model for trade in interruptible power, while organising it as a regular spot market incorporating demand. The market was, in principle,[8] open immediately to all potential buyers, including

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[8] Small consumers had to pay a relatively high access fee when changing contracts in the first four or five years.

households. Initially, the market was organised as a separate legal entity within the transmission company, Statnett, and was termed the Statnett Market.

- Common carriage principles requiring access to the network system on a transparent and nondiscriminatory basis facilitated market-based trade

- The dominant, state-owned and vertically integrated company, Statkraft, was split vertically into two separate legal entities: the generating company, Statkraft SF, and the transmission company, Statnett SF. For the other vertically integrated power companies, companies were separated into generating or trading divisions and network divisions for accounting purposes, but were not split into companies with separate legal identities.

- The network companies were subject to natural monopoly regulations designed to achieve economic efficiency in network operations. The regulatory regime was administered and enforced by the sector-specific regulator, the Norwegian Water Resources and Energy Directorate (NVE), on the basis of rate-of-return regulation. In 1997, income-frame regulations were introduced instead.

- The market liberalisation reform was implemented without changes in ownership, because the privatisation of the power sector was politically unacceptable. This contrasted with the UK, where privatisation was implemented before market liberalisation. There, privatisation was considered a prerequisite for successful electricity market reform from an economic efficiency perspective.

The main events that have taken place in the deregulation and market liberalisation process since 1991 are described below.

As mentioned above, Statnett began trading in the spot market for power (the day-ahead market) in 1991, when the NVE introduced the regulatory regime for network owners. In 1993, a financial forward market was established for the delivery of traded contracts. In 1994, this was replaced by a continuous trading system, and standardised financial futures contracts were introduced.

To facilitate trade in the retail market while avoiding investment in expensive metering equipment for retail customers, in 1995, load-profile demand measurement was introduced. In 1997, fees for consumer switching were also eliminated to stimulate consumer switching and market competition. In 1998, the Norwegian Competition Authority introduced a price information system for retail prices from power suppliers to improve market transparency. The time allowed for consumer switching was reduced to a week.

In 1996, a common Norwegian-Swedish power market was established to become the first intercountry integrated power market in the world. Nord Pool [9] took responsibility for power exchange for the common market from Statnett Market.[10] The Swedish transmission company, Svenska Kraftnät, became coowner with Statnett. In 1998, Finland became an independent price area on the Nord Pool power exchange. Denmark integrated into the Nordic system in 2002, since when there has been a common Nordic integrated electric power market (excluding only Iceland).

4. Market design and market operations

A complete market-based power system should be equipped with markets for the following five basic requirements or functions: (a) markets for trade in electricity; (b) markets and instruments for risk hedging in accordance with risk preferences; (c) short-term markets for production capacity [11] and balancing supply and demand; (d) markets for investment in new capacity; and (e) markets for trade in environmental energy products (such as green-certificate markets). Nord Pool has organised markets for functions (a), (b), and (e). Function (c) is generally handled by the transmission system operators in the individual countries. There are hardly any organised markets for (d).

Nord Pool is a nonmandatory power pool that organises approximately 40 per cent of the total trade in electricity in the Nordic power market. The rest is organised on the basis of bilateral contracts. Nord Pool's share in total trade on the organised spot market is a useful indicator of the liquidity of the market. This is discussed in relation to the volume of trade in organised financial markets in section 4.2.

Nord Pool also performs the functions of contract clearing and settlement. Nord Pool established a new environmental market for electricity certificates for renewable energy production (green certificates) in 2004.

4.1. Nord Pool's spot market—Elspot

Elspot is a contract spot market on which electricity is traded on a daily basis for physical delivery the following day (a day-ahead-market), with full obligation to pay. The bidding procedures are

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[9] See http://www.nordpool.com.

[10] See http://www.Statnett.com.

[11] Capacity markets are needed to provide two kinds of service (see section 4.3). These are: (1) the instantaneous balancing of supply and demand to prevent system breakdowns or fallouts; (2) accounting for deviations between planned production according to the supply and demand schedules at the time when the price is determined and the production is needed to meet demand at the time of delivery.

essentially the same as those adopted by Statnett Market in 1991. Market participants place bids in the Pool one day in advance for the next 24 hours of the following day. The Pool then aggregates the bids and prices for each hour based on supply and demand. The Nord Pool *system price* is the market equilibrium price for the aggregated supply and demand schedules for each hour. The spot-market system price functions as a reference price for Nord Pool's financial markets and the bilateral markets in the Nordic system. Currently, 280 participants trade daily on the Nord Pool spot market.

The system price is determined without taking into account potential capacity constraints in the transmission network system. If calculation of the system price indicates that the power flow between two or more areas exceeds capacity limits in the transmission grid, two or more area prices are determined. A capacity fee, defined as the difference between the system price and the area price, is then calculated. The transmission system operators in the Nordic countries set the capacity fee as an integral part of their operation of the system. Thus, the system operators are obliged to use the price mechanism in the spot market when adjusting power flows during periods of capacity constraints between bidding areas (see Subsection 4.3 below).

4.2. The markets for derivatives at Nord Pool

The types of contract traded on Nord Pool's financial markets comprise electric power derivatives and electricity certificates. The financial derivatives are futures, forwards, options, and contracts for differences. The contracts have been developed to meet the needs of market participants faced with market uncertainty and price volatility, and for risk hedging and risk management.

