Danish Energy Agency

Liberalisation of the Danish power sector 1995-2020

An international perspective on lessons learned

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Foreword

The liberalisation of the Danish power sector, along with the unbundling of long-established vertical integrated utilities, is one of the steps that led Denmark to be the forefront of renewable energy. Today, Denmark is the country with the world´s highest share of variable renewable energy in electricity production (50% in 2019) and has been for many years. Wind and solar power, in combination with flexible thermal power plants and international transmission networks, supply the Danish electricity demand, providing low electricity prices and contributing to a world class security of supply.

Building on these years of experience, the Danish Energy Agency has the mission of assisting countries around the world in following the same path and decarbonise the power system in a secure and affordable way.

These achievements could not have happened without a structural transformation of the electricity sector, including the unbundling of generation from the natural monopolies of transmission and distribution services. The liberalization of the Danish power sector, including equal access to the grid for all generators, has created a healthy competition among the stakeholders, which has served as a foundation for the development of the renewable energy industry in Denmark with continuously decreasing costs of renewable technologies.

The Danish example can inspire the many countries around the world, which are considering or commencing liberalisation of the electricity sector. Liberalisation and unbundling processes can lead to many positive aspects, such as easing the integration of renewables, attracting foreign financing and bringing down costs. Yet, the processes can be challenging, as they require fundamental changes and restructuring of the institutions, roles and responsibilities in the electricity sector. The Danish experience shows that a consensus on the transformation of the electricity sector has been challenging to reach, as the process is very complex and there is rarely a single clear solution, as different institutions can bear different opinions on specific aspects of the process.

This report highlights the key learning from the Danish liberalisation process, illustrating both the positive outcomes and the challenges faced during and after the process. We hope it will spark inspiration and provide guidance for our partners in the process, which led Denmark to sit amongst the world´s leaders in the integration of renewables.

Kristoffer Böttzauw, Director General of the Danish Energy Agency

Danish Energy Agency

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Abbreviations

ACER	Agency for Cooperation between Energy Regulators
CHP	Combined heat and power
DEF	Danske Elværkers Forening (Today Danish Energy)
DSO	Distribution System Operator
ENTSO-E	European Network of Transmission System Operators for Electricity
EPAD	Electricity Price Area Differentials
EU	European Union
PSO	Public Service Obligation
REMIT	Regulation on wholesale energy market integrity and transparency
SIDC	Single intraday coupling
ToU	Time-of-use
TPA	Third Party Access
TSO	Transmission System Operator
UMM	Urgent Market Messages

Executive summary

"… Establishment of the internal market in electricity is particularly important in order to increase efficiency in the production, transmission and distribution…" (EU, 1996)

"The purpose of the liberalisation was to create better conditions for competition, and thus to improve utilisation of production resources as well as to provide gains from improved efficiency in the operation of networks." (NordReg, 2006)

Liberalisation of the electricity sector in Denmark was motivated by two parallel movements: the development of the electricity market in Norway and Sweden, and the EU's focus on the European internal market, where electricity was also seen as a commodity that should be traded freely across borders. I.e. the purpose of the EU's internal market is the *free movement of goods, persons, services and capital*.

Today's wholesale electricity markets – with the day-ahead market as the key market – is very dynamic, liquid and has a high degree of competition. The efficient integration of 50% wind and solar generation in Denmark is to a high degree dependent on the dynamic properties of the wholesale market.

The retail market has developed more slowly, with related important infrastructure such as smart meters, soon to be in place. Benefits of liberalisation have been less clear in the retail market.

Security of electricity supply has been very high in Denmark. Liberalisation was introduced during a period with excess electricity generation capacity in Denmark. This was linked to a previous policy of being self-sufficient, as well as favourable financing rules for investments during monopoly times. Today, total dispatchable generation capacity (i.e. excluding wind and solar power) is less than peak demand. As a result, during periods with little wind and solar generation, security of supply is now dependent on electricity import.

While liberalisation has been achieved in many aspects of the power sector, some areas still require attention. These include regulation of monopolies (DSOs and TSO), development of significant amounts of demand response, and opening reserve and ancillary service markets for competition across EU borders and technologies. See Figure 1.

Summary of today's electricity market

Today, all Danish consumers can choose their electricity supplier as well as select between different types of contracts, e.g. a fixed electricity price for a period of time, a variable price, or various combinations thereof. There are currently 38 suppliers, which in total have 295 contracts to choose from. It is straightforward to change a supplier or type of contract, both of which can be undertaken online. 43% of electricity is currently sold on contracts with a variable price linked to

hourly wholesale market prices, while the remaining portion has a fixed price for a period of three months or more.[1]

An electricity supplier is the main interface to the consumer. All suppliers and generators are associated with a balance responsible party. The balance responsible party delivers plans to the TSO for generation, demand and trade. Both suppliers and balance responsible parties are commercial companies, and both can buy and sell electricity on the power exchange (day-ahead and intra-day). Electricity suppliers and generators can reduce price uncertainty by entering financial contracts involving future electricity prices.

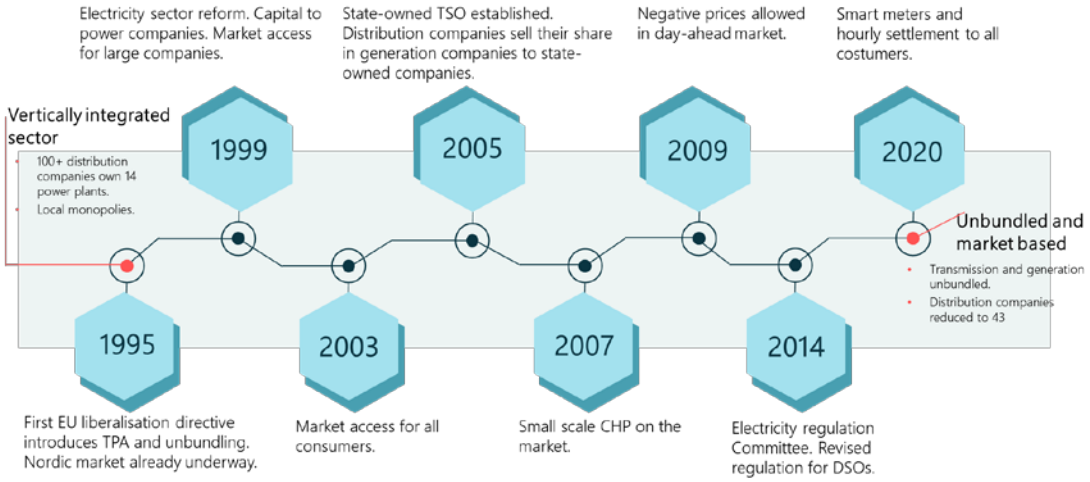


Figure 1. Overview of the Danish liberalisation process

DSOs are responsible for the distribution grid and for metering electricity demand (done via remote metering) and sending this data to the Datahub. Electricity suppliers, balance responsible entities and the TSO can extract relevant data from the Datahub.

See Figure 2 for a simplified representation of the key market participants.

[1] Forsyningstilsynet, 2019.

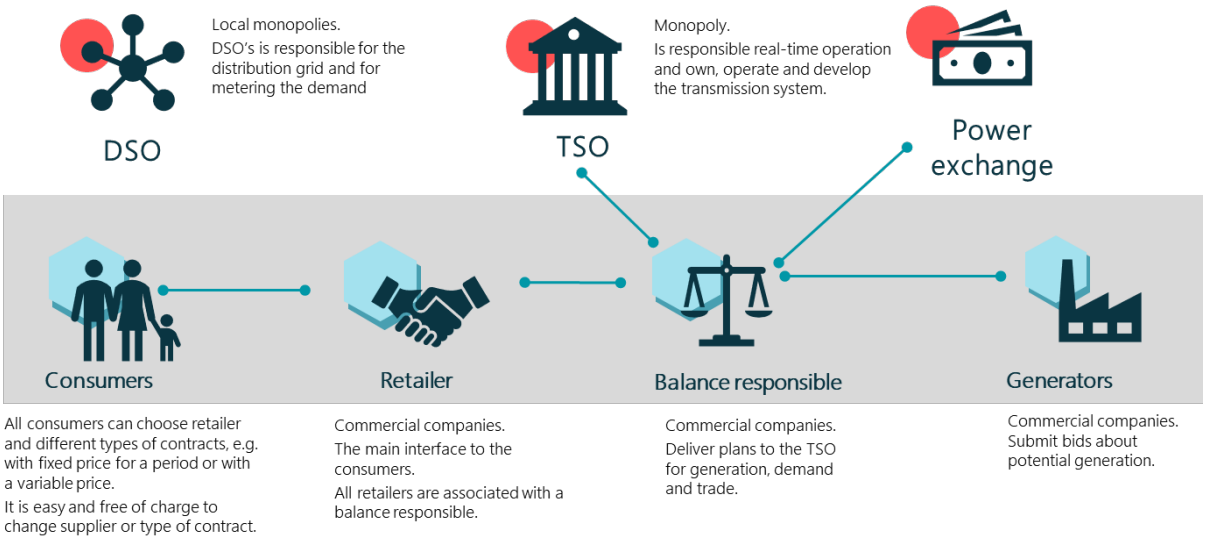


Figure 2. Key participants in today's electricity system. The consumer has limited contact with the DSO. The DSO is responsible for grid and meters.

Key learnings from the liberalisation process, 1995-2020

Chapter 1 of the current report details the liberalisation process of the Danish electricity sector, while Chapter 2 presents selected learnings from this process. Key aspects include:

- The 1999 establishment of a neutral TSO with ownership of the transmission system and the task of designing market rules was an important milestone. A key aspect here was the separation of generator companies and the TSO.
- An agreement, also reached in 1999, that prepared electricity generators for the new commercial world. As part of the agreement, capital was transferred to the generators. This was a political process that was deemed necessary to ensure a good start under the new regulatory regime.
- Competition from neighbouring countries, which has been critical for a well-functioning day-ahead market. This competition has been aided by the investment in several new cross-border transmission lines.
- Many additional steps taken to further develop the market, such as:
    - Making revenue from the market the main income for distributed generation (i.e. natural gas-based CHP units),
    - Transitioning from subsidy systems for wind power centred on fixed feed-in-tariffs to a system based on market prices plus a premium premium awarded through tendering mechanisms,
    - Allowing negative prices in the day-ahead market,
    - Coordination of 23 countries' day-ahead markets, making electricity a true commodity in the EU internal market, and an

  - Full integration of the European intra-day markets and an ongoing harmonization of the markets for ancillary services is broadening the areas of cross-border competition.
- Investment in modern electricity meters with hourly measurements for all consumers. The process will be completed by the end of 2020.
- Regulation of the monopolies (mainly DSOs). This has been complicated and has changed several times.
- Consumers having a relatively passive role in the process. Household consumers have shown little interest in understanding the new possibilities and changing contract type or supplier. For nearly all consumers, demand response is still in a very early stage of development, but hourly settlement may create more interest.

1. Liberalisation process

In Europe, the idea of a market for electricity started in the UK during Margaret Thatcher's tenure in the 1980s. In Norway, economists had some of the same ideas to de-incentivise over-investment in local hydropower. In the EU, the EU Commission wanted to expand the union from predominantly trade to other areas in order to further integration and economic prosperity. These trends started the outward push for liberalisation in Denmark, and to this day EU regulation to further integrate the European energy markets has been the dominant driver in Denmark.

Introducing competition in the power sector can be a way to increase the efficiency[2] of the sector as well as allowing access to private capital. Some key features of an ideal liberalised power sector are:

- Unbundling, as this ensures that the transmission grid supports competition to the largest extent possible. Owners of generator capacity must not be able to limit competition by controlling the use of the transmission grid.
- Hourly dispatch according to marginal costs for all generation technologies.
- Competition, as this ensures an adequate generator fleet in terms of dispatchable capacity, ability to deliver ancillary services, and compliance with environmental and climate goals.

While these aspects are easy to understand, the process of implementing them can be complex. Going from vertically integrated companies (generation, distribution, sales) to an unbundled setup with commercial units (generation and sales) and regulated monopolies (transmission and distribution) can have winners and losers – and may require difficult compromises. Strong interests may work against the changes.

In Denmark, the liberalisation process started in 1996 and development of regulation is still ongoing. In recent years, regulation of monopolies (DSOs and TSO) and developing the retail market have been in focus.

During the beginning of the liberalisation, Denmark experienced low growth in electricity demand (in the order of 1% p.a.) and over-capacity existed. The over-capacity was a result of favourable regulation of the generators (companies could collect 75% of investment costs from consumers in advance), but also due to a policy with a clear national focus: Denmark should be able to supply its peak electricity demand on its own.

Table 1 illustrates the key roles and, those responsible, before and after the liberalisation.

[2] By "efficiency" we mean that the service is delivered at low costs, this include all parts of the power sector, including choice of technology, number of staff etc.

Electricity sector	Pre 1996		Now 2020	
	Structure	**Price-regulation**	**Structure**	**Price-regulation**
Production	Local monopoly Vertically integrated	Non-profit Only necessary costs included in prices Monitored by Regulator	Commercial	General antitrust regulation EU regulation: REMIT
Transmission			Monopoly	Non-profit. Only necessary costs.
Distribution			Monopoly	Cost-caps monitored by Regulator
Suppliers	-	-	Commercial	General antitrust regulation EU regulation: REMIT

Table 1. Overview of the Danish electricity sector – before and after liberalisation.

Step by step

Before the liberalisation process began in the 1990s, the Danish electricity sector was comprised of local monopoly companies. From 1977, these companies were regulated by the Electricity Act, which stipulated that the sector should be operated on a non-profit basis (only necessary costs could be included in consumer prices). Prices and tariffs were monitored by a public regulator. New transmission and production capacity could only be established with approval from authorities, and companies could collect 75% of investment costs from consumers in advance.

For the generator companies during the monopoly times, priority was placed on security of supply, and for each company to supply “their” area and “their” consumers. Power exchange with neighbouring areas/countries took place when there were mutual benefits, and this benefit was shared between the two parties via mutual agreement.

Transition to a liberalised market-based system was/is a fundamental change, upending all the well-known structures, as well as thinking and culture in the sector. Hence, it has been a decades long, step by step, process with a number of milestones underway (see textbox below).

Milestones in regulation of the electricity sector

1991: First proposal for EU Directive for the internal electricity market.

1993: Revised proposal for EU Directive for the internal electricity market.

1996: EU Directive for the internal electricity market is adopted: Gradual market opening (3 phases) starting with consumers over 100 GWh/year

Market access for consumers over 100 GWh/year implemented in Danish law.

1999: Comprehensive law reform for the Danish electricity sector: New basic structure and regulation of companies. Transmission and distribution of electricity will continue to be natural monopolies separated from the new market-based activities (production, trade). Market access for consumers over 1 GWh/year by the end of 2000 and for all consumers by the end of 2002. Establishment of a new regulator.

Political agreement on economy of power companies. Due to relatively low electricity prices it was considered necessary to bolster power producers financially when transitioning from a non-profit to market-based system. In return, the power companies in East (Elkraft) and West Denmark (Elsam) agreed to merge.

2000/01: Implementation of opening balances and revenue caps for transmission companies (2000) and distribution companies (2001).

2003: New EU Directive for the internal electricity market. The directive establishes common rules for production, transmission and distribution of electricity, rules on how the electricity sector should be organised and function, and on market access. It establishes criteria and procedures for procurement, for licensing and for operating networks.

2004: Comprehensive Danish electricity law reform package based on a broad political agreement. It implemented the new EU Directive and, importantly, allowed companies to dispose of equity that until then had been tied up in the companies. In return, the companies transferred ownership of transmission networks and the TSO to the state. A new state-owned national TSO for electricity and gas (Energinet.dk) was established. The new regulation started a wave of sales and mergers that fundamentally changed the ownership structure of the Danish energy sector.

2007: The EU Commission presents the 3rd Liberalisation Package - with proposals to improve conditions for access to the grid in connection with cross-border electricity trade, separation of ownership of production, transmission and trade-activities, as well as proposals for a new regulation establishing a European Agency for Cooperation between Energy Regulators (ACER).

2010: Energinet is tasked to establish a Datahub - a central register from which market players can obtain all relevant measurement data for billing purposes and to handle supplier changes.

2011: EU Regulation on wholesale energy market integrity and transparency (REMIT). This strengthens the role of regulators in order to prevent abuse and promote open and fair competition in the wholesale energy markets, and to ensure consumer confidence in the integrity of the electricity and gas markets. This is implemented into Danish law in 2013.

2014: Following recommendations from an external Electricity Regulation Committee “supplier of last resort” (*forsyningspligt*) is abolished and replaced by a supply obligation, which obliges all electricity trading companies to supply electricity to all household consumers for a fee.

2019: The regulator publishes a study about transparency and neutrality of DSOs.

