ENERGINET

SECURITY OF ELECTRICITY

SUPPLY REPORT

2017

CONTENTS

Front page photo: Dismantling of pylons as part of cable laying at the Little Belt.

SUMMARY

In 2016, Danish security of electricity supply was high once again. Danes had power 99.996% of the time on average. Thus, 2016 was yet another year where Danish electricity consumers enjoyed a security of electricity supply level that was among the highest in Europe.

The work to ensure security of electricity supply is undergoing major changes due to the green transition, which involves much more wind and solar power.

Energinet's goal is to maintain the high level of security of supply in the Danish electricity system and continue to rank among the top European countries. This ambition is laid down in Strategy Plan 2014 and reflects the fact that a high level of security of supply is an important foundation for society and of great value to both businesses and citizens.

Therefore, Energinet continuously analyse developments and implements measures to ensure continued stable and cost-effective operation of the electricity system.

In future, cooperation across national borders, cooperation throughout the entire value chain, more IT support and flexibility in electricity consumption will come to play a far greater role than today.

There is also an increasing need in the years ahead for reinvestment in existing infrastructure (the transmission grid) to ensure that it will support the high security of supply level. Parts of the transmission grid are approaching the end of their technical service life.

STATUS ON SECURITY OF ELECTRICITY SUPPLY

Outage statistics and incidents
In 2016, the security of electricity supply level was just under 19 minutes of outage per electricity consumer.

No electricity consumers were disconnected during the year to ensure stability in the overall electricity system, and only a few incidents in the transmission grid resulted in power outages for electricity consumers. Thus, outages experienced by Danish electricity customers in 2016 were mainly caused by conditions in the distribution grids.

Moreover, there are no signs of an increase in the number of near-miss incidents, even with the Danish electricity supply in transition and the electricity system being optimised.

There were no hours in 2016 when the supply in the market failed to meet demand. Also, there was only one alert situation in Energinet's control centre, caused by an IT incident which temporarily affected Energinet's monitoring of the electricity system and suspended the market. There were no emergency situations in 2016.

TABLE 1: LIST OF INCIDENTS REPORTED TO THE INCIDENTS CLASSIFICATION SCALE (ICS) FOR DENMARK IN 2015 AND 2016.

CRITERIA	Scale 0	Scale 1	Scale 2	Scale 3
Faults on elements in the transmission sytem	2015: 11 2016: 1	2015: 8 2016: 13		
Exceeding voltage levels	2015: 0 2016: 0	2015: 0 2016: 0		
Loss of IT tools		2015: 1 2016: 3		

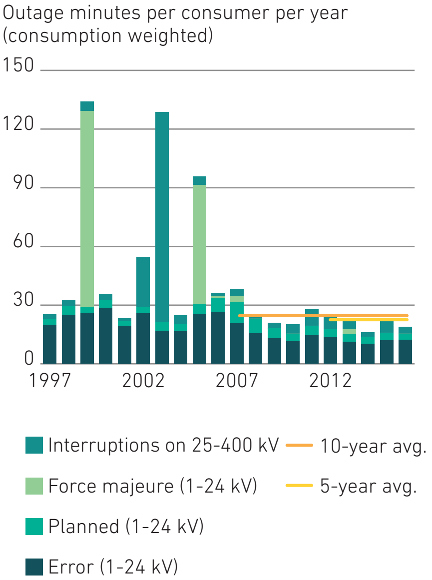
Incidents are classified in reporting on a scale from 0-3, where 3 is the most serious level:
- Scale 0. Local deviations with low impact on operational reliability.
- Scale 1. Serious incidents
- Scale 2. Extensive incidents in a large area
- Scale 3. Major incidents resulting in a blackout

An incident number comparable to that of 2015 was submitted to the European incident statistics in 2016. This was also yet another year with no incidents resulting in a violation of the voltage standards. The fact that, in recent years, Energinet's control centre has had great focus on voltage control has contributed strongly to this.

Security of supply
Security of electricity supply is "the probability that electricity is available on demand". Security of electricity supply consists of 'system adequacy' and 'system security', which are two partially overlapping elements.

FIGURE 1: OUTAGE STATISTICS FOR DENMARK, 1997-2017.

Source: Danish Energy Association.