As already mentioned, the reference price for those contracts is the spot-market system price for the total Nordic electric power market. The maximum trading time horizon is currently four years. For all financial derivative contracts, the principle of cash settlement applies; that is, there is no physical delivery of electricity on those contracts.

The basic distinction between futures and forward contracts is that the former are standardised contracts for a given quantity of power at a certain price in a specified time period, while the latter are typically nonstandardised. A division of labor between futures and forwards has developed at Nord Pool. This is because the time horizon for futures has been reduced from three years to between eight and nine weeks, while forward contracts apply to periods of up to four years. Thus, the market seems to favor short-term futures near the due date and favors long-term forward contracts near the end of the time horizon. This may be because of the difference in margin calls between futures and forwards.

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Futures are settled daily on a market-to-market basis. This requires a considerable cash commitment up-front. By contrast, forwards only require cash collateral during the delivery period.

The option contracts traded at Nord Pool adopt the European convention that contracts can only be exercised at the stipulated exercise date. Options combined with futures and forwards offer interesting strategies for risk hedging and risk management in electricity power trading. They also allow greater flexibility in contract portfolio composition and administration.

Contracts for difference (CFDs) were introduced to allow market participants to hedge against the price area risk. As already mentioned, the system operators determine area prices that differ from the prevailing system price when there are capacity constraints in the transmission network. Futures and forward contracts cannot hedge against this price area risk. Therefore, CFDs were introduced to enable perfect hedging even when the market is split into two or more price areas.

In 2004, Nord Pool began the trading of electricity certificates in Sweden, on contracts involving physical delivery. Nord Pool plans to introduce forward contracts for such certificates in 2005. A Norwegian market for electricity certificates is due to be created in 2007. The anticipated integration of the Swedish and the Norwegian markets is expected to increase liquidity and competition in the common market. In February 2005, Nord Pool also began trading in carbon emissions by using European Union Allowances (EUAs). Hence, it became the first deregulated market in Europe to trade in and clear such contracts.

The volume of trade in financial derivatives markets is currently about five times the volume of physical trade in the spot market. This ratio is used as an indicator of market liquidity and of how efficiently markets are functioning. The ratio is now increasing following a decline in 2003.

4.3. The balancing markets—capacity markets

Capacity markets are required to balance supply and demand in an electric power system to avoid system breakdowns or delivery fallouts. The following three major types of imbalance between supply and demand, which create the need for capacity markets or balancing mechanisms, can be distinguished. (a) Deviations can arise between the planned supply and demand schedules on which prices are determined in the day-ahead market and the actual demand schedule prevailing at the time of delivery within each hourly time section in the spot market. (b) Price deviations can arise because

of transmission capacity constraints. (c) There can be imbalances or interruptions because of stochastic fallouts of generation or power line capacity. We focus primarily on (b).

If the power flow between two areas exceeds transmission capacity, the price is reduced relative to the system price in the surplus (low-price) area and is increased in the deficit (high-price) area. This continues until the power flow matches the capacity limits. The system operator responsible for capacity regulation on the grid does this when capacity constraints arise.

However, within the Nordic system, different principles and methods are applied to balance capacity. In Norway, transmission capacity problems are resolved by the price mechanism in the spot market according to the principle of delineation of price areas described above. This is the responsibility of the Regulating Power Market, which is operated by the Norwegian system operator, Statnett. Statnett divides the country into two or more geographical bidding areas and stipulates the maximum transmission capacity between these areas. Every week, based on data from Statnett, Nord Pool then informs all market participants of the bidding areas that apply for the following week. Currently, four price areas generally apply, but the number depends on grid conditions and the relationship between supply and demand in the system. Because of reduced investment in transmission capacity relative to demand, capacity constraints have gradually become more binding. This implies that price area delineations have become more persistent.

Sweden and Finland form one bidding area in the spot market, while Denmark is divided into two. In Sweden and Finland, the counter-purchase principle is applied to manage internal transmission bottlenecks. Counter-purchasing involves system operators in Sweden and Finland paying for the downward regulation of production in the surplus area and upward regulation in the deficit area until the capacity constraint is eliminated. The cost of counter-purchases is financed by tariffs on power production. The balancing mechanism used for Sweden and Finland is known as Elbas.

The Regulating Power Market in Norway is organised as a bidding market in which a 15-minute time span applies to price determination. For imbalances, which cannot be handled within this period, Statnett can impose downward or upward capacity regulation on market participants at short notice (less than 15 minutes). Initially, market participants comprised a relatively small number of large power producers with considerable regulating capacity. Now, however, the market has been opened to participants from the demand side. These include firms in power-intensive industries and other large

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consumers that are willing and able to regulate their power consumption if the price in the Regulating Market gives them an incentive to do so.

4.4. The retail market

The organised markets at Nord Pool are wholesale markets for the common, integrated Nordic electric power market. The retail markets are largely national markets because of national retail-market regulations. However, integrated retail markets are also being developed.

Retail market competition in Norway has been stimulated by regulatory measures to increase market transparency and consumer switching. This switching has resulted from the abolition of switching fees and the establishment of a price information system for the retail market by the Norwegian Competition Authority (NCA) in 1998, as mentioned in Section 2. Note, however, that producers only compete on the electric power price. In Norway, this price accounts for roughly one-third of the total end-consumer price. The remainder comprises the grid-user price and public taxes and fees, which each account for one-third of the total price. Recently, the grid-user price component has increased relative to those of power prices and taxes and fees.