Denmark's trade with its neighbours has been continuously increasing over the last decades (see Figure 4 below). Transmission capacity between countries and market areas has increased significantly during the period, while large annual variations have been motivated by wet and dry years in hydropower-dominated Norway and Sweden. Also, before liberalisation, regional trade between countries was largely based on bilateral trade between utilities.

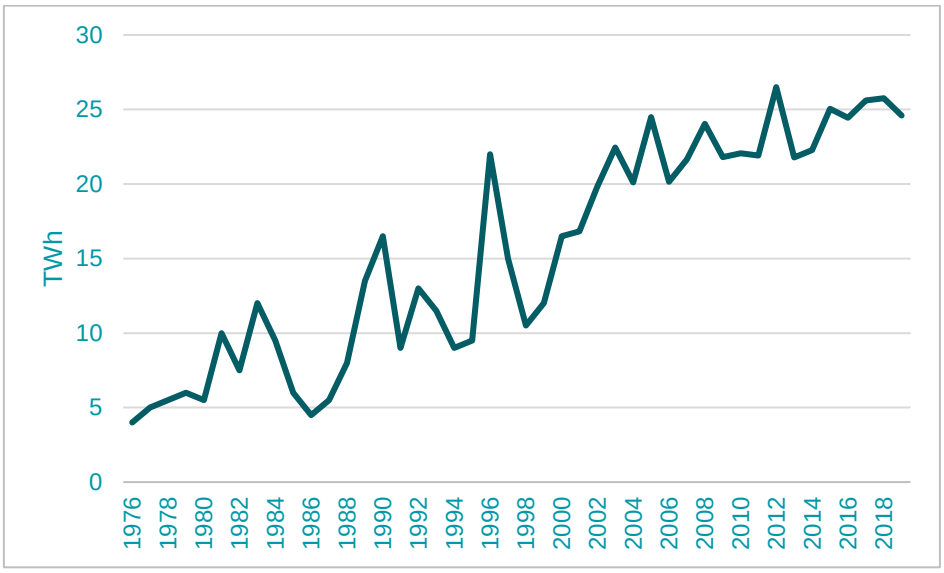


Figure 3: Indicator for trade. Sum of all import and export. Source: Data from 1976- 2000 from: (Jakobsen, 2007). Data from 2001-2019 from Energinet

Unbundling

In a vertically integrated setup, one company generates, transmits, distributes, and sells electricity to a specific area. This can be part of a centrally planned system where rules are in place to secure efficient operation. In such a system it may be challenging that the company tends to prefer its own generation as opposed to import, or that new generation technology may find it difficult to become connected to the system.

Like 3rd party access, "unbundling" is an important step in liberalising the power system. Electricity transmission is separated from the generators, and it may also mean that distribution is separated from suppliers. The infrastructure (the grid) is therefore neutral and can be used by any actor, such as new generation or generators from neighbouring countries.

In Denmark, the transmission grid is owned and operated by a state-owned Transmission System Operator (TSO). In other countries (e.g. in the USA), the grid can be owned by private companies, but the operation is controlled by an Independent System Operator (ISO). Both setups secure open access to the grid, including competition across technologies, and among local and foreign actors.

Type of unbundling	
Ownership unbundling	Suppliers cannot be owned by a DSO or have ownership relations to a DSO.
Legal and functional unbundling	Separate companies, separate executive boards (board members can overlap)
Identity unbundling	This was introduced in 2017. DSO and supplier must have names and logos that cannot be confused

Example of identity unbundling (CEER, 2019):

Supplier (and incumbent company)	Old DSO logo	New DSO logo
seas-nve	seas-nve	cerius

1.1. Starting point is 1995

The point of departure for this review is the state of the Danish electricity sector in 1995. Features of the Danish system in 1995 included:

- Distribution companies were local monopolies and were either cooperatives owned by the consumers or companies owned by municipalities. In 1995, there were more than 200 distribution companies (Copenhagen Economics, 2014). By 2019, this number was reduced to 43. Regulation has only created a moderate incentive for mergers.
- Distribution companies owned the generation companies, and these generators cooperated in two regional companies to undertake the daily operation and planning: Elsam (in West Denmark) and Elkraft (in East Denmark). This was a natural partition, as prior to 2010, West and East Denmark were not interconnected.
- Regulation had secured that the companies were well-consolidated. Generation companies could collect funds for future investments. The value of the electricity companies was estimated to be between 15 and 20 billion USD, and their debt was roughly 1 billion USD (Miljø og Energiministeriet, 1995).

Liberalisation of the Danish electricity sector has partly been motivated by developments in the other Nordic countries. Major steps in the direction of open competition was taken by Norway in 1991, by Sweden in 1994, and by Finland in 1996.

In 1995, the Energy Ministers from Denmark, Norway, Sweden and Finland[3] signed the *Louisiana declaration* in Denmark indicating a future with free and open markets without borders. Co-ordinated market development in the Nordic area was also considered a way to influence EU regulation. *Today, it can be concluded that EU regulation on day-ahead markets seems to be highly inspired by the Nordic power exchange Nord Pool[4].*

Nord Pool was established in 1996 by Norway and Sweden. Finland joined in 1998 and Denmark in 1999/2000. All transmission capacity between price zones is allocated to Nord Pool for the day-ahead market. Bilateral trade can take place, but only within the same price area.[5] This rule led to high liquidity in Nord Pool. Today, the day-ahead market is integrated across 23 EU countries and the generation structure is much more complex with significant shares of wind and solar powe. *Operation of the current system would have been very challenging without the international electricity market. In a large, interconnected system with a high number of variable and only partly predictable generators an optimal dispatch can no longer be based on a phone call or two[6].*

Case: Trade between Sweden and Denmark East – before liberalisation

The Nordic cooperation, Nordel (cooperation of Nordic generators – which also owned transmission), developed the rules for how power could be exchanged between countries. The system was based on trust and each side should present their marginal costs for decreasing or increasing their local generation.

In East Denmark, Elkraft supplied these prices based on a detailed model of the cost structure of the local thermal power plants. On the Swedish side, Vattenfall and Sydkraft supplied marginal prices from their system. The Swedish system consisted of nuclear and hydro (~50% of each) so the marginal price was dependent on the *water values*. The water value indicates the minimum price where (the limited) water inflow should be used.

Trade took place continuously (hour by hour) when the two sides found it attractive. Nordel rules were used to compute the price, which was the midway point between the marginal prices of the two sides.

After Nord Pool was established in Sweden (in 1996), and until Nord Pool was opened in East Denmark (2000), Elkraft traded as foreign trader on the Swedish market. The trade with Sweden was quite dynamic (hour by hour) as in the liberalised system, however trade was

[3] The Nordic Council of Energy Ministers
[4] Peter Jørgensen, Energinet.
[5] The Nordic day-ahead market is a zonal pricing system. See Danish Energy Agency (2020) for description of zonal pricing and nodal pricing systems.
[6] Peter Jørgensen, Energinet.

limited to a few market actors. The trade was especially high in dry and wet years in the Norwegian system.

The power exchange and the procedures dated back prior to the establishment of Elkraft in 1978.[7] Trade between West Denmark and Norway, Sweden and Germany were based on similar principles.

1.2. 1995-1998: Third party access and unbundling

The first time the EU described liberalisation of the electricity sector was in the 1988 green paper about *the internal energy market*. Key points introduced in this paper included:

- Open access to the transmission grids
- Removal of monopoly status for generator companies
- Unbundling into generation, transmission and distribution.

The green paper indicated that liberalisation could save up to 12% of total costs (Petersen & Rüdinger, 2009).

In 1988, there was broad scepticism against liberalisation of the power sector. In many countries, as in Denmark, the scepticism existed until 1995/96. In a 1995 report from PA consulting, initiated by Danish generator companies, unbundling was recommended, and this started a shift away from the scepticism (Petersen & Rüdinger, 2009). The opportunity for a generator to sell power across borders when the price was high was an incentive for generators to move from bilateral contracts to selling via the market.

In 1995, a newly established trader, Dansk Kraftimport, asked for permission to import electricity to East Denmark. At this time, Elkraft had the right to all import/export, and a long legal dispute started. This process garnered political attention, and it was clear that the existing regulation could not resolve the conflict.

During the 1990s, when most national electricity and natural gas markets were still monopolised, the European Union and the Member States decided to open these markets gradually to competition. The first liberalisation directives (First Energy Package) were adopted in 1996 (electricity) and 1998 (gas), to be transposed into Member States' legal systems by 1998 (electricity) and 2000 (gas).

In 1996, the first law governing liberalisation of the electricity market was passed by the Danish Parliament. This included a right to third party access to the grid and the idea of establishing a

[7] Based on an interview with Hans-Henrik Clod-Svensson, who oversaw operation at Elkraft from 1978 to 2004.

TSO. As mandated by the EU Liberalisation Directive, consumers with a demand above 100 GWh could now enter into electricity contracts with a supplier of their choice. However, at the time only six Danish companies exceeded this threshold.

In 1997, the association of Danish power companies (DEF) published a report recommending liberalisation and full competition. The report was a turning point for the power sector (Petersen & Rüdinger, 2009). The general attitude in the power sector was now to go beyond the EU directive and the Danish law - both from 1996. Generation companies saw the potential for less government control in a market system.

1.3. 1999: Electricity sector reform and capital to generator companies

In 1999, a broad political agreement was reached on a legislative reform of the electricity sector, and later that year the agreement was implemented into law. The agreement aimed at a clear separation between tasks relating to public obligations and commercial activities in the electricity sector and built on the decentralised structure with municipal or consumer-owned electricity companies. Two TSOs were established in West and East Denmark (Eltra and Elkraft System respectively), which took over coordination, including dispatch and system planning, from the generation companies.

The aim of the agreement was also to promote efficiency in the electricity sector through increased competition and more efficient price regulation of the monopoly portions of the sector. In order to do so, *income cap regulation* was introduced for the distribution companies. The framework was established in such a fashion that the regulator determined the cap for each company's revenue for each year, and this cap should reflect the company's efficiency potential.

As part of the agreement, more consumers could now choose their electricity supplier. I.e. in 2000 only consumers with an annual demand above 10 GWh could select their supplier, a figure that was reduced to 1 GWh in 2001, and by 2003 all consumers were free to do so.

In 1999, an addition to the reform agreement made it possible to transfer capital from the TSOs to the generation companies. The fundamental financial ambition for the TSOs was that TSO costs should be financed by the transmission tariff paid by the consumers. But some additional costs were imposed on the TSO to support the generation companies in the transition phase. In principle, this could also have been funded by the state budget which would lead to the taxpayers covering the costs instead of the electricity consumers. The taxpayers and the electricity consumers are to a very large extent the same people and institutions although the bill is shared differently in the two cases.

Under the reform agreement, the generation companies had to cover costs, including costs imposed on the companies during monopoly times. These costs included:

- Stranded costs (take-or-pay gas purchase agreements, scrapping of old power plants, pension liabilities),
- Fulfilment of supply obligations to district heating customers at reasonable prices. CHP plants might have to produce (to meet heat demand) when it was not feasible in the electricity market - without being able to raise heat prices
- Utilization of biomass and expansion with wind power since these technologies were not competitive at the time but were required to be developed to fulfil the political goals.

During 1999 however, generation companies raised concerns that they would not be financially able to meet these obligations without risking bankruptcy.

A group of experts from the generation sector, the Danish Energy Agency and the Ministries of Economy and Finance was tasked with analysing the economy of the generator sector.

The experts ascertained that the power plants would start with a net debt of approx. €400 million at the beginning of 2000. Since the power plants did not have savings or reserves to draw on, it was crucial how revenues and expenses developed in the short run. Due to the low prices in the electricity market at the time, there would be no significant profit margin at the power plants, as the marginal cost of the plants was at the same level as the electricity sales price. If this continued for an extended period, the power plants would not be able to cover their fixed costs.

Thus - with the assumptions used – the generation sector would start with a negative earning capacity, so that the net debt of approx. €400 million would grow initially - partly because of the low electricity price and partly because of residual investment in plants under construction. Around 2006, the net debt was estimated to be approx. €1.9 billion, after which the development would reverse.

Based on the calculations of the group of experts, the Government and a majority of Parliament agreed that the power plants would not be able to bear stranded costs and costs associated with meeting environmental obligations without an enhanced earning ability to and a strengthened capital base.

Thus, it was agreed that generation plants should be compensated for extra costs for environmentally friendly electricity generation and gas purchase agreements by:

- Existing RE plants owned by generation companies should be given green certificates for their electricity generation.
- Existing RE and small-scale natural gas-fired CHP plants owned by generation companies would also receive a regulated subsidy (a supplement to the sales price) for a four-year transition period.

- The generator companies would be compensated for stranded costs of gas purchase commitments.

In addition, the generation companies would have the opportunity to strengthen the capital base by:

- The generation companies were allowed to keep unused deposits, whereas before the liberalization the vertically integrated entities were obliged to return unused deposits to the consumers.
- Revaluation of transmission networks (in the opening balances for transmission networks, etc. when transitioning from the non-profit price regulation to the new price regulation) could be capitalized,
- The generation companies should receive payment for ancillary services from the TSOs in connection with the TSOs taking over responsibility for the security of supply.

The TSOs and the transmission network companies were to finance this capital injection by raising loans.

Generation companies received in total €1.2 billion to ensure that they would be able to operate in the future market. The costs were collected by the TSOs during a ten-year period to reduce the short-term impact on consumers.

In accordance with EU regulation, the funds were allocated for the purposes stated above, such as subsidies to wind turbines and small natural gas-based CHPs, and an obligation of future pension costs. Based on a Danish initiative, the EU Directive from 1996 stated that Service of General Interest also included environmental concerns - later transferred to the current Public Service Obligation (PSO). This has since driven the Danish green transition, e.g. subsidies to wind turbines (see section 1.4 below).

In return for the capital transfer (and as part of the agreement), generator companies accepted to merge into two companies, one on each side of the Great Belt (West and East Denmark). Due to the economic situation at the time it was considered essential that possible efficiency gains were realized as quickly as possible. In addition to this, some of the obligations imposed during monopoly times were put on the two groups of generator companies (ELSAM and Elkraft respectively) and by merging the companies within these groups it was not necessary to go through a complicated split of the obligations between individual companies.

For the two TSOs, the task of designing the market was formidable. Many aspects were not defined in the laws but were developed based on inspiration from Norway and Sweden. The TSOs established the new role of balance responsible parties. A balance responsible must present a plan for the hourly demand and generation the day before operation and is financially responsible for injections and withdrawals of electricity according to these plans. During the operating

hour, the TSOs would buy regulating power to balance the system if needed. The cost of this balancing power would then be distributed among the balance responsible parties based on their actual imbalances. The distribution of costs in this fashion was designed to create incentive "to be in balance". A common Nordic market for regulating power, particularly access to low-cost hydro-based regulating power in Sweden and Norway, has been key for enabling relatively low costs of imbalances in Denmark.

1.4. 2000-2005: Separate arrangement for "prioritised" electricity

For a long period of time, electricity from small natural gas-based CHP units and wind turbines was managed in a separate system. The amount generated by these prioritised sources was computed and all consumers were obliged to buy a share of their electricity demand at a regulated price.

In 2005, the system was simplified such that all electricity was sold on the free market, but a special tariff was introduced to collect the subsidy for the prioritised generation, the Public Service Obligation (PSO). However, in 2014 the EU deemed part of this set-up in violation of the EU Treaty, and as a result the costs are to be transferred from the TSO tariff to the state budget. This process started in 2017 and will gradually be implemented by 2022.

1.5. 2004: New ownership, TSO merger and new DSO regulation

In 2004, a major revision of the electricity law was passed by the Danish Parliament. The two TSOs in Denmark: Eltra in West and Elkraft in East were merged into one TSO (Energinet). Energinet was formed as the TSO for both electricity and gas. The ownership of the transmission grid was transferred to the state by the previous owners (cooperatives and municipalities). In return for this transfer of ownership, regulation that disincentivised selling of generator companies was abolished, and new regulation was passed that allowed cooperatives and municipalities to keep the proceeds in case they chose to sell their shares in the generator companies.

This resulted in a huge sell-off, initially to the dominant Danish and Swedish state-owned generator companies Dong Energy and Vattenfall. Today, Ørsted (previously Dong Energy) has consolidated its role as the largest Danish generation company. In 2014, a minority share of the company was divested to private investors, and in 2016 Dong Energy was listed in the stock market. The Danish government still owns a majority share.

Case: Merger of two large generation companies – and the competition authority

In 2004, ELSAM and NESA was merged and the process was closely investigated by the Competition Authority (today: Danish Competition and Consumer Authority). A number of actions were defined as part of the merger to secure that competition was not affected negatively.