Potentially, the lack of system security in the Danish electricity system has the most far-reaching consequences, as this may result in sudden and extensive blackouts in one or both Danish regions in a worst-case scenario. Lacking system adequacy is also a significant threat where the consequence will typically be planned disconnections of consumers in limited areas (so-called brownouts).

Ancillary services

Ancillary services is the overall term used for the production and consumption resources that Energinet pays to have available during the delivery hour. These are activated automatically or manually to ensure balance and operational reliability in the electricity system. Ancillary services consist of reserves and properties required to maintain power system stability.

The total cost of ancillary services was up in 2016, with ancillary service purchases totalling DKK 758 million against DKK 592 million in 2015. The increase is primarily attributable to increased costs of manual reserves in Eastern Denmark, due to replacement purchases in connection with the maintenance of a unit at Kyndby Power Station, which normally supplies part of the manual reserves in Eastern Denmark. Energinet also had to order a power plant put into operation in the maintenance period to procure adequate reserves, and the replacement purchase auction prices were very high.

Purchasing reserves and properties required to maintain power system stability gives Energinet's control centre manoeuvrability when faced with faults and thus contributes to system security.

FIGURE 2: ILLUSTRATION OF SECURITY OF ELECTRICITY SUPPLY CONSISTING OF SYSTEM SECURITY AND SYSTEM ADEQUACY, WHICH IN REALITY ARE TWO PARTIALLY OVERLAPPING ELEMENTS.

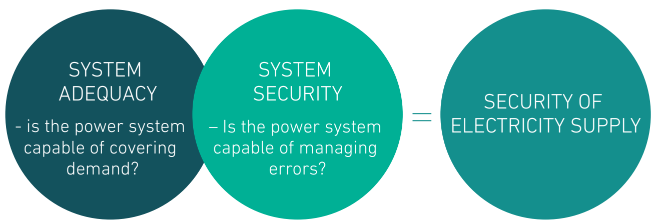
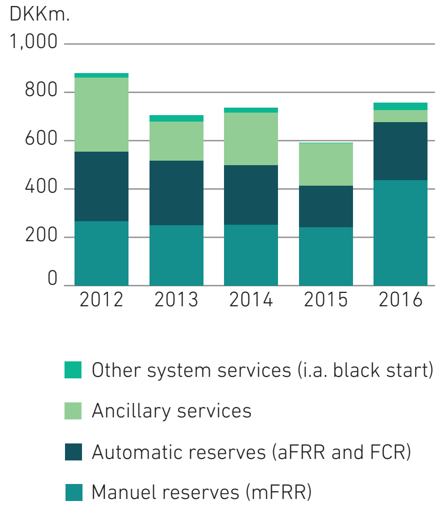


FIGURE 3: COSTS OF ANCILLARY SERVICES IN DENMARK IN 2012-2016.



The cost of purchasing properties required to maintain power system stability from market players in Western Denmark was down in 2016 as new analyses of the need for properties required to maintain power system stability documented a lower need than previously assumed. On the basis of these analyses, Energinet began to use existing components in the electricity system in a smarter way through automation.

In the course of 2016, Eastern Denmark's total need for properties required to maintain power system stability was analysed. The result was that in normal operating situations with optimised use of existing components, there is a total need for one ancillary services unit in Eastern Denmark. An ancillary services unit may be a major power plant or a synchronous condenser. Previously, assessments necessitated three ancillary services units in operation as well as an additional unit ready for start-up. Therefore, the cost of procuring properties required to maintain power system stability are expected to drop even further in 2017 if no special situations occur in the grid that require increased supplies of properties required to maintain power system stability.