The obligation to report retail prices to the NCA applies to around 170 suppliers, of which 50 to 60 operate regularly in the market. The number of consumers switching suppliers has increased steadily since the retail market was opened in 1995. During the first quarter of 2005, around 65,000 household consumers changed supplier, which represents 3 per cent of all households. In April 2005, 25 per cent of household consumers used a power supplier other than the dominant supplier in the area. However, the absolute number of consumers switching suppliers is not necessarily an appropriate indicator of increased competition. What matters is whether the number is sufficiently large to cause suppliers to set prices competitively.

Approximately three-quarters of Norwegian retail consumers have entered into some form of variable retail-price contract (such as a spot-market contract or a standard variable power-price contract). This exposes them to variations in the Nord Pool system price on the wholesale spot market. By contrast, in Sweden, 80 per cent of retail consumers pay a fixed price. This difference may have arisen because Norway depends totally on hydroelectric power, whereas Sweden only depends on hydroelectricity for 30 to 40 per cent of its total production. Consequently, price volatility has traditionally been higher in Norway than in Sweden. In a fully integrated market, however, price volatility should converge.

Tradition, contract types, and risk preferences may also explain the difference in contracting behaviour.

The retail market has become very transparent, in part because of the price information system of the NCA. However, perhaps the market has become too transparent. Perhaps competition has reduced the difference between the highest and lowest prices without reducing the average price. Since price information is widely available, the retail market may be vulnerable to the exercise of collective market power or tacit collusion between suppliers and, therefore, vulnerable to higher prices. Information on retail prices is readily available to everybody in the market. The Nord Pool system price, which is the reference for retail prices, is also widely known. Moreover, suppliers learn from data on past prices and market behavior as they meet each other frequently in the market. This hypothesis has not yet been tested empirically by using data on the retail market.[12]

4.5. Regulatory policy for electricity markets and networks

The regulatory policy for the electric power sector comprises a competition policy for electricity markets and a regulatory regime for network activities. In both cases, economic efficiency is the policy objective.

Norwegian competition policy has mainly been concerned with improving market transparency through the retail-price information system and eliminating the abuse of market power by dominant firms that have resulted from mergers and acquisitions among electric power companies. The NCA investigates mergers and acquisitions. It prevented the acquisition of Agder Energi by Statkraft on competition grounds. However, an appeal against the NCA's decision was made to the Ministry, to which the NCA is subordinated. Although the Ministry agreed with the NCA's analysis of competition, it allowed the merger to go through, albeit with modifications. Recently, the NCA has been preoccupied with the implications of transmission capacity constraints for competition in electricity markets.

A new regulatory regime for network companies was introduced in 1997. It was essentially a revenue-cap incentive mechanism,[13] but it contained elements of rate-of-return, price-cap and yardstick regulation. The regulatory period was defined for intervals of five years, but revisions could be

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[12] For discussion of the relationship between market transparency and the potential exercise of collective and unilateral market power, see Hope (2005). Market dominance and market power in electric power markets. A competition policy perspective. Report. Stockholm, Swedish Competition Authority.

[13] In Norway, this is referred to as 'income frame regulation'.

undertaken during the period. An annual income frame was set *ex ante* by the regulator (the NVE) for each network company, of which there were 225, mainly distribution companies. The transmission company, Statnett, was regulated on the same basis. The revenue cap was based on the total cost coverage of network activities, including a stipulated rate of return on invested capital. This rate was set at 8.3 per cent for the first year. An efficiency improvement factor was defined for each network owner, based on a data envelopment analysis (DEA) of the efficiency improvement potential for each company. For the first regulatory year, the efficiency factor was set at 2 per cent of the income frame for all network owners. However, it was subsequently modified to depend on the efficiency position of each owner in relation to the DEA-efficiency frontier. The highest annual efficiency requirement has been a factor of 4.5 per cent.

Although the regulatory regime was supposed to be evaluated and revised in 2001, following the first regulatory period, it was extended on more-or-less the same basis for the five-year period from 2002 to 2007. The NVE has commissioned much research and consultation on the design of the new regime to be implemented in 2007. An important and challenging issue facing the new regulatory model is the design of an incentive mechanism for optimal investment in the network that enables the market-based electricity system to function efficiently.

5. The development of the market following deregulation

Deregulation of the electricity market was expected to lower investment, reduce and equalise prices between consumers, lower net tariffs, and raise the rate of return on investment.

5.1. Prices

In a virtually completely hydro-based electricity market, we would expect increasing long-run marginal costs because of a scarcity of resources. Given this background, we would expect higher prices in the long run because the investment rule for private investors implies that prices equal long-run marginal costs. However, in the short or medium run, excess capacity implies that prices equal short-term marginal cost plus any shadow price on capacity restrictions.

In the introduction, we indicated that during the regulation period, the public sector invested in excess capacity. However, at the same time, it attempted to equate prices to long-run marginal costs. How is it possible to have excess capacity when long-run prices reflect long-run marginal costs? There are three obvious reasons. (a) Energy-intensive industries, which consume one-third of capacity, paid prices corresponding to one-quarter to one-third of long-run marginal costs; that is, instead of

increasing capacity further, electricity consumption should be reallocated to equalise prices between consumers. Prices would fall below long-term marginal costs and investment would cease. (b) Excess production in relation to domestic demand was sold on an international market in the form of occasional power at low prices. Instead of increasing capacity further, this production could have been allocated to Norwegian consumers by lowering domestic prices. (c) In the late 1980s and early 1990s, almost 5 per cent of the inflows to reservoirs were spilt [14] during the periods of spring melting and autumn rains.[15] This water could have produced electricity given that generator capacity was sufficient. Prices would have fallen and demand would have increased. Prices would have been too low to stimulate further investment; that is, existing capacities would have been sufficient for many years.