ELSAM was owned by 45 municipalities and DSOs from West Denmark. The company had 3,500 MW of large power plants, 400 MW of distributed CHPs and 400 MW of wind turbines. The ELSAM owners also had shares in suppliers. NESA was a DSO in the Copenhagen area (East Denmark) that also owned some generation (52 MW small CHP) as well as shares in the large East Danish generation company E2, and supplier activities. NESA was a shareholder company with two municipalities as the major shareholders.

In order to maintain competition after the merger, mandated actions included:

- The sale of all small CHP's
- 600 MW of capacity would be offered as *virtual power plants*: Auctions were to be held where other actors could control this capacity. This process can be seen as a way to increase competition, and because the winner of the auction does not have to own or operate the capacity more bidders can be expected.
- Shares in Elkraft (TSO for East Denmark) were sold to the state.

The authority studied the competition in the Nordic electricity market, e.g. hours with congestion, and concluded that with the above actions undertaken, the merger could be allowed (Konkurrencetilsynet, 2004).

As a result of the new financial freedom for the distribution companies, economic regulation was revised. Since 2000, electricity distribution companies had been subject to income caps based on necessary costs assuming an efficient operation of the company. Under the new regulation, a company's income could not increase based on tariffs per January 2004, calculated at real prices and unchanged activity level and assuming efficient operation. Future income caps for the grid companies were set based on the companies' 2004 revenues.

Case: From private transmission lines to full market operation

A well-functioning electricity market requires competition. In Denmark, cross-border trade and thus competition from electricity generators and electricity traders in neighbouring countries was an important element of market opening. Prior to the market opening, a large portion of the transmission capacity on the international connections was reserved for long-term contracts between the vertically integrated electricity companies. In connection with the market

opening, the TSOs freed up capacity on the links between the countries so that it could be made available for day-ahead trading. The transmission system operators thus allocated the trading capacity for spot market exchanges between countries and price areas.

In 1991, Vattenfall and Energi E2 (Swedish and Danish generation companies) agreed on establishing the 600 MW DC cable between East Denmark and Germany, and the cable came into operation in 1996. Under the agreement, Vattenfall had the right to transport 350 MW to Germany. In 1999, Energi E2's ownership was transferred to Elkraft (the TSO in East Denmark at the time), and Vattenfall's right to transport was maintained.

When the day-ahead markets developed on both sides of the connection, it was agreed to hand over the capacity to the market. This took place in three agreements from 2003, 2005 and 2006. For a period, Vattenfall received part of the congestion rents (price difference between the two sides) generated by the connection. Starting in 2003, direct auctions were held by Energinet for use of the line, and from 2010 the day-ahead markets in Denmark and Germany were fully integrated (referred to as implicit auction of the transmission capacity) (Højesteret, 2013).

1.6. 2005-2010: Small CHP on the market and negative prices

Natural gas-based combined heat and power (CHP) had earlier been paid with a time-of-use tariff (TOU). The tariff was developed to motivate environmental and distributed generation. Hundreds of such units were installed in Denmark, supplying heat to local district heating systems, and the total capacity today is roughly 1,900 MW. A new system was then introduced which combined a capacity payment with income from electricity sold on the market. In 2005, units with greater than 10 MW of capacity were put on this market, and this limit was reduced to 5 MW in 2007. Starting in 2018, the sole source of income from electricity production for all CHP units is from the market, while additional income is generated from the sale of heat to local district heating systems.

In the day-ahead market, the price in a specific area during a specific hour represents the marginal cost. I.e. increasing demand with 1 kWh would result in additional generation from the lowest cost unit with un-used capacity. Varying electricity prices illustrate the varying value of electricity.

Prior to 2009, spot prices could not be less than zero, which meant that in periods with excess electricity generation (e.g. from wind power, which due to subsides could have a negative marginal cost), a market price could not be found directly. To solve this, all generation was asked to reduce proportionally. With the introduction of negative prices, it becomes a competition of

whom can reduce generation at the lowest cost. Start/stop costs may result in power plants having to accept negative prices for a short period of time. Negative prices have led to improvements in the dynamic operation of traditional generation. For example, some coal-based power plants now have minimum generation as low as 10% of full load. Improvements in the dynamics of existing power plants are described in: (DEA, 2015), (Agora-Energiewende, 2017) and (Clean Energy Ministerial, 2018).

1.7. 2010-2015: West and East Denmark interconnected and international coordination

In 2010, a 600 MW DC line across the Great Belt between West and East Denmark opened and the two areas were directly connected for the first time (see Figure 4).

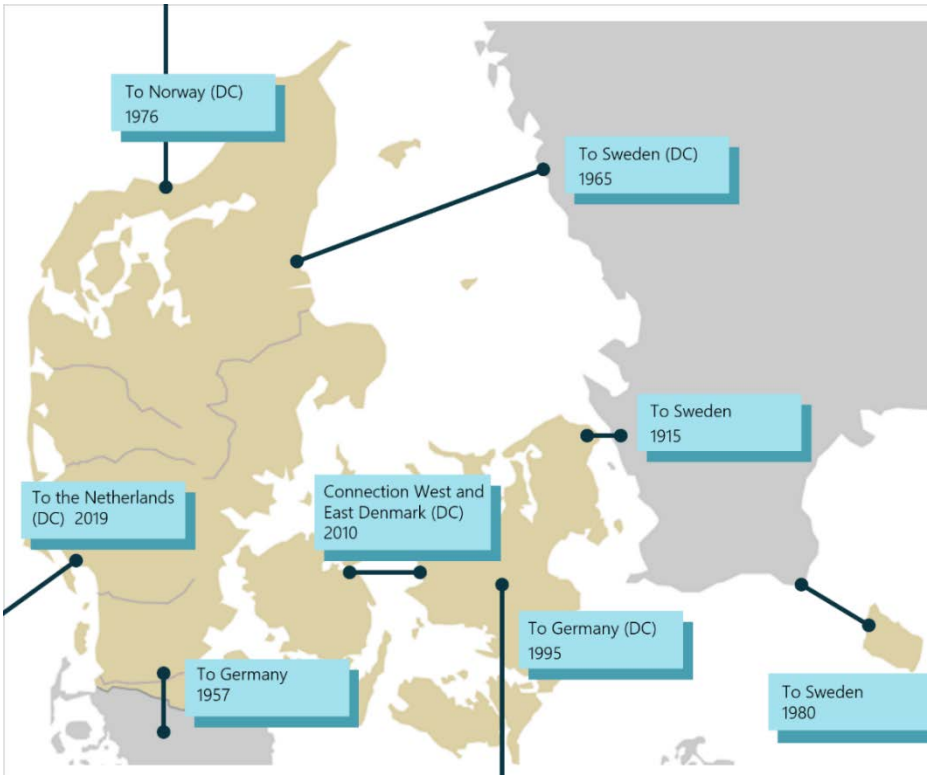


Figure 4. Internal and external transmission lines and the year of commission.

European integration of day-ahead markets developed during 2010-2015. Today, 23 countries in the EU have a common day-ahead market, from Norway to Portugal and Poland to Ireland (see Figure 5). A bid in one of the involved price areas will have impact in other areas, depending on the available transmission capacity. Because the large number of market participants and the variation in generation technology, the large market is seen as a significant improvement in terms of competition. Large investments are underway to increase the transmission capacity, e.g. three DC lines are being established from the north of Germany (home to ample wind and solar power capacity) to the demand centres in southern Germany.

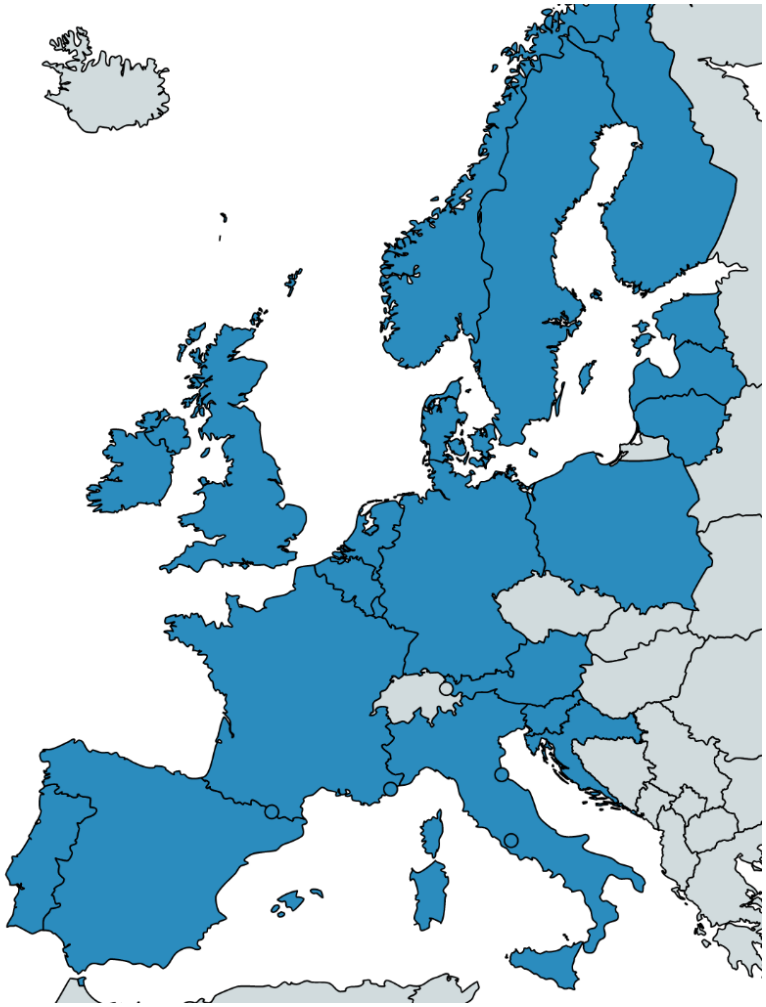


Figure 5: Countries with fully Integrated day-ahead markets. 23 countries, and an electricity demand of 2,900 TWh /year. (ENTSO-E)

Similar EU initiatives are underway, including making the intra-day and ancillary services markets coordinated over large areas. In June of 2018, single intraday coupling (SIDC) was launched. SIDC creates a single EU cross-zonal intraday electricity market. In simple terms, buyers and sellers of energy can work together across Europe to trade electricity continuously on the day the energy is needed. Today, 14 countries are participating, the Nordic and Baltic countries, Belgium, France, the Netherlands, Spain, Portugal, Germany and Austria. Seven countries are expected to join soon (see Figure 6).

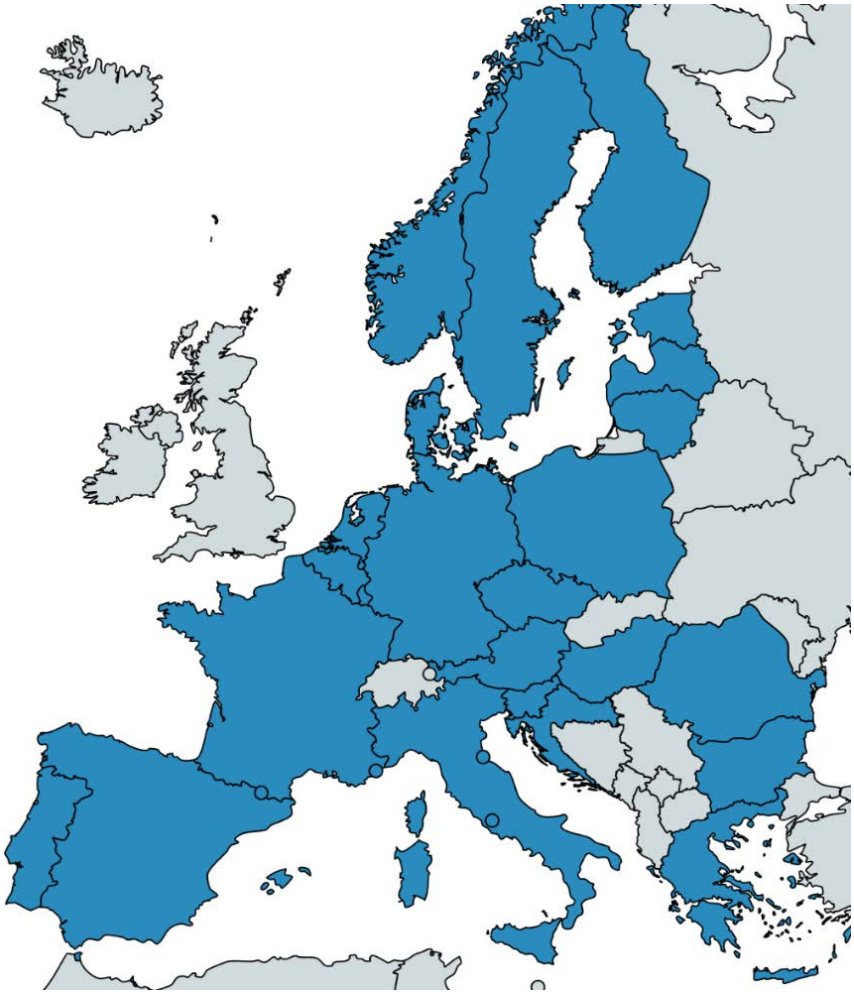


Figure 6. Coordinated intra-day markets

With the increasing amount of variable renewable production, interest in trading in the intraday markets is increasing, as it can become increasingly challenging for market participants to be in balance after close of the day-ahead market. Maintaining balance on the network closer to delivery time is beneficial for market participants and for the power systems alike, due to for example reducing the need for reserves and associated costs. In addition, the intraday market is an essential tool that allows market participants to take unexpected changes in consumption and outages into account.[8]

1.8. 2014: Electricity Regulation Committee

As part of a political agreement in 2012[9], an independent Committee[10] tasked with analysing the regulation of the Danish electricity sector was established. It was to, among other things, investigate whether the current regulation supported effective competition in the electricity market,

[8] See: en.energinet.dk/About-our-news/News/2019/06/13/xbid-first-anniversary-and-second-golive
[9] Agreement 22 March 2012 between the Government and four opposition parties on Danish Energy Policy 2012-2020
[10] Udvalg for el-reguleringseftersynet

while ensuring the necessary consumer protection. In addition, it should investigate incentives towards efficiency in the electricity sector, particularly whether the financial regulation of the monopolies (distribution companies and Energinet) provided sufficient incentives for efficiency improvements. The Minister appointed energy experts, sector representatives, consumer representatives and green organisations as members of the Committee.

Since the 2004 revision of the income-cap regulation, it had been amended a number of times (4 times between 2005 and 2011). In addition to the income cap, companies were also subject to a rate of return ceiling and to benchmarking. Regardless of their income caps the companies could not exceed the maximum stated rate of return on their grid assets (plus a turnover capital of 2 per cent). Benchmarking determined the level of costs that, for each distribution company, meant efficient operation. If the actual costs of the company were higher than this, the company would be required to increase efficiency. The requirement was implemented as a permanent reduction in the income cap.

However, this regulation was deemed inflexible and lacking the proper incentives. The Committee therefore proposed a new set-up where income-caps shall consist of 1) cost framework, 2) rate of return and 3) possibility of penalties for insufficient quality of delivery. Five-year regulatory periods were introduced, where the overall framework for the income caps is established every five years. The cost framework is determined based on average, historical, total operating costs and depreciations during the previous regulatory period. The cost framework is continuously adjusted for efficiency requirements and exogenous factors including changed activities, changed activity level, price development and grid losses. The companies are also subject to individual efficiency requirements determined by benchmarking (see Figure 7).

In the new regulation, the rate of return ceiling is to be abolished and the rate of return must instead be included as a component of the income cap. The return on the historical asset base must be determined based on the historically possible rate of return for the distribution companies. The return on the future asset base must be determined based on a market-based Weighted Average Cost of Capital (WACC) determined by the Regulator.

A main result of the Committee's work was a 2014 law that abolished the system from 1999, where consumers who did not select a supplier in the market were supplied by a "supplier of last resort" (a supplier with a license to supply in a specific area) at regulated prices. This law was replaced by a general obligation on trading companies to supply customers who requested it.