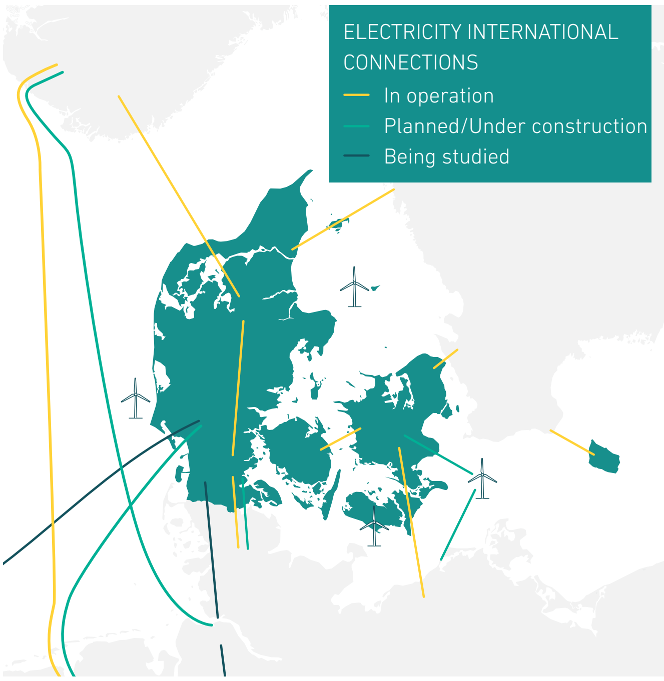
Generation adequacy

There were no cases of power shortage in 2016, either by disconnection of consumers or by insufficient capacity in the market. However, there were a few operating situations in which the loss of the largest unit in the system could have resulted in a power shortage due to maintenance work and breakdowns in the electricity system.

Grid adequacy

The total number of transmission grid faults rose in 2016 compared to last year. There were 13 incidents in 2016 in the HVDC (direct current) system which led to heightened awareness of the operation of the overall electricity system. None of the 13 incidents resulted in a disruption of supply for consumers.

FIGURE 4: INTERCONNECTORS IN DENMARK AND NEIGHBOURING COUNTRIES.



Information security

A high level of security of electricity supply requires great availability of IT tools. On one hand, modern IT plays a key role in the day-to-day operation of the electricity system. On the other hand, the use of IT also increases the electricity system's vulnerability to external attacks and internal faults in IT systems. Energinet continually works to ensure a high level of IT security and high IT system uptimes.

Energinet measures IT security based on the ISO 27001 IT security standard. At the end of 2016, it was found that Energinet's maturity level had reached the target for 2016 with an average Capability Maturity Model Integration value (CMMI value) above 3.5. The target is 4.0 in 2017. To obtain a CMMI value of 4, IT processes must have quantitative targets so they are predictable and meet the requirements of internal and external stakeholders.

International cooperation

Denmark is not the only country facing new challenges when it comes to ensuring security of supply while incorporating still more renewable energy. This is one of the reasons why common European rules on markets and electricity system operation are being prepared. More closely integrated and harmonised European electricity markets contribute to a cost-effective European electricity supply.

In 2015, the four Nordic TSOs decided to establish a joint office. The Copenhagen-based office will perform coordination tasks in relation to capacity calculations, outage planning and system reliability analyses. The initiative is in line with coming EU regulations which will require the establishment of Regional Security Coordinators (RSC) or regional security cooperation initiatives within the transmission area.

CURRENT AND FUTURE INITIATIVES

Generally, Danish security of supply is very high and will remain high in the years ahead, but not necessarily at the current level. Any challenges must therefore be taken into account, for example those related to the green transition in the coming years.

While making the transition to an increased use of renewable energy, Energinet must also continue to focus on developing the work to safeguard security of electricity supply. Energinet works, among other things, to improve operating methods, contribute new markets, build new electricity infrastructure and maintain and renovate the existing transmission grid.

In the past year, Energinet focused particularly on implementing the initiatives presented in last year's security of electricity supply report that included topics such as generation adequacy, market trends, grid adequacy, Nordic RSC and IT security.

Generation adequacy
Forward-looking risk assessments show that the risk of consumer outages is different for the two parts of the country. For Western Denmark, the risk of a power shortage is deemed very low for the 2017-2025 period.

In Eastern Denmark, Energinet projects that, over the next 10 years, the risk of power shortages in general will increase relative to today and will exceed Energinet's objective from Strategy Plan 2014.

According to the simulation results, an average consumer in Eastern Denmark will be without power for 7 minutes in 2018 and 33 minutes in 2025 due to power shortages. Seven minutes equates that the average consumer is expected to have 99.9987% of the demanded energy supplied, while 33 minutes correspond to 99.9937%. The risk of brownouts may be reduced by, for example, maintenance planning, market solutions (e.g. strengthened efforts to ensure flexible consumption), a new production capacity framework and establishment of new infrastructure for new areas. Calculation results are subject to uncertainty, but indicate that a few brownout situations must be expected over the next 10 years.