Since the spillage of water from the reservoirs in the Norwegian hydropower system is regulated by competition rules under deregulation, previously excess capacity competes in the market. When excess capacity competes in the market, electricity prices are below long-run marginal costs in the short and medium run. This persists until demand increases and production capacity constrains growth. Then prices increase again and stimulate further investment. Deregulation of the market also puts downward pressure on prices by generating an expected efficiency gain in terms of operating costs and investment costs in capacity per MWh. Moreover, as discussed in the introduction, there is a major increase in market efficiency; that is, greater price equality between consumer groups.

The figure shows changes in the spot price and average prices among consumer groups in 2002. First, the spot price is low in comparison to the end-user prices prevailing in 1993. This is mainly because of excess capacity and the splitting of the market. Neither the end-user market nor the spot market were fully developed after two years of deregulation.[16] Second, there is almost no correlation between the spot price and end-user prices after four to five years of deregulation, although there was an increasing trend in all prices. In this period, end-user prices were similar among consumer groups, which suggests that the market eventually functioned as expected.

Since 1997, the Nord Pool market was extended when Sweden and Finland deregulated their markets.[17] The fee on contract switching for small consumers, which was introduced in 1991, was

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[14] Source: Statistics Norway: Report 90/1.

[15] Norwegian power capacity is almost completely based on hydroelectric power.

[16] Small consumers had to pay a high access fee when changing contracts in the four or five years following deregulation.

[17] Market expansion increased the amount of surplus power and prices fell.

eliminated in this period. End-user prices then followed spot prices on a downward trend. Nevertheless, end-user prices remained above the spot price. When the spot price increased in 2000, the gap narrowed.

As expected, figure 1 shows that fluctuations in the spot price were negatively correlated with those in hydropower production. Since demand elasticities are low (see Bye et al., 2003), a modest change in supply may have a large impact on the spot price.

Hence, deregulation did put a downward pressure on the electricity price, seem to have reduced price differentials between consumers and have closed the gap between end-user prices and market equilibrium prices.
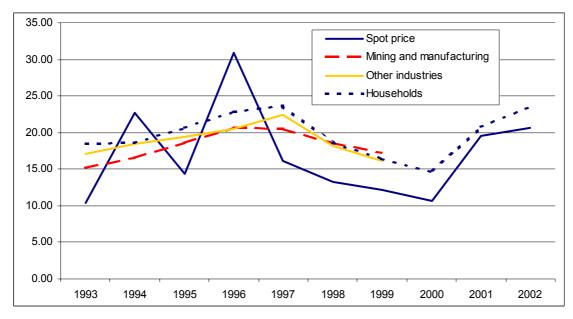
Figure 1. The spot and consumer prices, Nøre/kWh fixed 2002 prices
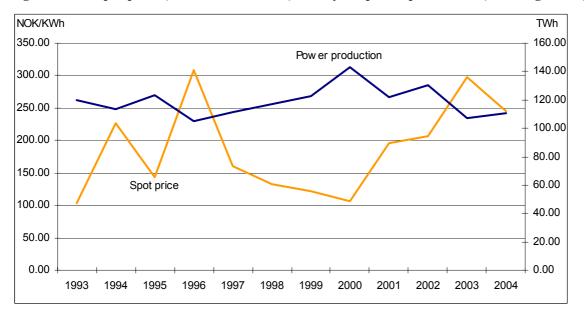

Sources: Statistics Norway and NordPool.

Figure 2. The spot price (NOK/kWh left axis) and hydro power production (TWh-right axis)

Sources: Statistics Norway and NordPool.

5.2. Investment in power production capacities

During the regulation period and in the six years after the deregulation of 1991, production capacity in Norwegian hydro power plants exceeded demand; that is, under normal inflow conditions, Norway was a net exporter, see figure 3.[18] After 1997, production and capacity has been lower than demand, except in 2002–2003, when inflows were well below normal. Prices increased dramatically and demand responded.

Investments in new production capacity began to fall in the early 1980s, see figure 4, long before deregulation. This was mainly because of a sharp increase in the marginal cost of expansion and a continuing increase in environmental concerns. These concerns made expansion politically unacceptable. After deregulation, investment continued to fall and reached a low level. As demand increased, Norwegian capacity was restricted and prices increased.

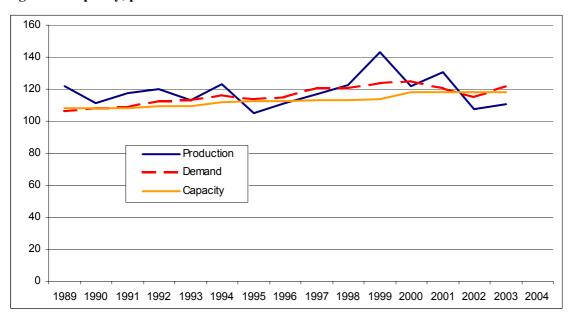[18] 'Normal' refers to the average over the period 1970–1999.