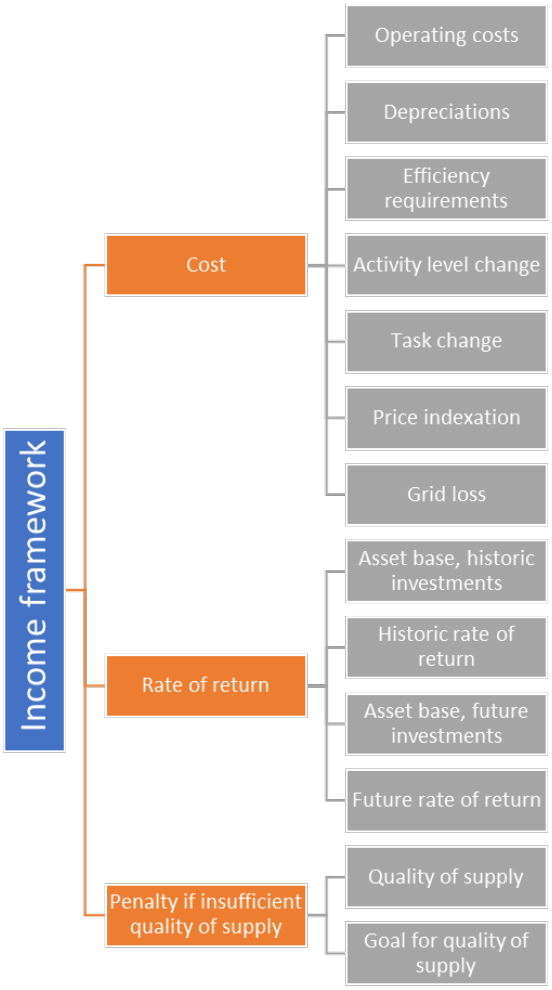


Figure 7. Elements of proposed income regulation for distribution companies.

In 2016 the supplier-centric model was introduced (where all communication from customers goes to the supplier and the DSO is less visible). It proved difficult in practice to develop the data system technology needed, and the implementation had to be postponed several times before coming into effect. A central element of the supplier-centric model is the Datahub (see below). All DSOs will send their measurements of demand to the Datahub and the suppliers can access the data from the Datahub (and not the individual DSO). The consumer will pay the supplier, including electricity taxes, while the supplier will forward money to the DSO (DSO tariffs and taxes) and to the TSO. Finally, the DSO will send the taxes to the Ministry of Taxation. Managing the flow of taxes is complicated and it required long negotiations to reach an agreement. For households, taxes amount to more than 100% of the raw electricity price, so these taxes represent significant amounts.

1.9. 2016-2020: One bill, smart meters and tariffs

Today, suppliers are still dominated by companies with a history based in the old distribution companies. Some independent suppliers have entered the market, however their share of the

total market has been limited by a reluctance to change suppliers, particularly in households. Only between 6-8% of customers select a new electricity supplier each year (with the higher end of the range being large customers). 62% of all electricity is sold to *passive* consumers, i.e. consumers who have not actively selected their supplier (Forsyningstilsynet, 2019).

In Denmark, heating is a major part of the total energy consumption but is typically supplied by district heating or natural gas. Danish households therefore have a relatively small annual electricity demand, which combined with the aforementioned high electricity tax means that the actual market price of electricity represents a relatively small portion of the total electricity bill, thus likely reducing interest in changing electricity supplier or contract type. For example, a typical single-family Danish house (with heating provided via district heating or natural gas) consumes electricity in the order of 4,000 kWh/yr. This costs roughly 1,300 USD (including taxes and VAT), such that the raw electricity price is only 17% of the total. Grid tariffs and taxes except VAT (25%) are fixed and are not influenced by selection of supplier (see Figure 8).

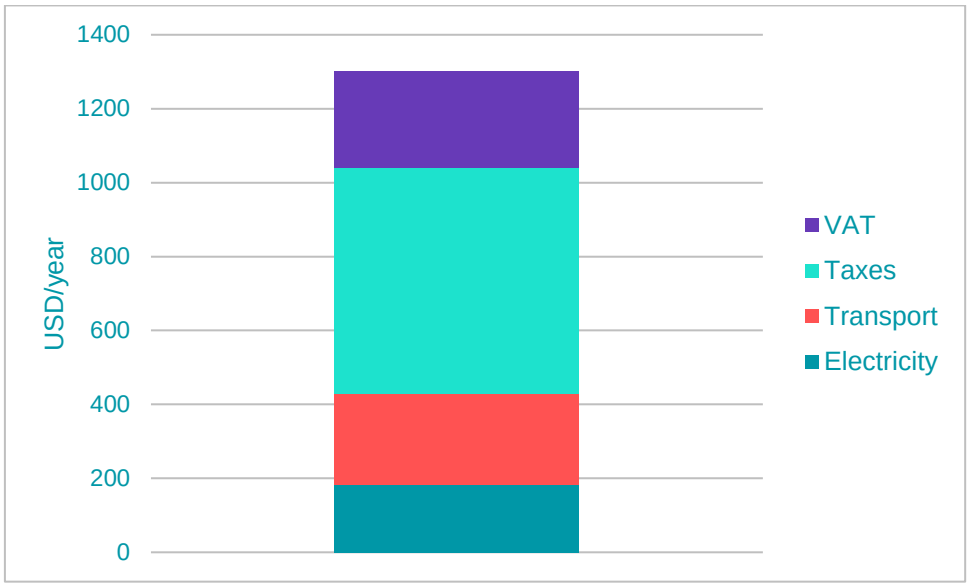


Figure 8. Typical composition of the electricity bill for a Danish household with a 4,000 kWh/year demand.

Until 2016, a consumer who selected a new supplier would receive two electricity bills, one from the distribution company (grid tariff and taxes), and one from the supplier. Today, the system has been simplified for the consumers, and only one bill is sent. The supplier also includes grid tariffs and taxes, and the supplier is thus the only contact for the consumer.

By the end of 2020, all consumers will have smart meters with remote reading and hourly settlement. This will make it possible for customers to buy electricity via innovative contract types, e.g. a spot price with hourly prices. The roll-out of smart meters has partly been motivated by EU regulation.

As an example of technologies that can benefit from hourly prices, heat pumps are available today with a connection to the internet and the ability to gather spot prices, where the user can indicate on a scale from 1 to 5 (separately for space heating and hot water) how sensitively heat generation should be adjusted to prices. Electric vehicles can also be charged in a similar way.

While flat DSO tariffs have been prevailing since 2003, the use of Time of Use (TOU) tariffs is now spreading. For households, TOU tariffs have two steps (see Figure 9 below). The peak period is defined as between 17:00 and 20:00 during the months from October to March. For companies, a three step TOU is used.

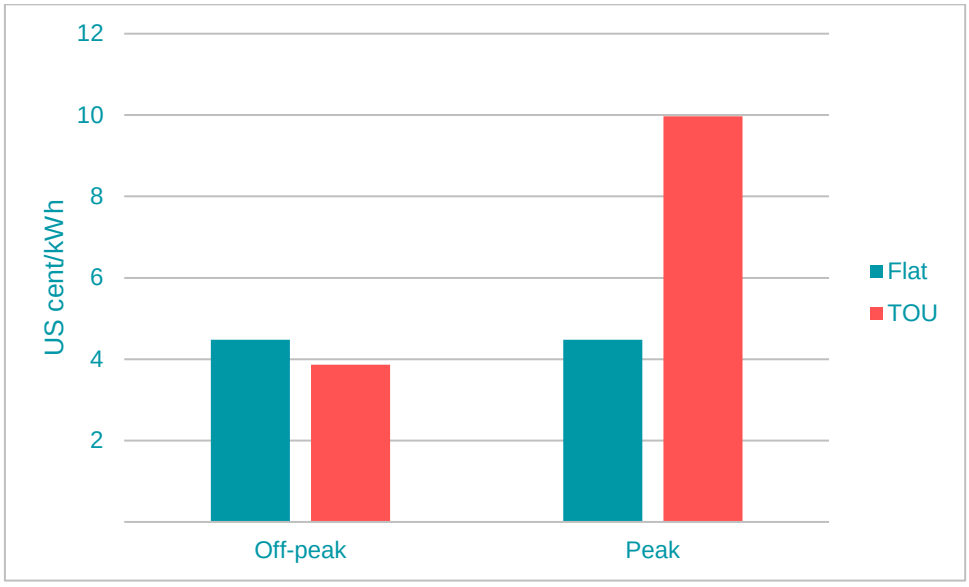


Figure 9. DSO tariffs. Example from the Copenhagen DSO: Radius. The flat tariff is for customers without smart meters, while the time-of-use tariffs (TOU) is for customers with hourly settlement.

1.10. Current market and regulation

Key electricity markets

Today, the main electricity market is the **day-ahead** market. Before 12:00 the day before operation generators and suppliers submit bids to Nord Pool spot market. The typical bid form (hourly bid) indicates that a generator is willing to generate in a specific hour if the price is above X €/MWh. Other forms for bids include block bids covering several hours. Based on the bids and the transmission capacity to other price areas, a price is settled for each hour. The day-ahead markets are coordinated across 23 countries, and in general, competition is strong. The price is settled according to marginal price, so activated generators within a price area will all receive the same price – equal to the most expensive bids that has been activated. Import/export on

transmission lines is determined by the bids in the areas on the two sides of the line (called implicit auctioning[11]). The cleared bids in the day-ahead market is the main basis for the first plan sent to the TSO for the planned operation for the next day.

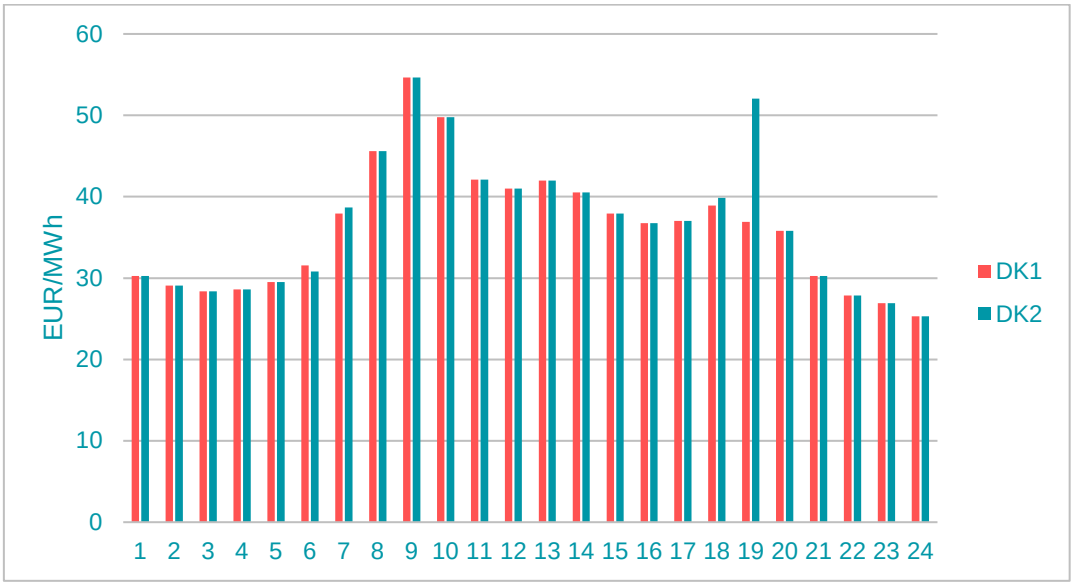
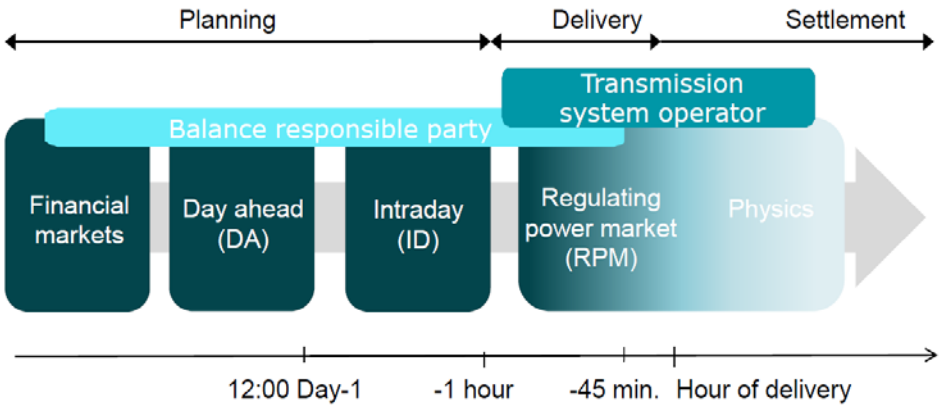


Figure 10. Day-ahead prices, March 5th, 2020. West (DK1) and East (DK2) Denmark. Nord Pool.

Once the day-ahead market is settled, the **intra-day** market will open. Here electricity can be traded until one hour before the operating hour. While the day-ahead market is a coordinated auction for all bids, the intra-day market is based an anonymous, continuous, and bilateral trade (like a stock exchange). When buy and sell bids match, a trade is made. The volume on the intra-day market is increasing but is small compared to the day-ahead market.



[11] It is called *implicit* auction of transmission capacity because the bids that determine the flow on the interconnectors is about the marginal price for potential generation. By minimising the total costs, the relevant bids are activated, respecting the maximum flow on the interconnectors, and this will also determine the actual direction and flow on the interconnectors. Earlier *explicit* bidding has been used, e.g. on the border between Denmark and Germany. See also: Danish Energy Agency and the Electric Power Planning and Engineering Institute (2020).

During the operating hour, the TSO uses **regulating power** to adjust the balance between demand and generation. This is a manual reserve (also called mFRR) that can be activated with 15 minutes notice. The regulation can be up or down. The Nordic countries have a common list (the NOIS list) with bids to be activated as regulating power. If transmission capacity allows, bids can be activated in other price areas. The national TSOs are the only buyers, but there is a rich variety of technologies that offer their bids, including e.g. hydro and small distributed generation and wind power (typically only down regulation for wind).

The most expensive bid for regulating power determines the costs of imbalances (imbalances are deviations from the planned operation). The prices are constructed so the balance responsible has an incentive to be in balance. The large amount of hydro in the Nordic system results in low imbalance costs. Only in a few hours (typically when there is no available import capacity) can the imbalance price be very high.

Financial contracts

For generators, the key market is the day-ahead market as the physical dispatch is determined here. Hour-by-hour a price is found, and the generator will generate via units where this price is above the short-term marginal costs. However, generators can reduce their risk by entering financial contracts. Financial contracts are commercial products that e.g. can be traded on Nasdaq.[12] Many different products exist, and

Table 2 provides some examples. These products are measures against the system price in the day-ahead market. The system price is an artificial reference price that would exist if there was no congestion in the transmission system. As can be seen from the table, years in the near future have the highest trade volume (the open interest indicates the net volume of contracts traded).

Product	Price (€/MWh)	Open interest (MW)
2021	20.55	6,679
2022	23.50	2,409
2023	24.55	1,027
2024	25.74	441
2025	27.35	167
2026	28.42	80
2027	30.39	102
2028	30.57	65
2029	30.72	0

[12] See: www.nasdaq.com/solutions/nordic-power-products-european-commodities
And this for price examples: www.nasdaqomx.com/commodities/market-prices

Table 2. Prices for selected futures. These product covers the system price (see text) for a specific year. Data from March 25th, 2020.

Contracts can also be traded for upcoming quarters, months, weeks and days. It is also possible to buy Electricity Price Area Differentials (EPAD) contracts, which are settled against the price-difference between the system price and the price in a specific area.

In addition, suppliers can use financial contracts to reduce their risk. E.g. it is possible to offer fixed price contracts to consumers by balancing this with a financial contract for the same period. When generators and suppliers use financial contracts to reduce price risk it is called hedging. Investors can also use financial contracts as speculation object, similar to speculating in the future price of other commodities, such as oil, metals, or foodstuffs. Speculation will increase the liquidity of the markets for financial products.

Regulation on Wholesale Energy Market Integrity and Transparency (REMIT)

REMIT is an EU regulation designed to increase the transparency of the European energy markets and adding tools for reducing insider trading and market manipulation. REMIT was adopted in the European Union in 2011. The national regulators and the EU agency ACER has been tasked with the supervision and regulation of energy markets in accordance with REMIT. The functions of the regulation are that it:

- Defines market abuse. This includes market manipulation, attempted market manipulation or insider trading,
- Explicitly prohibits market abuse,
- Requires effective and timely public disclosure of inside information by market participants,
- Obliges firms (e.g. TSO and power pools) professionally arranging transactions to report suspicious transactions.

TSOs and power exchanges (e.g. Nord Pool) must report if they observe suspicious transactions. Generators must publish all information that are important for the prices in the market. This can be outages of power plants or transmission lines which must be announced in Urgent Market Messages (UMM). See Figure 11.

Event	Infrastructure	Available	Unavailable	Event Start	Event Stop
Unavailability of electric… Transmission	DE-LU → DK2	600 MW	0 MW	from 01.04.2020 07:00	to 03.04.2020 17:00

Figure 11. Example of an UMM. By sharing such information, all market participants can react. From: umm.nordpoolgroup.com/#/messages?publicationDate=all&eventDate=nextweek

2. Selected focus points

2.1. Status 2020: Successful wholesale market

Flow on transmission lines are based on prices in the different price areas. The coordinated European wholesale electricity market covers 23 countries and is probably the world's largest, comprising 2,900 TWh/year. Competition is strong, and the market has been unable to settle only on very few occasions. See (DEA and EPPEI, 2020, Danish Energy Agency and Energinet, 2018) for a presentation of the Nordic electricity market. The day-ahead market is considered to be well functioning with efficient pricing – a success.