One specific initiative which may improve long-term generation adequacy in Eastern Denmark is an additional electricity connection to Western Denmark. A project has been launched to determine whether a new connection is a socio-economically attractive solution for strengthening the power balance in Eastern Denmark.

As one step towards ensuring generation adequacy in Eastern Denmark, Energinet wanted to create a strategic reserve in the 2016-2018 period to contribute to supply in highly critical situations Energinet decided to cancel the call for tenders in December 2015. The tender was called off because Energinet did not expect to be able to implement it, as the European Commission saw the reserve as a breach of the EU rules on state aid.

Since then, the European Commission has carried out a sector inquiry into capacity mechanisms. Based on this, Energinet assesses that it is not possible to make a call for tenders for a strategic reserve at present. Energinet reduces the risk of disconnecting consumers in the event of shortages in Eastern Denmark through improved coordination of maintenance work on international connections, power plants and own installations as well as generally optimised outage times in connection with construction projects. In addition, Energinet has ensured a shorter start-up warning time at one power plant.

The market
Energinet is currently focussing on

132 kV power pylons near Copenhagen.

two key areas within market trends: Changes in the future market model are based in particular on the European network codes and the conclusions from the Market Model 2.0 project.

As concerns market initiatives, these must be coordinated to a large extent with international partners in accordance with, among other things, the pan-European network codes. In addition, amendments to the Danish Electricity Supply Act (Elforsyningsloven) may be required in order to implement a few of the initiatives.

Grid adequacy
Energinet currently faces substantial reinvestment in the Danish transmission grid. Extensive work is therefore being done to structure and optimise reinvestment in the existing transmission grid. Reinvestment planning takes into account the state of components and how critical the components are to the electricity system as a whole.

Reinvestment means more maintenance in the transmission grid than previously, which increases the risks in the electricity system in terms of both system security and system adequacy. Energinet therefore focused heavily on maintenance planning, also in cooperation with neighbouring TSOs.

A particular focus area is Copenhagen where the rise in electricity consumption and the decommissioning of thermal power plants result in a need for a new supply structure. Energinet expects to establish a new transmission connection to Copenhagen to secure the supply from the rest of Zealand into Copenhagen. Today, Energinet already continuously assesses the need for local production in Copenhagen and when needed Energinet initiates measures such as orderings to ensure continuous high security of supply in Copenhagen.

International cooperation
A working group was appointed in 2015 at the European level to develop a new market-based and probabilistic method for assessing generation adequacy uniformly across borders. This major focus on transnational cooperation on assessing generation adequacy will also be a key point in the future. The next report is expected in autumn 2017. Within the Nordic cooperation, the four Nordic TSOs decided to prepare common generation adequacy assessments for 2017-2018. The assessments aim to highlight the challenges faced by the Nordic countries, and place more emphasis on effective transnational solutions.

The establishment of the RSC office in Copenhagen significantly strengthens Nordic coordination. The office is already staffed with participants from the four TSOs and is expected to be in full operation at the end of 2017.

Information security
If the same focus and activity level are maintained throughout 2017, Energinet will be able to reach the target set for the end of 2017 of a CMMI value of 4.0. To raise maturity, Energinet is working to improve IT security at all levels, and to identify potential threats to electricity and gas system operations.

Energinet also aims to ensure that modern information technology is used in and seen as an integral part of the electricity and gas system design. This means incorporating data security in processes, systems and components.

1. SECURITY OF ELECTRICITY SUPPLY

The Danish security of electricity supply ranks among the best in Europe, and Danish consumers have enjoyed a very high level of security of electricity supply for many years. A necessity indeed, as a secure electricity supply is vital to basic functions in society, including hospitals and businesses, and to private consumers.

Security of electricity supply is measured by whether there is power when the consumer flicks the switch. Security of supply monitoring is carried out through regular risk assessments that use generally approved methods to estimate the probability that electricity is available to consumers on demand.

Ensuring a high security of supply involves a complex interaction between the physical electricity grid, the electricity market, producers and consumers. In other words, it is not just a question of power line sizes or the number of power plants and wind turbines.