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Figure 3. Capacity, production and demand. TWh
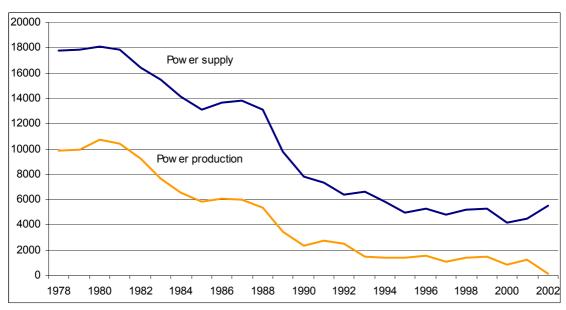

Source: Statistics Norway and NVE.

Figure 4. Investments in power supply and power production. Mill NOK - 2002 prices

Source: Statistics Norway.

However, when Sweden, Finland, Denmark and other northern European countries deregulated, excess capacity in these countries kept prices low and imports to Norway high.

An important issue is whether deregulation provides sufficient incentives for investors to participate in expanding the electricity sector in Norway. This issue is high on the public agenda and skepticism is widespread. However, conclusions are often confused with the potential effect of persistent regulation of energy resources because of environmental concerns. Politicians seem unanimous in blocking new investment in large hydropower plants, gas-fired power plants and nuclear and other thermal plant technologies. Hence, there are restrictions on the supply side. Consequently, prices increase. The only feasible alternatives seem to be renewable technologies based on, for example, wind, biomass, solar energy and wave power. Since these technologies are costly, their market prices are not sufficiently high to stimulate investment in the absence of strong financial support.

5.3. Rate of return on power production

Excess capacity relative to demand implies low capacity utilisation (before 1991) or low prices (after 1991) and a low rate of return on investment. A low rate of return hinders investment in new capacity. Unlike in the manufacturing industry, the rate of return in the power sector in Norway has been low since deregulation.[19] However, the rate of return has recovered since 2000 because hardly any investment in new capacity has taken place while demand has increased by, on average, between 1 and 1.5 % per year for the last 10 to 15 years. In a hydropower-based electricity production system, one can expect the average rate of return to be higher than in other industries (such as manufacturing).
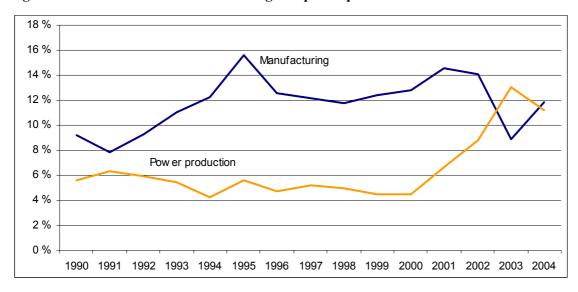
Figure 5. Rate of return in manufacturing and power production. Percent

Source: Statistics Norway

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[19] In much of the manufacturing industry in Norway, the rate of return varies because of international business cycles (in, for example, aluminum, ferro alloys, chemicals, and pulp and paper). This explains the low rate of return in manufacturing in 1991.

This is because the basic resource is scarce and marginal costs are increasing.[20] Scarcity is not yet a problem, but will become one as the market develops.

5.4. Investment in networks

In the 1950s and early 1960s, much of the power production capacity in Norway was expanded through 'combined' projects. Power projects were implemented and energy-intensive manufacturing were developed at the same location. Manufacturing industry was located near power plants to minimise transmission costs and benefit from the cheap energy based on the resources from large waterfalls. These developments were on the western coast of the country. Over time, demand grew because of growth in demand from services and the residential sector, mainly in the densely populated areas in the east of the country.[21]
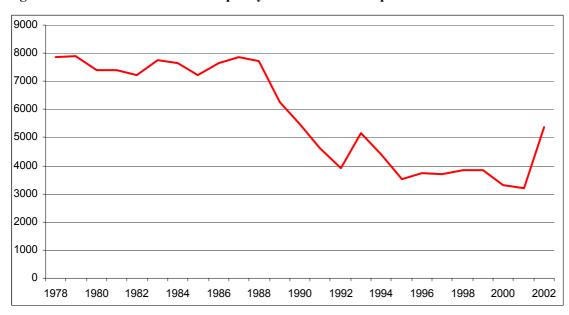
Figure 6. Investment in network capacity. Mill NOK - 2002 prices

Source: Statistics Norway

The location of hydropower in thewest increased the need for transmission capacity from west to east and, to a certain extent, from north to south. As higher fuel oil prices in the 1970s (introduced by

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[20] New investment will not occur unless prices cover the long-run increases based on marginal cost. This applies unless there is backstop technology that limits increases in marginal costs or unless there is unlimited import capacity at fixed prices.

[21] Demand from the residential sector was five times higher in 2004 than in 1960, while demand from manufacturing industries was only about twice as high. The residential sector used almost the same amount of electricity as did the manufacturing industry in 2004.

OPEC in 1973–1974 and again in 1978–1979) and increasing environmental concerns triggered a sharp increase in sulfur taxes and regulation of the sulfur content in oil products, massive substitution of fuel oil with electricity took place in the heating sector. Along with aggregate economic growth, this raised demand for capacity investment in the distribution network. Once this large infrastructure project had been completed, investment in network infrastructure capacity decreased.