The day-ahead market has opened for investment in new technologies such as electric boilers. These were motivated by the occurrence of negative prices, and their installation has limited the frequency of very low prices. Wind power in Denmark is currently generating what corresponds to 47% of annual electricity demand. The efficient integration of variable generation is heavily dependent on the three electricity markets: day-ahead, intra-day and regulating power. Via these markets, Danish wind power and Norwegian and Swedish hydro power interact. Simply stated, by generating according to market prices, hydro essentially acts as a low-cost storage of wind power.

The day-ahead market in Denmark is very liquid, with more than 80% of electricity being traded on the day-ahead market. The key reason for that is that any trade outside the relatively small Danish price areas must take place via the day-ahead market. Flow on the cross-border lines are determined by bids in the day-ahead market (called implicit auctions as described previously). Flow will always be from low price areas to high price areas.

Many steps have been taken to develop a liquid day-ahead market. As was mentioned in the previous chapter, until 2004, small natural-gas based CHPs were paid for electricity generation via a time-of-use tariff with three price levels. Production was dispatched as "prioritised production" and not integrated in the market. In 2004, the system was changed to end the concept of prioritised production, include small producers in the market, and to increase the volume of traded electricity. The former tariff included a substantial subsidy element, and the challenge was how to handle the transformation process for the more than 300 small producers. The solution was to transform the subsidy system to a "generation-independent-capacity payment" for a period of up to 15 years. Since the subsidy now was independent of generation, it no longer disturbed the market-dispatch of these units. The incentive for generating was clear: the unit should maximise generation in hours with the highest prices – independently of when they appeared. The expanding capacity of wind power meant that the timing of the expensive hours was not only determined by peak demand, but also when wind production was low. The subsidy ended in 2018, and today natural-gas based CHPs only receive revenue for electricity from the day-ahead market (or other markets they are active in, e.g. delivering regulating power).

Since its introduction in 1999/2000, the day-ahead market has delivered market-based prices in practically all hours. Only in a few extreme cases has market settlement not been achieved. In these rare cases when there is not sufficient generation, all demand bids are reduced proportionally (and vice versa if there is too little demand).

The price variation in the day-ahead market has motivated traditional generation to increase their flexibility. Existing coal-based plants have been refurbished so they can now run with minimum generations as low as 10% of full capacity. In addition, as mentioned previously, low electricity prices have motivated investments in electric boilers in relation to process heat for industrial purposes and in district heating plants. In recent years heat pumps have also been introduced for supply of some low-temperature heat demand. (Danish Energy Agency and Energinet, 2018; Clean Energy Ministerial campaign, 2018).

Since 2003, customers with a demand over 100,000 kWh per year have been able to enter a spot price contract with a supplier. This will often be cheaper than a fixed price and provides incentive to adjust demand according to hourly prices. By the end of 2020, all customers including households will be equipped with smart meters and have this possibility. Households with electric heating (direct electric heating or heat pumps) or electric vehicles may increase demand in hours with low electricity prices. Some heat pumps sold today can automatically download prices and adjust the heat generation based on simple input from the user.

Figure 12 displays the transformation of the Danish electricity system from 1985 to 2015. In reviewing Figure 12, the most notable developments are the emergence of a large number of distributed plants (illustrated by the blue circles) and wind power (blue diamonds). While the latter has received much attention in international circles, the growing flexibility of the numerous distributed plants (in part driven by market liberalisation as described above) is one of the reasons that such a large penetration of wind energy can be integrated into the Danish energy system.

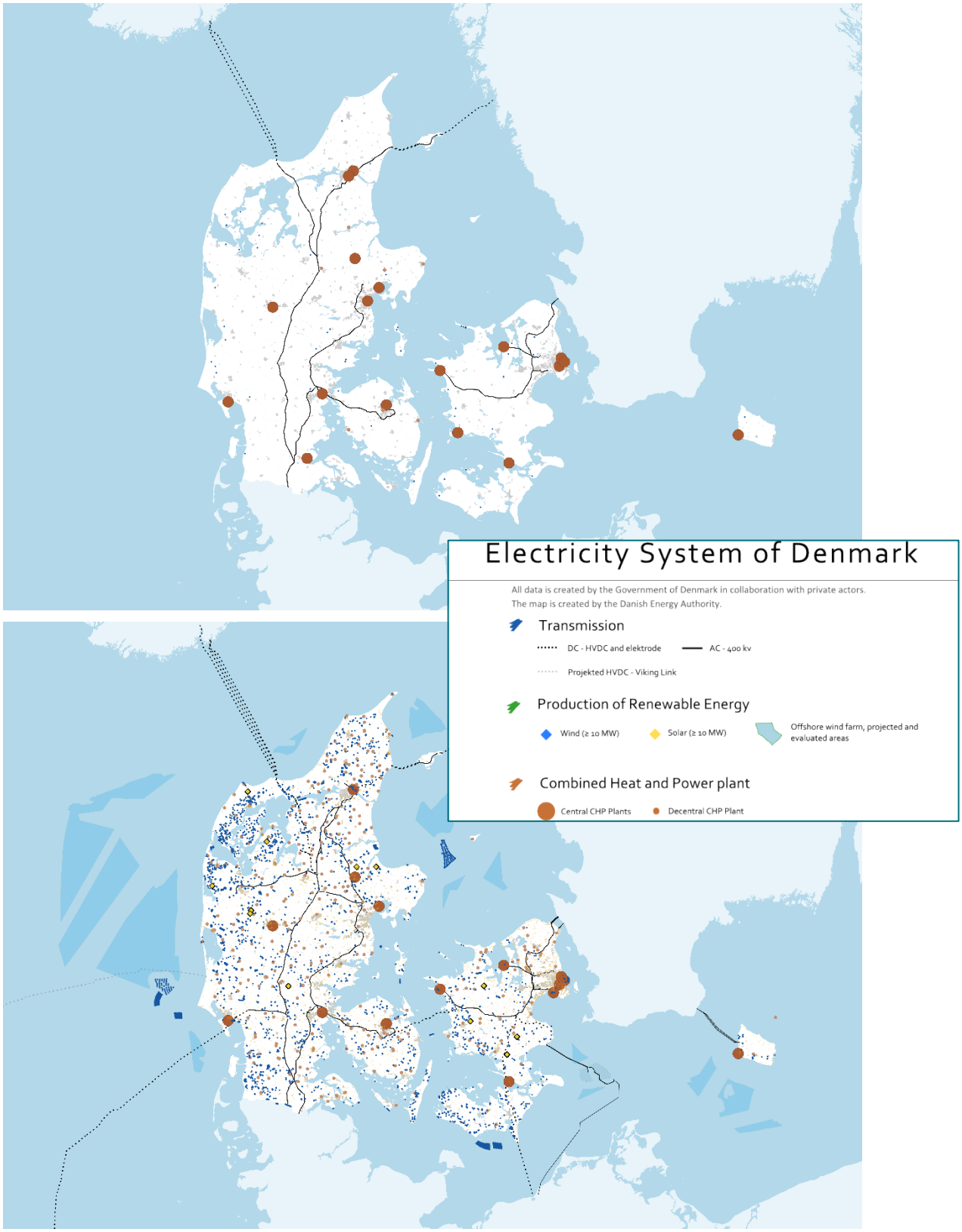


Figure 12. Danish electricity system, 1985 and 2015. Red circles are central power plants, blue circles distributed plants, diamonds are wind power. ens.dk/sites/ens.dk/files/Statistik/foer_efter.pdf

2.2. Slower transition in retail market

There has been a continuous but slow process involving mergers of DSOs. Today there are 16 major DSOs and more than 26 smaller DSOs (see Figure 13). Andel who owns Cerius recently acquired Radius and thus covers most of East Denmark while N1 will cover a large part of West Denmark. This is fewer DSOs than previously, however the number of companies to serve a population of less than 6 million can still be considered relatively high.

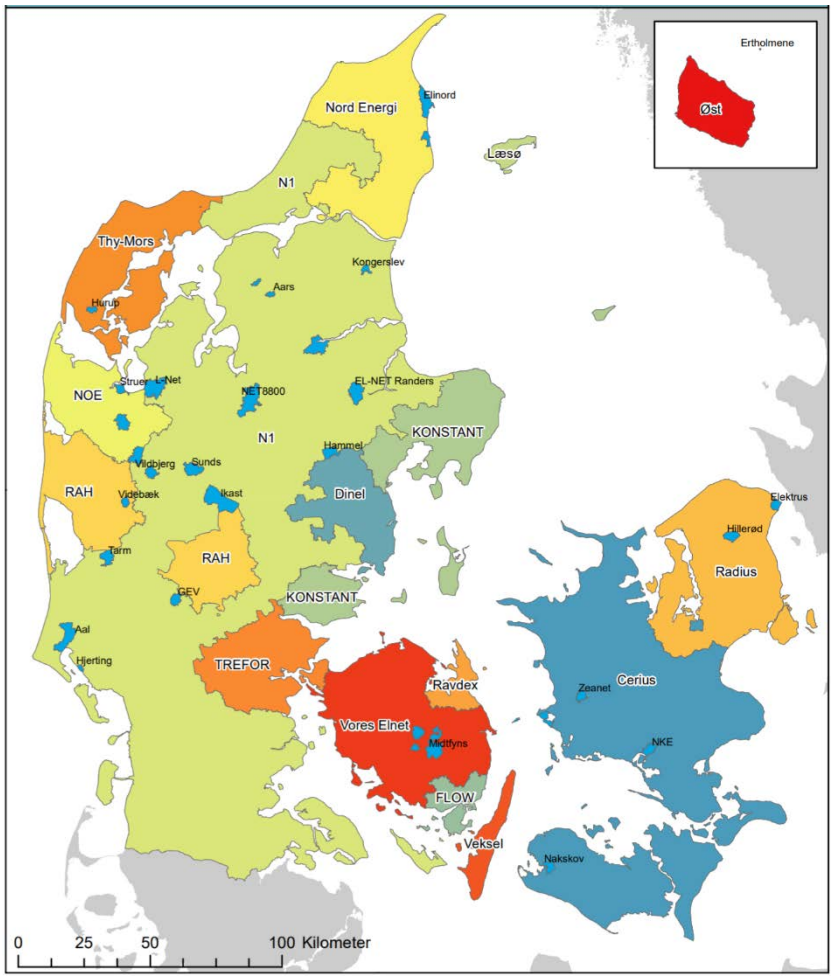


Figure 13. DSOs in Denmark, 2020. ens.dk/sites/ens.dk/files/Statistik/elnetgraenser.pdf

New suppliers have entered the retail market but have a limited market share. (Energinet Datahub, 2020). Legal unbundling is a requirement between suppliers and DSOs whereas ownership unbundling is not a requirement in line with the applicable EU rules. For example, prior to its sale, Radius (a DSO) was owned by Ørsted (an energy group that also owned generation and supply companies), so while DSO and supply were different legal entities in terms of separate companies, they were still owned by the same group, Ørsted. Several steps have been taken to reduce the link and benefits for incumbent suppliers to be connected to DSOs: the name and logo must be clearly different (2017), and with the One bill reform (2016), DSOs are

becoming nearly invisible, as the main contact for the consumer is now the supplier. The regulator has analysed the potential for increased efficiency for DSOs, including the potential for misuse of intra-group contracts (Forsyningstilsynet, 2020, b).

Thus far, interest in selecting a new supplier and/or contract has been limited. As was discussed in section 1.9 previously, high taxes and tariffs (that are fixed) may be partly responsible for this low interest. This is partially confirmed by the findings displayed in Figure 14 below, which lists surveyed consumers reasons for not changing to a new supplier. Here, nearly 35% of the respondents indicated that the savings were not large enough to urge a shift, only surpassed by those that found the shift too difficult to understand.

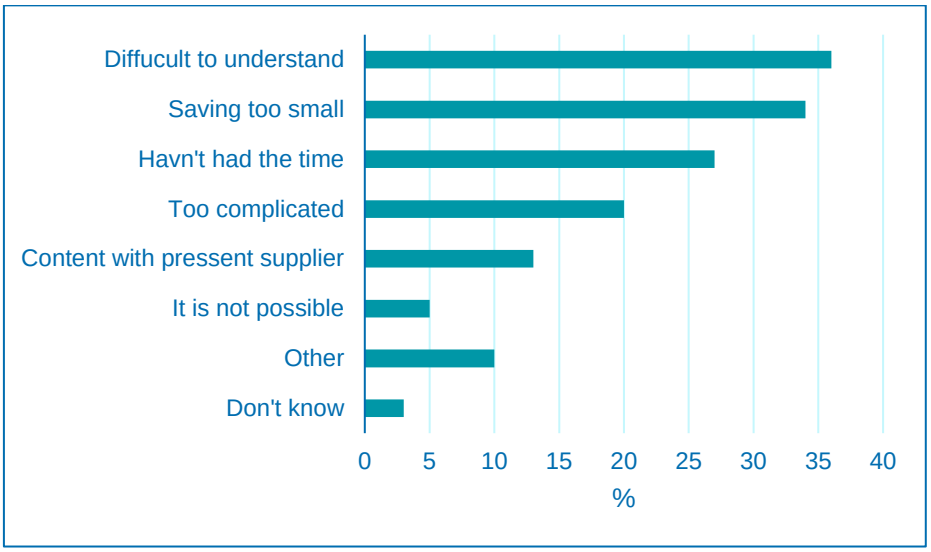


Figure 14. Reason for not changing supplier – among those that have considered to shift. Survey by EnergiWatch/Voxmeter (2018). 2,000 interviews.

Analyses from 2011 concluded that the development in electricity prices from 1995 to 2009 was relatively constant for large consumers, but increased for households (Ea Energianalyse, 2011). Part of the reason for this discrepancy could be due to regulation in place at that time for customers that did not actively change supplier. This supplier of last resort regulation often resulted in customers paying more for their electricity than those that actively changed supplier. I.e. the Danish regulator estimates that a typical household (4,500 kWh/year) can save between 20 and 120 USD/year by selecting the best contract (Forsyningstilsynet, 2019). This regulation was removed in 2014, where the supplier of last resort was replaced by an obligation on supply companies to supply these customers with market prices rather than regulated prices.

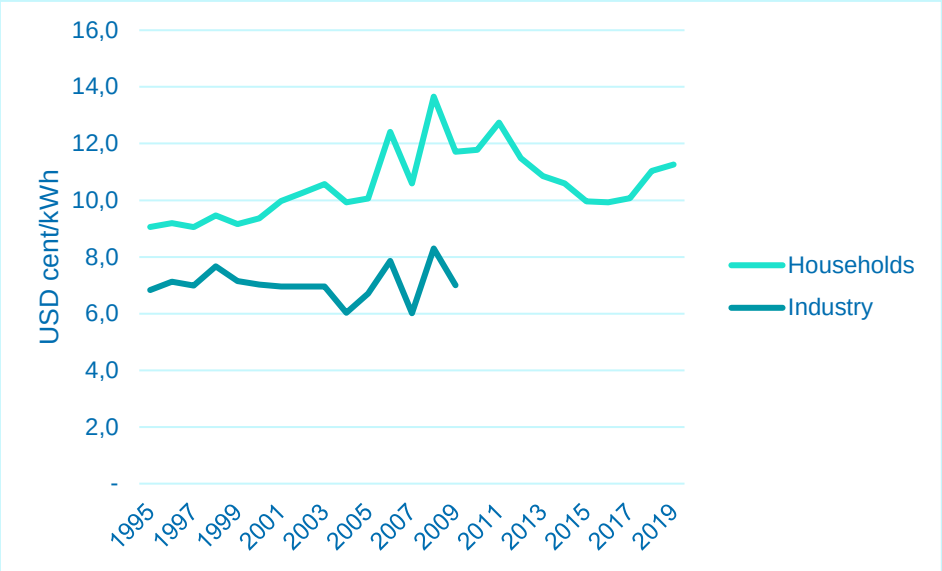


Figure 15. Electricity prices in households and industry. 2009 prices. Excl. taxes, VAT and the PSO tariff (subsidy to clean energy)[13].[14]

Summary

The liberalisation of the Danish electricity sector seems to have gone particularly well for large consumers. They gained early access to the market and have experienced stable prices (1995-2009). Meanwhile household consumers experienced increasing prices from 2003-2009 but decreasing prices from 2011-2015. The retail market might evolve, and consumers become more active when new data-technology is implemented. New smart meters in all households by the end of 2020 will enable customers to obtain savings by moving demand from high price to low-price periods of the day and thereby provide more incentive to select suppliers that offer such products. This incentive will increase even more as electricity intensive transport and heating (electric cars and heat pumps) become more dominant. Many research and development projects have been undertaken or are on-going to demonstrate new types of digital business models to support this development.