1.1 Security of supply in an international context

Historically, security of electricity supply has primarily been a national issue, with initiatives to ensure a high level of security of supply rooted in national legislation. In line with the electricity market becoming increasingly European and with electricity flowing across borders, it has become an increasingly regional and international issue. In addition to the aim of establishing a common deregulated European market, the ambition is for consumers to decide to a greater extent what level of security of supply they want. The consumer may potentially decide on the level of generation adequacy.

However, it will be a lengthy process to get the electricity market to play such a central role in maintaining security of supply. Experience in recent years has shown that there are still barriers to the development of a smoothly operating single market for energy. Individual member states still hold a national focus which affects the functionality of the single market and therefore its ability to ensure adequate production capacity on its own.

WINTER PACKAGE

On 30 November 2016, the European Commission introduced a major legislative package called "Clean Energy For All Europeans", also called the "Winter Package".

The Winter Package constitutes a key element in the implementation of the EU's Energy Union, which was launched in February 2015. The Energy Union sets the direction for the future European energy and climate policy and was established to contribute to the EU reaching its 2030 climate and energy targets as well as its long-term objective of a fossil fuel-free economy in 2050. The package contains a large number of legislative proposals within the energy field, which must be negotiated over the coming years:

- Electricity market design
- Governance of the Energy Union
- Energy Efficiency Directive
- Energy efficiency in buildings
- Renewable Energy Directive

132 kV power pylons near Copenhagen.

To accommodate this, the European Commission published an energy package (also called the Winter Package) in the autumn of 2016 which extends EU cooperation, and also the cooperation on security of supply. Energinet sees the Winter Package as a necessary next step towards jointly solving any future challenges for the electricity system while also benefitting from the value inherent in solving problems across borders.

A good example of this development is network codes for operational cooperation and the establishment of the Nordic RSC (Regional Security Coordinator) in Copenhagen. The main purpose of establishing a joint Nordic RSC is to ensure that the Nordic electricity system will also function effectively in future with increasing quantities of green energy from wind and solar power.

1.2 Legal framework

Energinet is Denmark's transmission system operator and legally founded on the Danish Act on Energinet.dk (Lov om Energinet.dk) and the Danish Electricity Supply Act (Elforsynings-loven). Energinet owns and operates Denmark's main electricity and natural gas grids and is responsible for the security of electricity and gas supply. Energinet works to ensure balance in a sustainable energy system with increasing quantities of renewable energy. This is done through international, market-based solutions and cooperation across the energy sector's value chain.

The Danish Electricity Supply Act contains various provisions for the framework for a high level of security of electricity supply, and various authorities are assigned tasks and competences in relation to this. In section 27 a(1) of the Act, Energinet is assigned the overall responsibility for security of electricity supply in Denmark. This obligation creates the foundation for Energinet's core tasks when it comes to underpinning a high level of security of electricity supply. The Danish Electricity Supply Act is expected to be revised in the coming years.

ACT OF ELECTRICITY SUPPLY

Section 27 a(1) of the Danish Electricity Supply Act forms the basis of Energinet's core tasks, which include:

Monitoring security of supply in the electricity system for the entire value chain, including historical trends and expectations for the coming period. Monitoring comprises, among other things, an assessment of system adequacy, which includes assessing whether there is adequate power to cover demand (generation adequacy) and whether there is sufficient infrastructure to transport the electricity from the production unit to the consumer (grid adequacy).

In addition, it must be assessed whether the electricity system is sufficiently robust to maintain supply in the event of sudden malfunctions – system security. This includes, for example, assessing whether the electricity system can handle the random outage of a component, e.g. a line, so that a system collapse can be avoided.

Ensuring that physical balance is maintained and ensuring an appropriate level of technical quality throughout the electricity system. Daily operation of the electricity system must, among other things, ensure that electricity generation and electricity consumption balance at all times. Through active and ongoing updates of forecasts and operational planning towards the individual delivery hour, it is possible to minimise imbalances before they occur at the moment of delivery.

Not only is such proactive operation a cost-effective way to balance the electricity system, but it also provides Energinet's control centre with an in-depth and ongoing insight into the resources present in the electricity system at any given time.