These developments could explain the sharp decrease in network investment that occurred between 1988 and 1993, which is illustrated by the figure. However, this is just part of the story. The decrease in investment also coincided with the debate that took place before and during deregulation of the Norwegian electricity market in 1991. While power production and trade were exposed to competition, a new regulatory regime was introduced for transmission and distribution network companies in 1991. Rate-of-return regulation and 'yardstick competition' reduced network tariffs. The network reimbursement policy was replaced by yardstick competition to secure cost efficiency and an improved social investment strategy in capacity. When the profitability of network investment fell, investment also declined. Investment in networks increased again in 2002–2003 because of the upgrading of existing networks and the installation of new capacity designed to alleviate temporary network constraints.

5.5. From rate-of-return regulation to income regulation

With the introduction of the new Energy Act, rate-of-return regulation was introduced for network companies. In 1997, this regulation was replaced by income regulation. An important aspect of income regulation is the efficiency rate (see Appendix A), which is specific to the distribution network and, *ceteris paribus*, reduces annual allowable network-specific income. Given capacity and utilisation, the net tariff is reduced by this efficiency rate, which is based on both yardstick competition and a catching-up-period rule.[22] On average, the network tariff in Norway is expected to fall by about 20 per cent between 1997 and 2005.

Figures 7-8 show changes in total income and the network tariff in this period. Income was on an upward trend before 2003, when it fell. Over the whole period, real income fell by 1.5 per cent, which is less than the fall in the efficiency rate. This was mainly because of an increase in transmission capacity, as income per transmitted kWh fell by about 18 per cent in this period. Operating costs drove tariffs up, while the fall in interest rates reduced them.

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[22] The catching-up period in this rule is the period that firms are allowed for catching up with the leading firm.
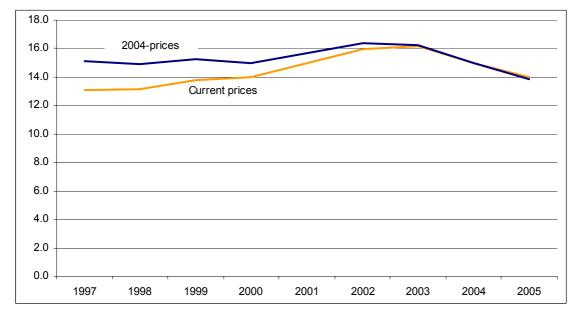
Figure 7. Regulated total income in networks. Current and fixed (2004) prices. Billion NOK

Source: Statistics Norway and NVE.

Figure 8. Net-tariffs. 2004-prices. Nøre/kwh

Source: Statistics Norway and NVE.

Because regulation is more sophisticated and because supply and demand are stochastic, transmission tariffs and regulated income per transmitted unit may behave differently in the short run. However, in the longer run, transmission and distribution networks must pay back excess income and may add

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accumulated, but insufficient, income to future regulated income. The regulatory regime allows this adjustment to take time (several years). According to the regulatory authority, this fully explains the increase in tariffs over the last three or four years. As tariffs had previously been low, tariffs had to increase to make up the income shortfall. Since precipitation and inflow were low in 2002 and 2003, and the resulting high prices in the market reduced demand substantially, income regulation resulted in higher tariffs per transmitted and distributed kWh. According to the regulatory authority, *ceteris paribus*, tariffs are expected to fall over the next two years.

In the longer run, interest rates, operating costs and the spot-market price (the price of transmission losses) are expected to increase. This may offset the downward bias that is due to the yardstick efficiency gain measure.

Another important issue is whether the new regulatory regime provides sufficient incentives to invest in infrastructure capacity in this sector. This is a widely debated issue in Norway and represents a further challenge.

5.6. Market structure and concentration

The dominant producer of hydropower in Norway, Statkraft, is a state-owned company. Before deregulation of the electricity industry, Statkraft produced around 30 per cent of Norway's power. However, much of its output was delivered to the energy-intensive manufacturing industry on the basis of long-term contracts. Statkraft's share of the remainder of the market was less than 15 per cent. Private firms provided about 10 per cent of Norway's production capacity, while municipalities and counties owned the rest.

Following deregulation, many of the companies under local-government ownership were turned into limited-liability firms. Larger regional power companies were established, partly through acquisitions and mergers among local-government entities. The state-owned company, Statkraft, also grew through mergers, acquisition and the purchase of shares in other large and small power companies, partly encouraged by politicians, although there was some obstruction from the competition authority. Politicians focused on Norway as part of a larger Nordic integrated electricity market in which Statkraft was a minor player. That is, competition prevailed, and the authorities wanted to develop Statkraft as an important player in the international market. The competition authority accentuated changes in regional markets, that is, when transmission was constrained and the market leader could

exercise market power. Eventually, Statkraft was allowed to purchase companies, but was also forced to sell divisions to increase competition.

Bye et al. (2003) report a Hirschman–Herfindahl concentration index for the Norwegian market based on direct ownership of 0.1634. One that incorporates inactive but incentive-based cross-ownership is 0.1980. A third index that controls for demand [23] and incentive-based cross-ownership is 0.3325. They concluded from the traditional measure (0.1634) that the Norwegian market remains concentrated. However, if we take into account cross-ownership, the market is reasonably concentrated (0.3325). For the whole Nordic region, they found a cross-ownership, incentive-based index of 0.1138, which suggests an unconcentrated market.