Since 1999, regulation of DSOs has been developed and changed numerous times, but thus far it appears that the ambition to create an uncomplicated and predictable regulation set-up has not yet been achieved. The complexities of the matter seem to stand in the way, but despite this, efficiency in DSOs has improved and consumer prices have only increased moderately – so gains have been made.

[13] Source: 1995 – 2002: Ea Energianalyse, 2011. 2003 – 2019: Forsyningstilsynet (https://forsyningstilsynet.dk/tal-fakta/priser/elpriser/prisstatistik-4-kv-2019) and Danmarks statistik (https://www.dst.dk/da/Statistik/emner/priser-og-forbrug/forbrugerpriser/forbrugerprisindeks)

[14] See Figure 16 for the development in the day-ahead price.

2.3. Successful unbundling in production and transmission

Denmark was not first in line to embrace the concept of liberalisation but adapted to the development in the Nordic countries and in Europe. Importantly, Denmark made it a priority along the way to ensure that market development supported environmental considerations (renewable energy, energy efficiency and overall green transition).

For the electricity sector, unbundling of generation, transmission grids and trading was an important starting point in the process. It transformed the identities and rationale of the new companies – whether commercial or monopolies - and was a prerequisite for the companies to assume their new roles in the market system. The Danish unbundling was relatively thorough from the start – in contrast to some countries, where it has been a long process to get the existing monopolies to relinquish control and ownership of some of their activities.

This likely also contributed to the fact that early scepticism and resistance in the sector was overcome within a relatively short period of time. The companies started to focus on the possibilities in the new set-up and to influence its implementation – rather than fight against it.

What also eased the transition might have been the fact that Denmark at the start of market opening had over-capacity in the production sector, and at the same time could transfer capital to the generator companies to bolster them financially before they faced competition (see more in Section 2.5 below).

2.4. Outstanding issues for DSOs

Currently, it is required that suppliers are legally and identity-wise unbundled from any DSO with interest in the supplier (Energitilsynet, 2018). However, an analysis of the competition on the retail market and whether it is possible to identify further initiatives that can promote the competition via enhanced separation of monopoly and competition activities is undertaken. The analysis is still ongoing and no decisions have been taken. One part of the analysis has concluded that that the current regulation of DSOs could be further improved. One issues that has been highlighted is that in many cases the DSO has only a few staff, and a lot of the activities in the DSOs are realised in daughter companies. This can be a challenge for the regulator as all contracts between DSOs and daughter companies on internal trading must be “market based”, but that can be difficult for a regulator to control. Since 2012 the regulation has specified explicitly that all internal transactions must be market based i.e. that no transfer pricing is allowed.

In a recent decision, a DSO was convicted for over-charging in relation to energy efficiency activities that the DSO must realise (Forsyningstilsynet, 2020). The DSO thus collected an extra cost from users, and the value was transferred to the unregulated daughter company. The DSO has appealed the case.

Future regulation of DSOs

One part of the analysis of the competition in the Danish retail market the regulator indicates that the current regulation of DSOs could be further improved (Implement, 2019). The analysis found that there are several issues where separation, transparency and oversight are insufficient to guarantee against behaviour that can reduce the competition:

- Unequal treatment of all actors: The DSO may give prioritised service to connected companies.[15]
- DSOs may pay for marketing that would mainly benefit connected companies.
- Staff is shared between DSOs and connected companies and knowledge is therefore inevitably shared. Often none or only a few staff are employed by the DSO. All functions are delivered by daughter companies (also servicing the commercial companies).
- Offices are also shared, again with a potential exchange of knowledge.
- IT systems are shared. This may give access to commercial data, like customer data.
- Many DSOs do not have systems in place to monitor and secure independent decisions.
- Since many services are delivered by daughter companies, the risk of transfer pricing exists. Documentation of fair market-based prices is non-existent (particularly in small DSOs).
- Many DSOs purchase electricity to cover grid losses directly from connected companies.

The study focussed on these *potential* weaknesses. It does not document whether the possibilities are used in practice.

According to the study, two paths can be followed to improve the situation:

- Stronger regulation with an increased requirement for documentation of transparency and fair prices.
- Unbundling of ownership of DSOs and other companies. This would result in less need for regulation, but is considered as an *intrusive* step, and would also remove any synergies between companies.

2.5. Transfer of power plants to a market-based system

Prior to market liberalisation in 1999, the Danish thermal power plants basically were organised in two groups:

a) Eight generator companies that owned and operated 14 large-scale power plants that changed to market-based operation early during market liberalisation

[15] The Danish DSOs are legally unbundled from mother companies. It has not been required that these must be ownership unbundled.

b) Several hundred small-scale plants and a few waste incineration plants, which continued operation for some years according to their existing time-of-day tariffs – outside the market. Today all of these plants also sell their full production on the common markets.

In general, the larger generator companies saw positive prospects in the market opening. The belief was that Danish power plants would be very competitive due to their high efficiency and combined heat and power production. In addition, some actors hoped for (and expected) less "regulation" in a commercial market setting. However, two incidents in the first decade after the market opening challenged these positive expectations.

Firstly, the Nordic hydro-based electricity prices plummeted around 1999/2000 due to large amounts of precipitation (what is commonly referred to as a 'wet year' (see Figure 16).

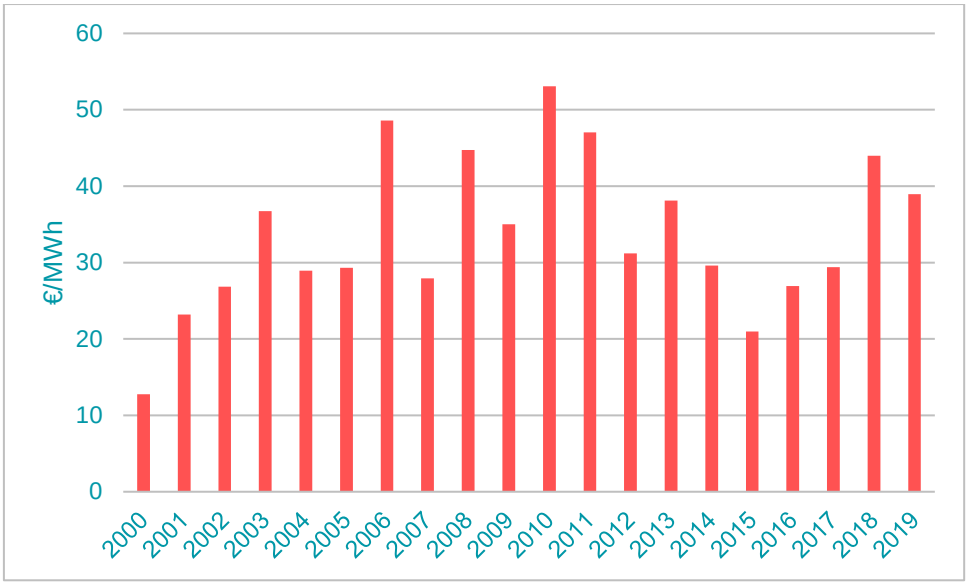


Figure 16. Nord Pool system price. The system price is a theoretical price that would exist if there was no congestion in the Nordic system.

The Danish generation companies, which had no substantial equity or guaranteed credits, immediately faced a liquidity challenge. Thus, politicians decided to transfer €1.2 billion to the generation companies under the condition that the companies merge into just two production companies and agreed to deliver security-of-supply services to the TSO as part of the deal.[16] Settling on the amount of capital required was difficult, partially because in 1999, the power prices were low, and this may have increased the need for capital. A clause in the 1999-agreement stipulated that it could be reopened in the event that assumptions changed. However, this clause was never activated, the generator companies succeeded in adapting to market conditions, and none of the companies went out of business.

[16] See section 1.3 for a more detailed description of this process

Secondly, the global financial crisis in 2008 led to reduced electricity consumption and low electricity prices. The losses in the liberalised power sector were enormous throughout all of Europe, including in Denmark. A central actor in one of the two large companies at that time stated that the financial crisis seriously increased efficiency in decision making. This crisis also led to the sale of all of Vattenfall's combined heat and power plants to local municipalities in order to curb losses.

A lesson from this episode is that severe shocks can lead to substantial efficiency gains being achieved, both in terms of asset management and operations, but also dispatch. This led to more clarity in investment decisions, more flexibility in operations (integration of renewables), and more clarity in defining the necessary production-adequacy for security of supply purposes.

2.6. Security of supply

Security of supply can be divided into two parts: adequacy (that the needed capacity for generation and transmission exist), and security (that the system can withstand sudden failures).

The Nordic electricity wholesale market is in principle an energy-only market.[17] Prices in the day-ahead market are set as marginal prices (as the most expensive bid needed to supply electricity demand). Generators send in bids based on their short-term marginal costs and are activated when the hourly price is higher than their bid. The difference between their hourly bid and the hourly settled price (the margin) can be used to cover fixed costs. This is also the case for new generation: investments should be covered by the margin collected in the energy-only market.

Since the introduction of the energy-only market it has been discussed if enough new generation can be attracted. Some key-elements in the discussion are:

- Some technologies, e.g. renewable energy, receive a subsidy which is disturbing the market. Such subsidised investments reduce the power needed from non-subsidised generation and reduce their prices and sales volumes.
- The existence of a sufficient volume of demand response has been considered an argument for an energy-only market to create the right incentives for new generation. Demand response is demand that reacts to prices. As such, demand response should act as peak generators, and set the price in the hours with a tight power balance. It is typically industrial demand, but can also be household demand, e.g. from heat pumps or electric vehicles.

[17] In other markets, a capacity market also exists. In the Nordic market, revenue from the energy-only market is expected to cover the capital costs for generators. This can happen because the hourly price is defined as the marginal price, and generators benefit from the hourly settled price often being higher than their marginal costs. See Danish Energy Agency and the Electric Power Planning and Engineering Institute (2020) for a comparison of markets in US, Europe and China.

The expected future, where wind and solar power will enter the market in even larger volumes without a subsidy, may challenge the energy-only market. Thermal baseload plants will experience reduced production and the need for peak generation will still exist. However, it may be difficult to create viable business cases for thermal power plants with only few full load hours. The dependence on high prices in these specific “peak hours” will become great. The challenge is that price projections, especially for these peak hours, are highly uncertain.

The European Union, the ENTSO-e, and several countries have expressed concern about the future *adequacy of production* in the electricity market. Thus, different types of so-called *capacity mechanisms* have been introduced, which are divided into two main types by the EU commission:

- *Capacity markets,* where in principle all market participants can bid their eligible capacity into a separate market. Capacity markets are thought of as a permanent framework for handling adequacy.
- *Strategic reserves,* where some market participants are pulled out of the ordinary day-ahead market, and only stand in reserve when the market clearance is in danger. Strategic reserves are thought to be a temporary framework and can be phased out if, and when, there are grounds for sufficient confidence in the energy-only market, including demand response, to deliver the necessary adequacy of production.

For both types of capacity mechanisms, strict EU approval processes must be followed to avoid unnecessary distortion of adjacent electricity markets.

Denmark is in favour of the strategic reserve model if need exist. So far, no strategic reserves has yet been procured. The TSO defines the volume and the payment to strategic reserves must be determined in a fair competitive process, including participation of demand-resources. Strategic reserves can only be activated when the market ceiling price is reached (currently 3 Euros/kWh). This rule is to make sure that all available commercial resources have been bid into the market before the strategic reserve is activated.

The Danish discussion about the need for a capacity mechanism can be illustrated by the expected development of the capacity balance in Denmark (see Figure 17). Today, the Danish peak demand can almost be covered by dispatchable generation (the need for reserves are not considered here). However, in the coming years the supply will be heavily dependent on import and increasing demand side flexibility.

While the national tasks for related to security of supply has been reduces, the European tasks has been increased. ENTSO-E (European TSOs) are constantly monitoring the adequacy from

an international perspective. See appendix 2 for a description of short and medium term adequacy analyses done by ENTSO-E.

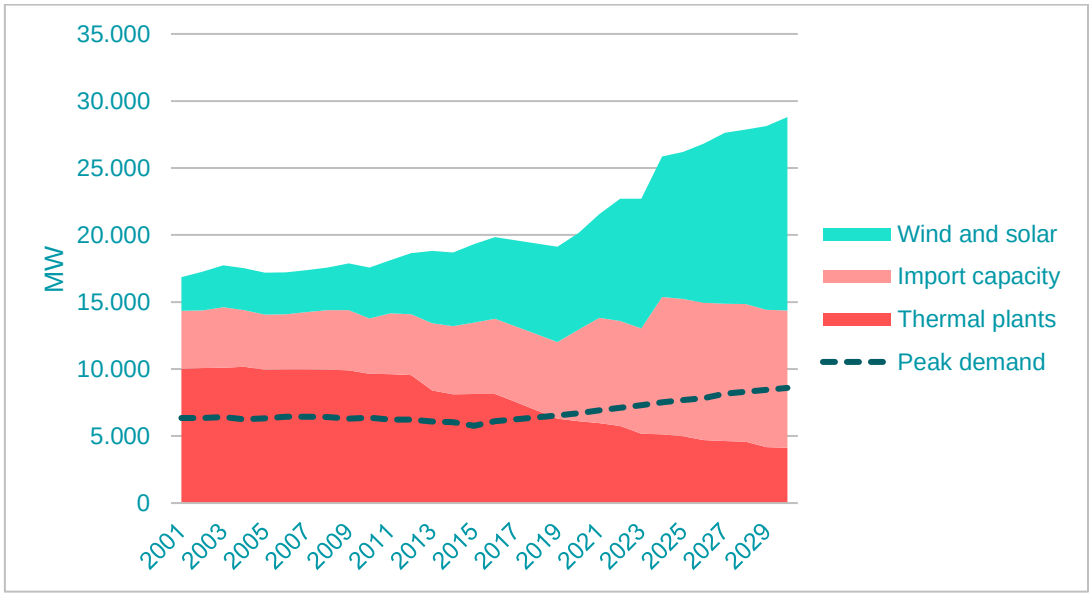


Figure 17. Development in the national capacity balance. Historical data (2001-2016) combined with expected data (2019-2030). 2017 and 2018 is interpolated. Data from Energinet and DEA.

2.7. Integration of wind and solar power

In 1980, the Danish Power sector was dominated by a few generator companies which operated 14 power plants. In the 1990s, hundreds of distributed CHP plants were constructed, suppling heat to local district heating systems. After 2000, wind power expanded, and in recent years also solar power has reached a significant volume. Today, wind and solar power supply nearly 50% of the annual electricity demand.

The market system, including market-based trade over interconnectors, plays a critical role in the efficient integration of the variable generation. When there is generation from wind or solar, other generation must be reduced, and this is decided in an open and technology neutral competition in the power market. Local and international generation are competing – to the extent that transmission capacity is available.

Trading electricity over long distances can be motivated by the fact that wind power is only loosely correlated when sites of 500-1,000 km distance is compared. Smoothing takes place because wind fronts have a smaller extension.

Denmark is a transit country with a significant amount of North-South power flow. The hydro plants of Sweden and Norway interact with the large European power system through Denmark. This also means that congestion often occurs, but in many cases, there is congestion *either* North *or* South of Denmark – not in both markets at the same time. Therefore, competition can

take place at least in relation to one of the two big markets - North or South of Demark, respectively.

The strong competition and the dynamic pricing in the spot market (including the possibility of negative prices) has been a major driver for traditional generation to be more flexible. See: Ministerial campaign (2018), Danish Energy Agency and Energinet (2018), Danish Energy Agency (2018) and Danish Energy Agency and the Electric Power Planning and Engineering Institute (2020).

Private investors have been responsible for a significant share of investment in new wind and solar generation.

3. Lessons learned

In Denmark, the early drivers for liberalisation of the power sector were changes in EU regulation and liberalisation processes taking place in neighbouring countries. The Danish “non-profit” power sector was thought to be quite efficient with low prices, AAA credit ratings, and high security of supply standards. Domestically, there was no strong political desire for electricity market liberalisation.

In retrospect however, the liberalisation process and the new market structure has yielded impressive results in terms of efficiency gains, organisational clarity, creativity and most importantly, the ability to integrate vast amounts of variable renewable energy in the form of wind and solar power. Although progress towards a green transition (such as developments in large- and small-scale CHP, biomass, and energy efficiency) were made during the monopoly era, it is difficult to imagine that the green transition could have taken place at the same speed (especially the massive wind power expansion), without some form of liberalisation and unbundling.

When discussing electricity market liberalisation in other countries, the challenges faced may be more prominent. Potential examples could include access to finance, challenges pertaining to security of supply, and/or weaker governance structures.

A fundamental prerequisite for a successful liberalisation is a strong and unbiased public regulation as the interface between the public and the private domain.