Developing the framework for a smoothly functioning and internationally interconnected electricity market which can ensure balance between consumption and production. A smoothly functioning market ensures the right incentives for both consumers and producers to maintain balance between consumption and production in both the short and long term.

Effectively operating and investing in the transmission grid, taking into account security of supply. Investments and maintenance of the transmission grid constitute key elements in maintaining security of electricity supply.

The transmission grid must be able to deliver the necessary power in normal operating situations as well as in situations where there are reasonably predictable faults and outages in the grid. Infrastructure capacity and design are therefore vital to the overall security of electricity supply.

Ensuring that adequate production capacity is available if the market fails to do so. In principle, being market players, production and trading companies, have the possibility to decide the level of production capacity, consumption flexibility and storage. However, the commercial players do not have direct responsibility for security of electricity supply, and are not obligated to supply power to the market during normal operation.

Adequate production capacity must be assessed to ensure overall generation adequacy, which indicates whether there is adequate energy to meet demand at the hourly level.

1.3 Costs of security of electricity supply
Cost-effective security of electricity supply is about ensuring that the electricity system works, so the players in the entire value chain can supply energy to customers when they need it.

When looking at the total cost level in respect of security of supply, the costs in the entire value chain must therefore be assessed. This may, for example, include ancillary services, IT tools, reinvestment or expansion of the electricity grid due to rising consumption or changes in production. But it may also be costs of production as well as the distribution and transmission grids – i.e. the elements included in the consumers' electricity price. Indirectly, trends in the consumers' electricity price (excluding taxes and duties) are therefore an expression of the total cost of security of electricity supply. This report describes, among other things, ancillary services, IT security and the need for new infrastructure in Copenhagen.

When it comes to assessing whether to invest more or less in maintaining a given level of security of electricity supply, it is appropriate to assess whether tools should be introduced to minimise risks in the entire value chain, as incidents that may lead to electricity outages for consumers are often rare.

In other words, it is an assessment of whether insurance should be taken out against insufficient supply. In this context, costs become a question of looking into different types of insurance and comparing these with the risk reduction they provide. A high level of security of supply in Denmark is deemed to have great social value, and several insurance policies have therefore been taken out against insufficient supply in the Danish electricity system.

A high level of security of supply involves costs, and it is therefore not possible to have 100% security of supply in practice, as this would require infinite backup of both generation and infrastructure, making this infinitely expensive, as illustrated in Figure 6.

Moreover, many risks are cost-intensive to address at a national level. A high and cost-effective security of electricity supply in Denmark therefore also involves assessing options in close international cooperation.

FIGURE 6: ILLUSTRATION OF THE RELATIONSHIP BETWEEN COSTS AND SECURITY OF SUPPLY.

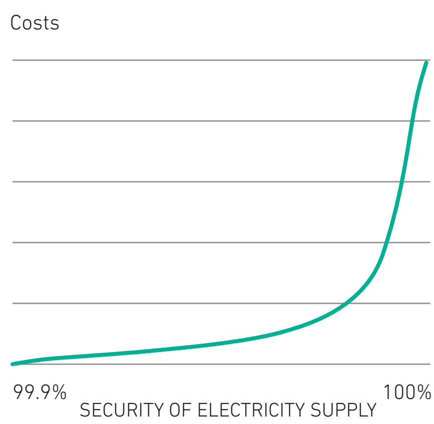
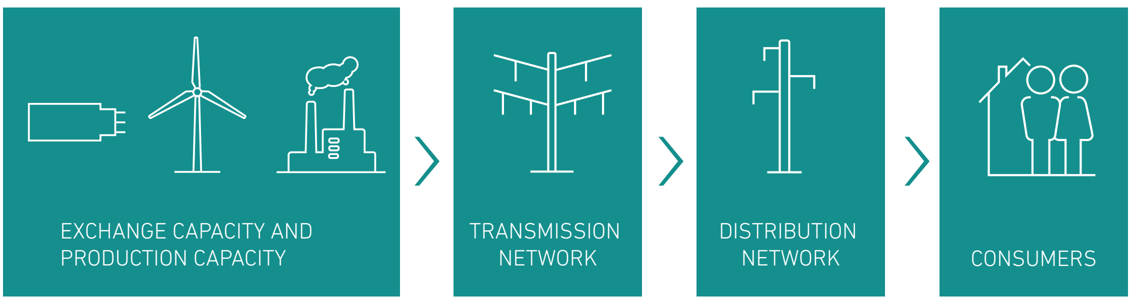


FIGURE 5: A TRADITIONAL ELECTRICITY SYSTEM, FROM PRODUCTION TO CONSUMER.