The relevant issue is whether the Nordic market is an integrated market or a regionalised market. Hourly data on area prices indicate the scale of transmission constraints and allow a calculation of the scope of the relevant market. In 2001, the Nordic market was fully integrated 51.8 per cent of the time and regionalised otherwise, based on calculations for seven Nordic regions. The most populated area in Norway, the south, was classified as a separate area less than 10 per cent of the time, while the northern part of the country was a separate area nearly 20 per cent of the time. Thus, the issue of market power is relevant.

Generally, it is difficult to prove the abuse of market power, especially in a hydropower system in which the primary energy source, and implicitly total production from a reservoir, is determined by inflows (given that the regulators monitor any waste of water). However, concentration is not all that matters; any plant on the margin in a restricted price area, even a small firm, may abuse market power. Clearly, mergers or acquisitions that increase concentration should be prevented. Alternatively, transmission capacity between regions could be increased.

6. A market under stress—a real test

The Nordic electricity market was exposed to an extreme primary energy shock between 2002 and 2003. A short-term shortage of precipitation and inflow sharply increased prices and led to vigorous discussion of the functioning of the deregulated market when exposed to such extreme situations. Policies that could to relieve these so-called 'infirmities' in the market were discussed. However, Bye (2003) showed that the market functioned remarkably well; producers tried to optimise the value of

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[23] That is, the index controls for demand according to ownership share.

water, as expected; electricity trade followed anticipated patterns; and consumers responded as predicted by theory. (See Bye et al., 2003, and Fehr et al., 2004).

During the period of regulation of the Norwegian electricity market, a security-of-supply rule was introduced for investment decisions. According to this rule, there should be enough capacity at any time to satisfy demand. The primary supply (precipitation and inflow) is stochastic in a power system dominated by hydropower. Demand changes because almost 90 per cent of heating is electric and outdoor temperatures vary substantially. The any-event security-of-supply rule thus implied excess capacity in normal situations and water spillage in above-normal inflow conditions. When deregulation was introduced, prices and investment fell. Firm-specific profit maximisation reduced excess capacity over time. Stochastic supply and demand eventually increase price fluctuations. If the rains fail, as they did in the autumn of 2002, prices are expected to increase.

The fundamental profit-maximisation problem for a hydropower producer is to optimise the value of stochastic inflows of water over time (Førsund, 1994). The reservoir is an instrument for equalising prices over time. Under simplifying assumptions, it leads to the maximisation of profit from the production of power. If enough producers compete efficiently, if no transmission constraints occur, if there is sufficient storage capacity, and if precipitation, inflow and weather are normal, then equalising prices between periods also optimises the social surplus. If there are no constraints, this optimising strategy generates equal prices for electricity over time and place. In practice, these assumptions are simplistic, but sufficient for the reasoning that follows, except for the inflow uncertainty. For further discussion of a more complex system, see Førsund (1994) and Bye (2003).

In the Norwegian hydropower system, water typically flows into the reservoir during the snow-melting period from early May to mid July and in the rainy season from mid September to late October. The high-demand period is winter, from October to April, while demand is low in summer, from May to August. In a hydropower system, profit-maximising behavior involves equalising the value of water (the price of power) between periods. To do so, the storage capacity of the reservoirs is used.

In the spring of 2002, since the inflow to the hydro reservoirs exceeded the normal level, production increased and prices decreased. The water level was above normal. Producers had the incentive to produce to avoid an overflow in the rainy autumn season. However, the autumn rains did not come, which resulted in a 20 TWh (17 per cent of Norway's annual production) inflow shortfall within 6 weeks, relative to the normal inflow for this period. The probability of this happening was

approximately 0,5 per cent. Prices in the spot market increased to an all-time high level (and quadrupled on average within two months). Over a period of 12 months, average spot prices increased by almost 50 per cent. Demand fell by about 5 per cent, despite many manufacturing companies having fixed-price contracts. Some companies even sold power back to the electricity companies under these fixed contracts.[24]

During this period, physical rationing of power was discussed because of a possible draining of the reservoirs during winter. Some focused on a possible malfunction of the market (because of abuses of market power, irrational behavior by new firms, and the inadequacy of the market for dealing with extreme events). Politicians threatened to reregulate the market and proposed several measures for dealing with extreme situations. They were primarily motivated by public and media focus on the possibility of rationing and severe price effects on the income distribution.

At the request of the Minister of Administrative Affairs, Bye et al. (2003) evaluated the event and concluded that the market functioned as expected and that the market dealt with the extreme almost perfectly. The historic rate of return in power production explains low investment in production capacity and is not a consequence of malfunctioning or the abuse of market power. Moreover, between 2002 and 2003, expectations of futures prices (contract prices for hedging two or three years ahead) were low despite the high prices specified in physical contracts. Thus, short-term prices did not justify an expansion of productive capacity. High prices simply reflected a water shortage and the need to stabilise water values over time, which reflected great uncertainty. The water balance in the summer of 2002 was well above normal. This put downward pressure on prices to increase demand and generate a water balance that was low enough to accommodate the autumn rains. Because the rain failed and the water balance fell, the market had to adjust to restore the water balance in the spring of 2003. Since imports were restricted, domestic prices had to rise.

Although the market seems to have functioned well, Bye et al. (2003) identify issues for further study and follow-up by the competition authorities. One issue is the future design of contracts. The market seems to have been competitive despite the fact that transmission was restricted between Norway and other countries almost 60 per cent of the time during the winter of 2002–2003. However, there seems to have been a problem because of price differences in the contract market, both in the wholesale market (see a forthcoming study by Bye et al., 2005) and in the retail market (see Fehr et al., 2005).