3.1. Change of culture and vision

Liberalisation and unbundling are long processes. In the Nordic countries and the EU, it has taken decades, and 100% unbundling has still not been achieved.

During the process there were conflicting interests in the former monopolies. Some embraced the changes, while others resisted. Transition from monopoly to market upends existing structures and, in many cases, changes positions of power and influence and roles in the sector. Resistance and scepticism of the new set-up should be expected.

Liberalisation implies a change of culture within companies, to a more business-oriented approach. This is particularly true for the commercial actors, but also for the remaining monopolies. In some cases for example, the old Danish non-profit regulated monopoly companies were over-staffed and there were examples of questionable spending (Trong and Limann, 2009).

Unbundling is the starting point of the liberalisation process and it is an important task to *explain* to decision-makers, as well as the general public, what liberalisation means. For most people, it is not always an easy concept to understand. With unbundling, new roles and new and diverse company visions and structures emerge. As an example, Ørsted has transformed from a fossil fuel-based power and infrastructure company, with a national focus, to a renowned international

frontrunner in deployment of offshore wind. Such a transformation could probably not have taken place to the same extent, without the push from unbundling and liberalisation. See appendix 1 for a description of the development of Ørsted.

However, the Danish experience also shows the importance of not "overselling" the effects of liberalisation to decision-makers and the general population prior to implementation:

- The Danish electricity sector reform in 1999 was expected to result in lower prices for the average households. That proved not to be the case for all consumers.
- Oftentimes liberalisation is expected to lead to less regulation. However, in practise liberalisation does not result in less regulation, rather the opposite. New regulation includes rules for instance about transparency and competition (REMIT), as well as new regulation of DSOs.

3.2. Political consensus

In order to overcome resistance to liberalisation, a strong regulation backed up by a solid political majority can be a driver. In Denmark, milestones that pushed comprehensive changes were: the EU directives for the internal electricity market starting in 1996, the energy reform package from 1999, the 1999 infusion of capital to the generator companies, and the 2004 regulation that allowed generator company owners to keep the proceeds when they sold their shares.

However, the Danish experience also shows that it is not necessary to wait for large-scale comprehensive regulation to be in place in order to start development towards a market system. Prior to the EU regulation, Norway started introducing a market system (to prevent over-investment in hydro), and from there it gradually spread to the other Nordic countries.

It should also be noted that implementation of the market system in Denmark did not take place solely through a few large steps, but also via an ongoing interaction between regulation and implementation in the sector. Rules and regulations were adapted several times to reflect practical experience and address unforeseen problems. As mentioned above, regulation of the monopoly portions of the sector proved to be complicated, in part due to complexities in company structures and financial set-ups. However, efficiency gains have been achieved, and thus regulation has at least been partly successful. This is based on two important prerequisites:

- A thorough unbundling at the beginning of the liberalisation process to achieve a clean separation between commercial and monopoly activities (TSO),
- A strong, active, and independent Regulator is needed. The Regulator also needs to have a consumer perspective regarding the evaluation of the electricity market. This is because few actors represent the consumers, and the regulation can be difficult to understand by laymen.

3.3. Transitional arrangements

Changing regulation can create resistance, change the value of assets and induce sunk costs. for. An efficient tool to mitigate regulatory risks and resistance, can be the design of transitional arrangements that allow more time for stakeholders to adapt. EU regulation has shown several examples for such transitional arrangements. Key requirements have been:

- The arrangement must be accepted by the EU. State aid to national companies is not accepted.
- The arrangement should have an end date.
- The scope should be limited, e.g. provide a longer transition time to small generators
- The arrangement should be a transition to a desired end-state, e.g. market-based dispatch.

In Denmark such transitional arrangements have been applied in relation to small CHPs, consumers access to the market, and the use of smart meters and hourly settlement. Regarding small CHP´s the arrangement secured that the value of electricity produced by small CHP´s established before the liberalisation, would not be affected by low market prices for up to 15 years.

3.4. Thorough unbundling (TSO)

Unbundling creates independence between actors on the electricity production and demand sides, which leads to a new dynamic and more transparency than existed in the monopoly non-profit set up.

Clear division of responsibilities is important in order to implement the role of the new TSO. See Figure 18. The main objectives for the TSO are to ensure:

- Efficient operation and expansion of the main electricity infrastructure,
- Open, equal access for all users of the grids,
- Well-functioning markets.

In Denmark, the TSO is tasked with maintaining both short term and long-term security of supply, including emergency preparedness.

Data collection is an important part of TSO operation, both in relation to market function and security of supply. For example, the Danish TSO has been able to detect if there was questionable conduct on the part of a producer and subsequently make the producer aware of this conduct. The TSO is also able to assist competition authorities or the Regulator if cases of questionable conduct should occur (as required by EU regulation).

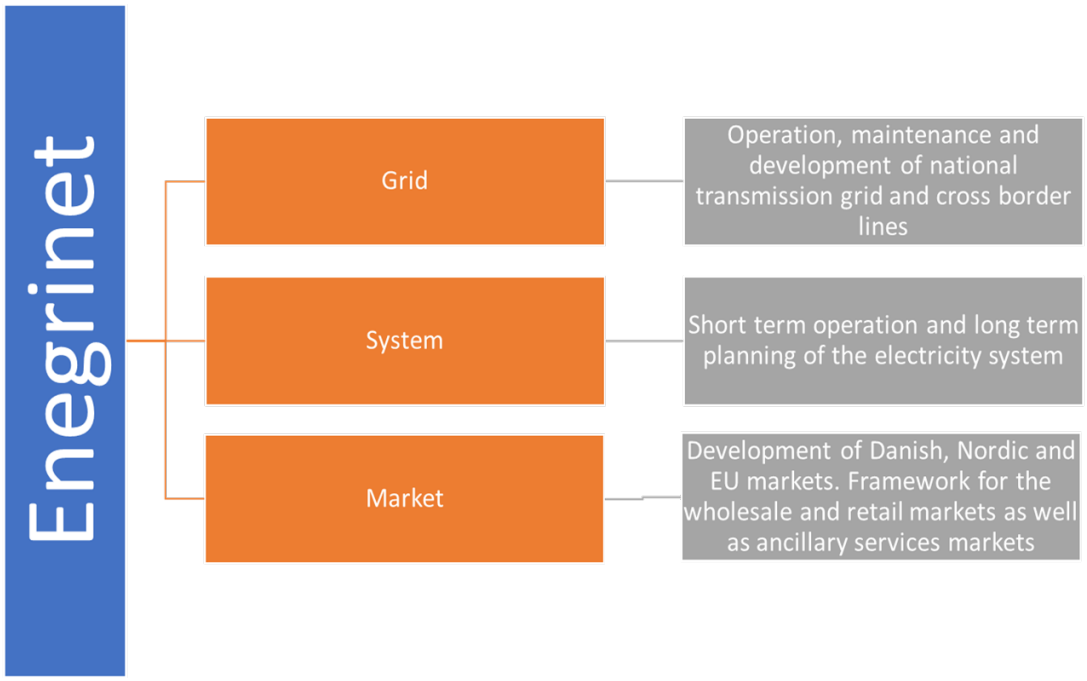


Figure 18. Main tasks for the Danish TSO. Gas activities are not included.

3.5. Strong Regulator

Legitimacy in process and institutions are vital to a successful transformation from monopoly to market. Trust in the political process, trust in fair and equal regulation (implemented by an independent, active, resourceful, and skilled Regulator), and trust in fair and transparent marketplaces create an environment where confident actors, including potential investors, will engage.

One important role for the Regulator is that of consumer protection. In a free market there is a power disparity between individual customers on the demand side and the companies (sometimes large corporations) on the supply side. Thus, there is a need for effective supervision of the sector.

The Danish Utility Regulator has existed since monopoly times but has expanded and reorganised several times since then, with latest such development coming in 2018. An evaluation of the Danish regulator recommend that the Regulator should also give feedback to the Ministry about the practical function of rules and regulation, including critical evaluation of efficiency of regulation. (RMC/IMG, 2016)

Today, the Danish Utility Regulator oversees all three utility sectors: electricity, district heating and natural gas. Its stated purpose is “securing consumer interests in the utility sectors by striving for a higher level of efficiency, the lowest possible costs in the short and long term, a stable and secure supply, and a cost-effective development in technology and climate-friendly initiatives”.

Specifically, the Regulator regulates prices for services from DSOs (in accordance with the income framework for each company) and benchmarks the DSO's economic efficiency for calculating the individual efficiency requirement - as well as the general efficiency requirement imposed on DSOs. It also administers the economic regulation of the TSO (Energinet), including ensuring only necessary costs are included in prices.

It should be noted that specific complaints between household customers and their supplier since 2004 have been processed in an Appeals Board (Ankenævnet for Energiområdet) with representatives from consumer interests and the electricity sector, chaired by a judge.

Several issues require approval from the Regulator. Among these are terms, conditions, and methods for access to the distribution and transmission networks, market participants' access to and use of data from the data hub, methods, conditions, and terms for the TSO's operation of the transmission network, connection requirements for power generation, and consumption units for the transmission and distribution networks.

The Regulator generally oversees energy companies' compliance with rules and regulations, including the obligation of electricity suppliers to ensure that relevant and accurate information is available at any time on all products, including prices and terms on the electricity suppliers' website. Moreover, the Regulator maintains its own electricity price guide (elpris.dk) with information on electricity prices, discounts, and terms in the Danish electricity market. This is of special importance to small consumers when selecting a supplier.

During the first phases of liberalisation, the Danish Utility Regulator seemed to play a rather passive role towards market misbehaviour, i.e. only taking up specific cases when complaints were made. However, in later years the Regulator has been more proactive in terms of initiating cases on its own accord.

As described above, price regulation is complicated when implemented in practise and no matter how strong the Regulator is, it cannot match the detailed knowledge of the companies. Thus, trust and common understanding between the Regulator and the sector is important.

3.6. Utilise new digital technologies

While the wholesale electricity market development has been a success, the retail market in Denmark has developed relatively slowly, and still lacks active customers - for various reasons as described above. It is expected to improve when smart meters are rolled out by the end of 2020, thus enabling new sales products reflecting time-of-day prices.

Such technology was not available when the Danish liberalisation process started more than 20 years ago. Thus, countries starting the liberalisation today have the advantage of new data-technology and thereby the means to create demand response and a better functioning retail market.

3.7. New regulation for the green transition

While the trend in the recent 20 years of regulation has been to reduce monopoly activities and increase the role of open markets, a new direction may be needed in the green transition. With an increasing share of variable generation from wind and solar power certain investments may be attractive from a socio-economic perspective, but may be too uncertain for private investors. DSOs and TSOs may acquire a role in providing infrastructure that assists in integrating the variable generation – e.g. reducing curtailment. This may include new grid elements, storage facilities or programs to support demand response. The future EU regulation is expected to include a balance between efficiency and the green perspective.

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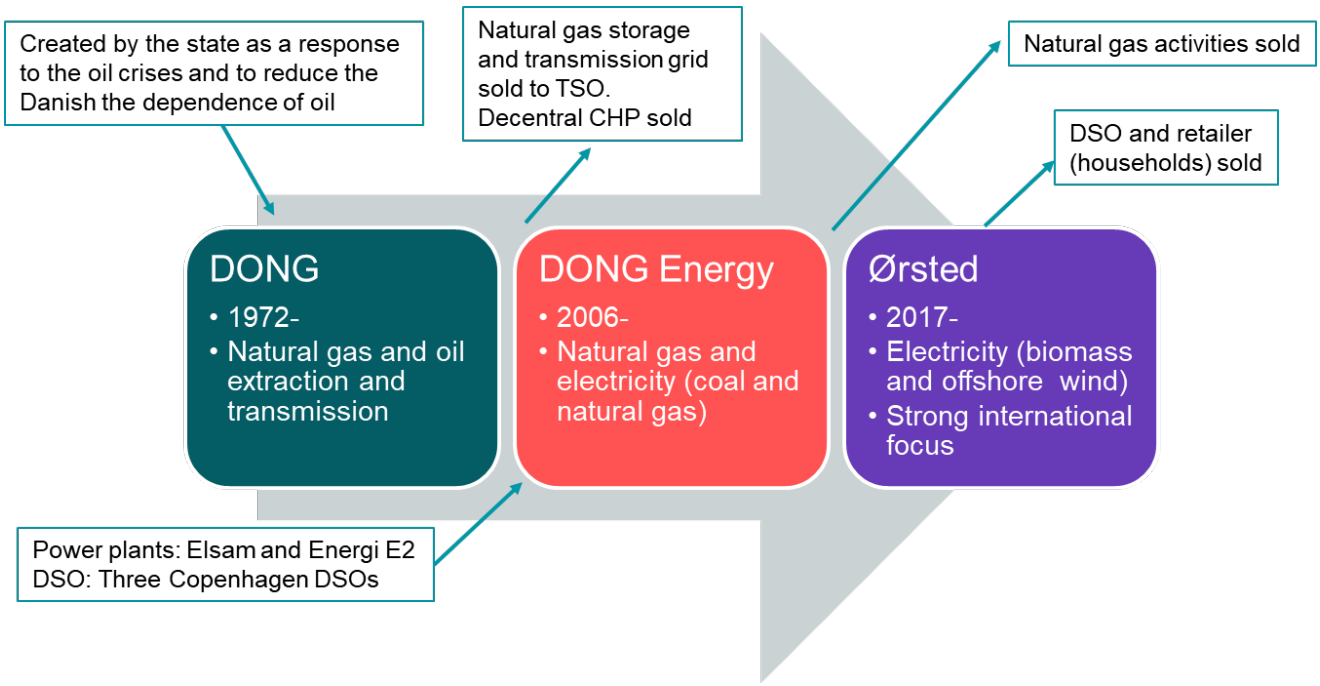
Appendix 1: Power companies

DONG/Ørsted

The company Dansk Naturgas A/S was founded in 1972 by the Danish government to manage gas and oil resources in the Danish sector of the North Sea. The company was renamed to Dansk Olie og Naturgas A/S (DONG). In connection with the liberalisation process DONG acquired consumer- and municipality owned utilities and was renamed to DONG Energy.

In 2008 DONG Energy shifted to a green profile and decided on a comprehensive restructuring of the company's electricity production. The vision was to change from 85% fossile dependency to 85% renewable energy before 2020. As a consequence, the company invested heavily in offshore wind turbines in both Danish and foreign waters and is now a global leader in green electricity production. Oil and gas upstream assets, pipelines and electricity- and gas distribution networks have all been divested. In 2017 Dong Energy changed its name to Ørsted, marking the completion of the green transition,



- 1972-2002: DANSK OLIE OG NATURGAS A/S. The state-owned company worked with exploration, transport and trade with natural gas and oil. The company was a key actor in the introduction of natural gas in Denmark. Natural gas was introduced as a means to reduce the high oil- dependency of Denmark.
- 1999: 572 employees.
- 2002-2006: DONG A/S
- 2003: 1,156 employees
- 2005: Purchases 10% of the Danish gas field Ormen

- 2006: DONG Energy A/S: Merger of six power companies (DONG, Elsam, Energi E2, Nesa, Københavns Energi og Frederiksberg Forsyning).
- Central power plants: Asnæsværket (1,057 MW), Avedøre (810 MW), Esbjergværket (378 MW), Kyndbyværket (664 MW), Skærbækværket (392 MW), Studstrupværket (700 MW) – mainly based on coal and natural gas.
- DSO part: DONG distribution
- 2007 (ultimo): 4,585 employees
- 5,682 MW thermal capacity, 828 MW renewable energy. 20,000 km electricity distribution grid. 6,500 km natural gas distribution grid. 1,000,000 electricity customers,240,000 natural gas customers. Activities in Denmark, UK, Norway, Sweden, Germany and Poland. State own 73% of the shares.
- Transmission grid (132 kV) and natural gas storage (Lille Torup) sold to the TSO.
- 2011: Engineering section sold to Rambøll. 115 employees are transferred.
- 2013/2014: New stocks sold to Goldman Sachs and Danish investors (pension funds). State has maintained majority.
- 2016: Stock traded on the stock exchange.
- DSO: New name: Radius Elnet
- 2017: New name: Ørsted. Oil and gas fields sold. 1,400 employees are transferred.
- 2019: The DSO Radius (1,000,000 end-users) is sold to SEAS/NVE (the other large DSO in Eastern Denmark). Included was 700,000 residential customers from the retailer section and the street lighting contracts. 750 employees are transferred.
- Staff: 5,800
- In 2019 the global installed offshore wind capacity owned by the company was 6,820 MW, and the additional capacity is under construction. In 2025 the company expect to have 15,000 MW offshore wind capacity distributed in many countries.
- 68% of the heat and power is based on biomass.
- Power plants partly or complete on biomass: Studstupværket (2016), Asnæsværket (2020), Avedøreværket (1990)
- 2018: Ørsted acquires Deepwater Wind and Lincoln Clean Energy, two US wind developers
- 2020: Ørsted ranks #1 in Corporate Knights' 2020 index of the Global 100 most sustainable corporations in the world
- 2020: All wooden biomass will be certified sustainable.
- 2025: Goal is to reach carbon neutrality

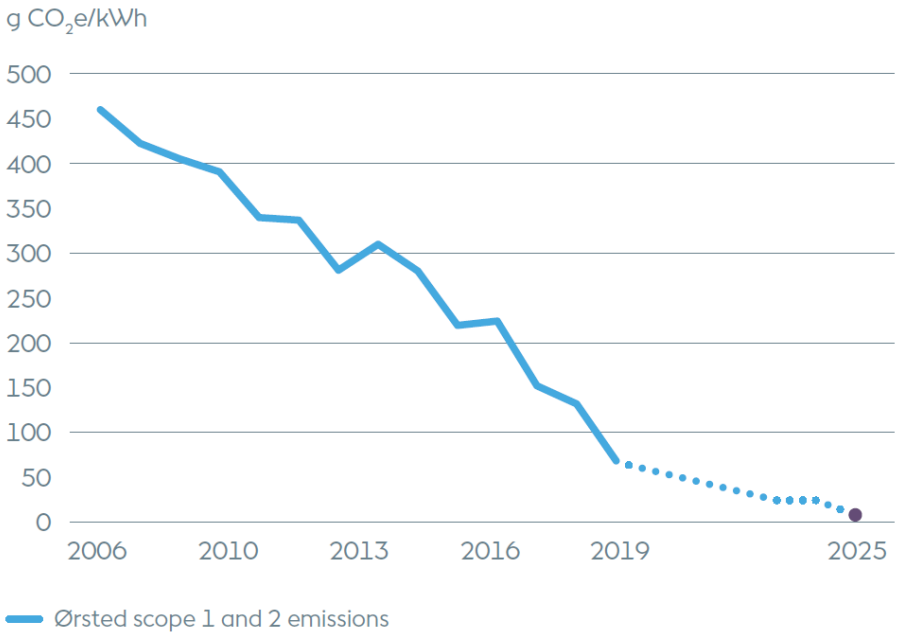


Figure 19. Specific CO2 emission. Actual and prognosis.