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[24] These contracts represented a combination of price and volume contracts.

7. Some challenges

In a comprehensive EU-financed research project on European electricity reforms, known as SESSA,[25] the Nordic electric power market model was suggested as a potential benchmark for market organisation and the efficient functioning of electric power markets.[26] However, even if the Norwegian and Nordic electric power markets and their regulatory systems performed reasonably well in terms of competition and economic efficiency, there is scope for improvement. Some issues and challenges in this context are as follows.

1. *Market dominance and market power*. Investigations by competition authorities and research studies have not documented instances of the exercise of market power in the Nordic power market, either unilaterally or collectively.[27] However, market power is a recurring issue in the debate on the Nordic market. This is partly because of the characteristics of electricity as a commodity in market terms and partly because of the increase in market concentration following restructuring of the market through mergers and acquisitions between electric power firms. The issue of market power suggests the need for the design of a system for monitoring the market and its regulatory system, as argued by Hope (2005).

2. *Design and operation of investment markets*. The Nordic market has performed reasonably well in terms of the efficient *operation* of a market system with a fixed capacity, because the excess capacity that had built up before the market was reformed has meant that further investment is not required for capacity expansion. Thus, investment is optimal and capacity is adequate. There is no overall investment planning system for the Nordic electric power system and there is a lack of investment markets for optimal investment within the integrated Nordic market.

3. *Network integration and system operation*. The Nordic transmission network system remains decentralised in the sense that national transmission companies are responsible for the operation of, and investment in, the national network, and for system operation. Cooperation between transmission companies takes place on a voluntary basis through NORDEL. The regulation of network companies and the handling of network constraints are not harmonised on a Nordic-wide basis, which results in potential inefficiencies in the functioning of the power markets. A common, independent transmission system operator for the integrated Nordic market is also lacking.

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[25] For documentation, see the SESSA webpage, www.sessa.eu.com.
[26] See Hope and Singh (2005).
[27] See the Nordic Competition Authorities (2003) and Hope (2005).

4. *Integration of the Nordic market with the European electricity market at large*. Economic efficiency could be increased if the Nordic market were more closely integrated with the European electricity market. Although insufficient transmission capacity limits such integration, transmission investment is planned. For example, an undersea cable between Norway and the Netherlands is being developed. The more mature Nordic market in terms of market organisation, competition and regulation, may promote power market liberalisation in Europe.

8. Summary

During the regulation period, investment in production and transmission capacity in the electricity market was subject to cost reimbursement, through either direct prices in the market, cross-subsidisation between utilities or direct public subsidies. There was no direct link between market prices and investment or between market prices and operating cost efficiency. Several studies report substantial inefficiencies in the production, transmission, distribution and market distribution of electricity.

The new deregulated market was intended to build on the principles applied in an already existing spot market for interruptible power. Vertically integrated power companies were split into divisions on an accounting basis. A derivate market was opened to deal with hedging against uncertainty. Introducing common carriage and securing access to the grid on a transparent and nondiscriminatory basis opened up the electricity network. The network companies were subject to regulation, the objective of which was to increase economic efficiency.

Following deregulation, electricity prices fell, prices between consumer groups became more equal, investment declined in both production and transmission capacity and, over time, the return on capital increased. In addition, market concentration increased and opportunities to exercise market power arose as the market became more regionalised because of transmission constraints. Market power does not seem to have been abused. The stochastic electricity market is occasionally tested by extreme events, particularly on the supply side. However, the market seems to have handled these events well.

Some challenges remain with respect to market concentration, the design and operation of investment markets, network integration and system operation, and integration of the Nordic and European electricity markets.

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The network income regulation formula

The income regulation formula (R) includes a four-year average of operating costs, D, a capital cost element, $(\delta + r + r^*)K_t$, which includes depreciation, δ, and the rate of return, r, a consumer price index adjustment, P^{ci}_t / P^{ci}_{1996}, the cost of transmission losses, $(\tau X_t)p_t$, at market prices, p_t, an efficiency requirement, $\prod_{i=1996}^{t}(1 - \kappa_i)$, and some additional adjustment for investment and operating costs, $I^*_t + C_t$.

$$R_t = \left\{ \left[\sum_{i=t-3}^{t} D_i / 4 + (\delta + r + r^*)K_t \right] \left(P^{ci}_t / P^{ci}_{1996} \right) + (\tau X_t)p_t \right\} \prod_{i=1996}^{t}(1 - \kappa_i) + I^*_t + C_t$$

About the authors

Einar Hope has, since mid-2004, been Professor Emeritus at the Norwegian School of Economics and Business Administration (NHH) in Bergen. There, he was Professor of Energy Economics from 1999; this chair was donated to the NHH by the Norwegian petroleum company, Statoil. From 1995 to 1999, he was Director General of the Norwegian Competition Authority. Before that, as head, from 1975, he established three applied research organisations that were affiliated to the NHH. These were the Institute of Industrial Research (IØI), the Centre for Applied Research (SAF) and the Foundation for Research in Economics and Business Administration (SNF). Most of his scientific work spans Industrial Organisation, Energy Economics and Competition Policy. He was instrumental in the regulatory design of Norway's electricity market reform and its implementation from 1988. He has also chaired, or been a member of, a number of governmental committees on competition and regulatory policy issues and reforms.

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