Vattenfall – Denmark

Vattenfall is a Swedish state-owned electricity company. Beyond Sweden, the company generates power in Denmark, Finland, Germany, the Netherlands and the United Kingdom. The Vattenfall Group employs a total of more than 20,000 employees, whereof app. 250 in Denmark. The name Vattenfall is Swedish for waterfall.

After the Swedish liberalisation in 1996, Vattenfall started to invest its earnings in European expansion especially in thermal power plants. The acquisition of power assets in Denmark from 2006 can be seen as part of this ambitious international expansion strategy. In the last decade Vattenfall has had a growing focus on wind power.

- 2006 – 2015: In 2006 Vattenfall acquired Fynsværket (439 MW), Nordlyllandsværket (410 MW) and Amagerværket (218 MW). These was late sold in 2015 to local district heating companies (municipalities) in the three cities Odense, Aalborg and Copenhagen. Employees in Denmark: 700.
- 2013: Vattenfall Engineering is sold to COWI and 70 employees are transferred.
- 2020: Employees in Denmark: 250. Has a number of on-shore and off-shore wind farms operating in Denmark, including Horns Rev 1 and 3 (556 MW). A total wind power capacity Denmark, UK, Germany, the Netherlands and Sweden is 3.3 GW.

Appendix 2: ENTSO-E system adequacy activities

The European Network of Transmission System Operators for Electricity (ENTSO-E) performs system adequacy analyses for the integrated power system of its members. ENTSO-E publishes both a bi-annual, short-term outlook for upcoming season (winter/summer) and a mid-term outlook for the next 7-10 years.

Short term adequacy outlook

ENSTO-Es short-term adequacy reports are called seasonal outlooks. For each short-term outlook there is also a review on the most recent winter/summer. Also, changes in generation capacity are reported. In Europe examples of typical critical situations are:

- High demand: Wednesday at 7 pm
- Low demand combined with high generation from wind and solar: Sunday 5 and 11 am.

The summer outlook is combined with a review of the most recent winter. The seasonal analyses are published twice a year (before 1st of December and 1st of June). Data is published on the ENTSO-E home page.

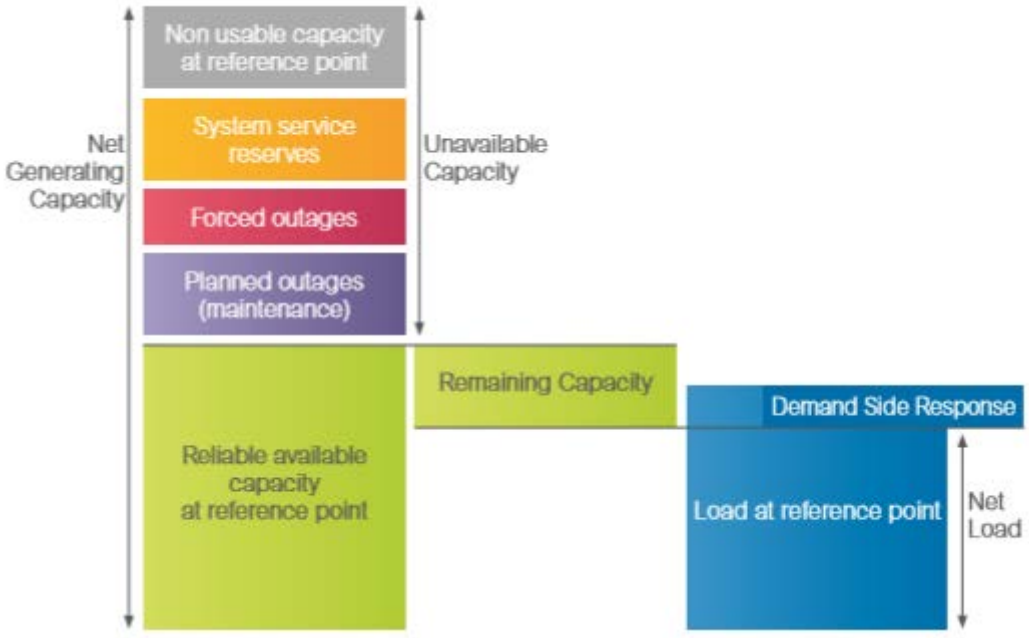


Figure 20. Upward adequacy approach

Figure 20 illustrates the general ENTSO-E deterministic approach calculating the “remaining capacity” under normal conditions and “severe conditions”. “Normal conditions” correspond to normal weather conditions resulting in normal wind generation and hydro output and an average outage level. “Severe conditions” correspond to extreme weather conditions in terms of higher demand and in terms of reduced generation output (lower wind and restrictions/constraints on power plant production).

The Seasonal Outlook analyses are performed first at the country level and then at the pan-European level, examining how neighbouring countries can contribute to the power balance of a power system under strain. Additional probabilistic analyses are performed for countries where a system adequacy risk has been identified.

The colour in Figure 21 illustrates the generation capacity compared to the peak demand.

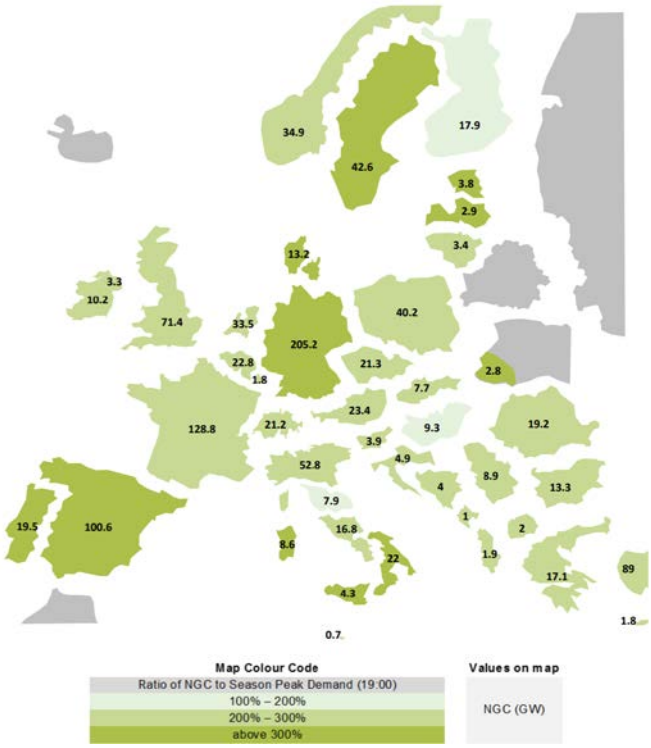


Figure 21. Net generating capacities (in GW) and colour according to their ratio to expected national peak demand in the winter season

Figure 22 illustrates which areas are dependent on import at least in one of the studied weeks during normal conditions, while Figure 23 shows the results under severe conditions. The severe condition is a 1 in 20 years situation: In winter a cold wave, and in summer a hot wave. The severe condition is then combined with the occurrence of overall very low wind and solar irradiance (a 5% percentile based on meteorological database, covering 34 years).

As part of ENTSO-Es seasonal outlooks, the level of hydro reservoirs is monitored.

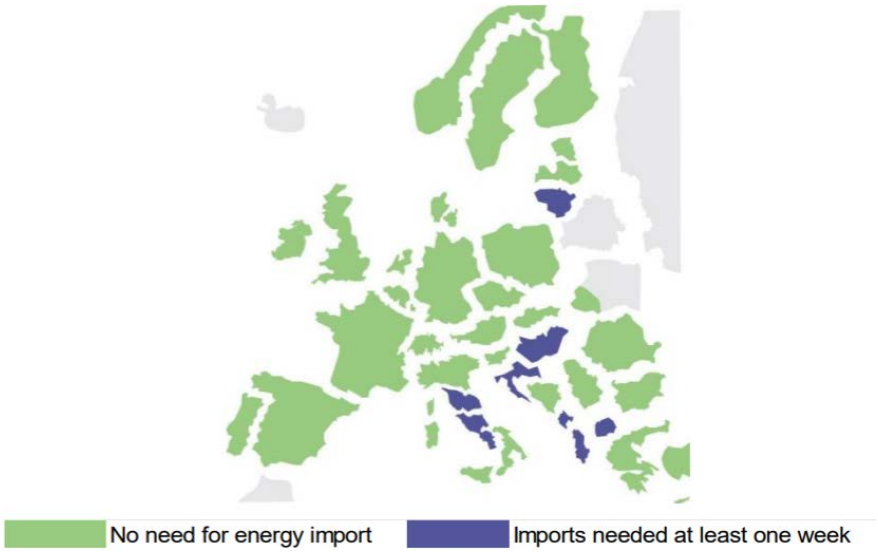


Figure 22. Adequacy under normal condition.

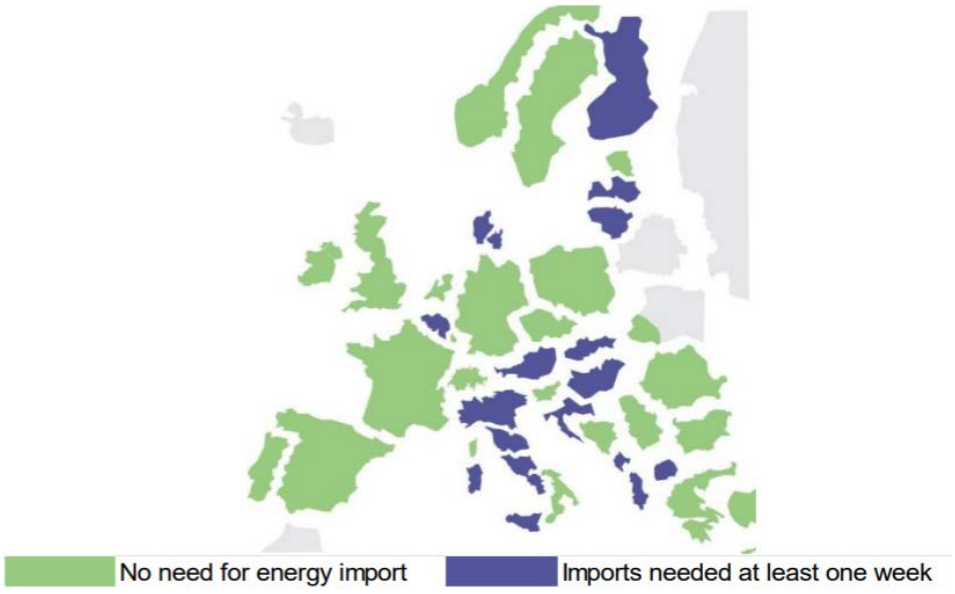


Figure 23. Adequacy under severe conditions.

On top of the deterministic analysis for all countries additional stochastic analyses is performed for selected countries. As an example, see Figure 24 where Italy is analysed. The figure shows adequacy dependent on the daily temperature and generation level from wind and solar. The green dots show cases, where adequacy is ensured without the need to import electricity, while

the blue dots show cases, where adequacy can only be ensured using import. There are no red dots, which would indicate a deficit even when taking import options into account.

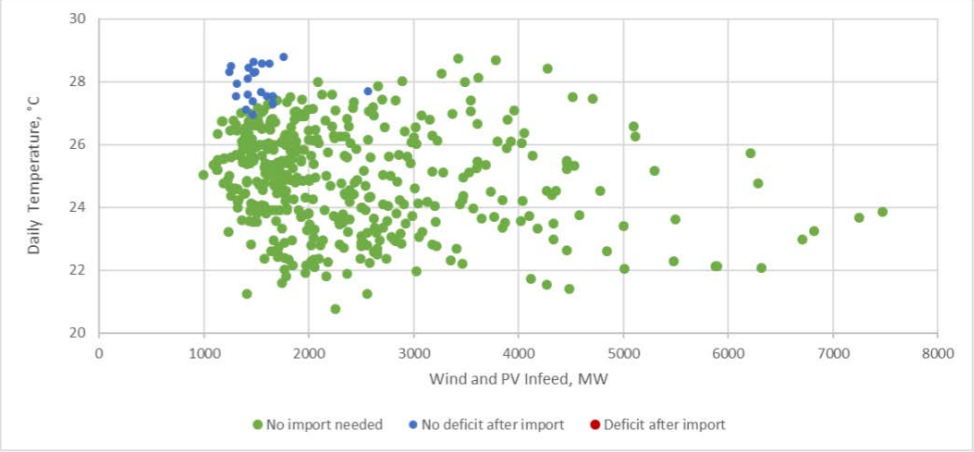


Figure 24. Result from a probabilistic sensitivity analysis – week 30 in Italy. Results for all Italian areas.

Medium term adequacy

The annual mid-term adequacy forecast (MAF) examines the system adequacy for the next 10 years. The approach for the medium-term analyses can be summarised (see Figure 25):

- Future electricity demand and generation fleet is described together with a description of cross-border transmission capacity.
- For each country an empirical relationship between temperature and electricity demand has been established. This includes the impact of both heating and cooling.
- 34 years metrological data are used to generate possible electricity demand, hydro, wind and solar power generation for each hour of the year.
- For each constructed year a Monte Carlo process is performed, with random draws of outages of individual plants and grid elements.

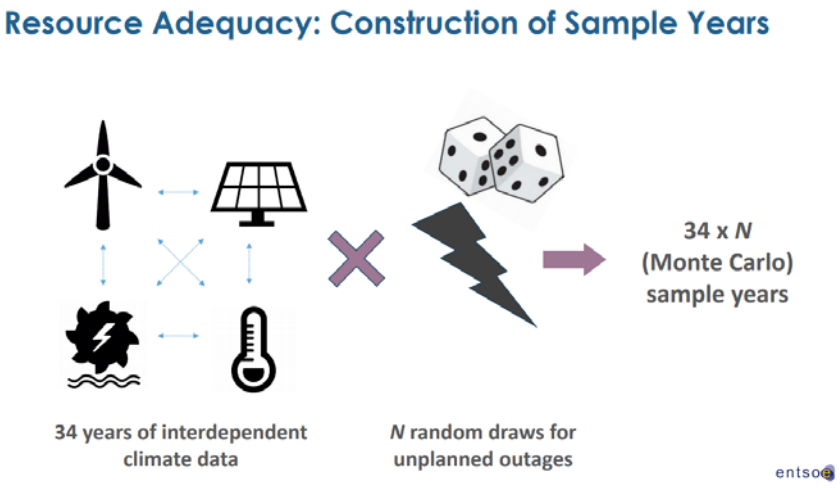


Figure 25. Source: ENTSO-E.
docstore.entsoe.eu/Documents/SDC%20documents/MAF/2018/MAF%202018%20Public%20Webinar%20-%2019.10.2018.pdf

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