2. HISTORICAL SECURITY OF ELECTRICITY SUPPLY

Danish security of electricity supply ranks among the highest in Europe. Danish electricity consumers have thus enjoyed very high levels of security of supply for many years. This is also true for 2016, which saw a very low number of outage minutes per consumer as well as a low number of incidents in the electricity system that impacted the security of electricity supply.

2.1 Outage statistics
Faults and outages have been recorded via the Elselskabernes Fejl- og Afbrudsstatistik (ELFAS) statistics since 1967. The statistics are compiled by the individual grid companies reporting system disturbances at the distribution level and Energinet reporting system disturbances at the transmission level. ELFAS provides a comprehensive basis for analysing Danish security of electricity supply in a historical perspective.

Outage statistics are not yet calculated at the individual customer level. This will only be possible once all consumers have digital electricity meters and are registered in the central DataHub.

The outage statistics indicate the extent to which consumers have experienced outages on average. Some consumers will experience outages lasting anywhere from a few minutes up to several hours, while others will not experience outages at all.

In 2016, the number of outage minutes was still very low. There were just less than 19 minutes of outages, which is lower than in 2015.

Figure 7 shows the average duration of electricity supply outages in minutes per consumer per year (consumer-weighted) in Denmark. The columns in the figure are divided into 1-24 kV and 25-400 kV voltage ranges. For the 1-24

FIGURE 7: OUTAGE STATISTICS FOR DENMARK, 1997-2017.
Source: Danish Energy.

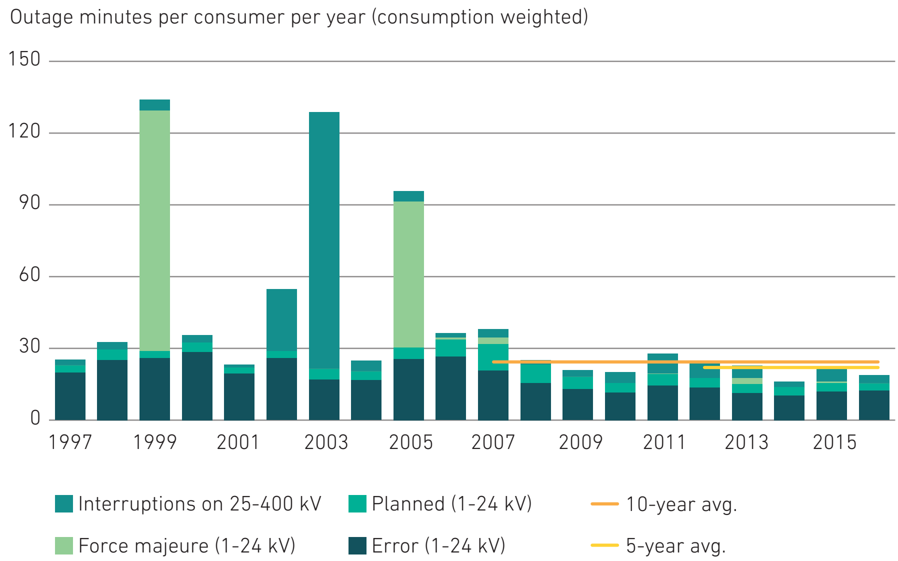


TABLE 2: AVERAGE OUTAGE MINUTES OVER THE LAST 5, 10, 15 AND 20 YEARS.

Min/year	5 years	10 years	15 years	20 years
Distribution < 25 kV	16.1	19.1	25.8	31.2
Transmission og distribution >= 25 kV	4.5	4.4	12.5	10.1
Total	20.6	23.5	38.3	41.3

kV distribution level, where the majority of outages occur, outages are also divided into cause. Historically speaking, power shortages have not caused consumer outages in Denmark and are therefore not included in the figure.

Apart from one-time incidents – such as a fault in the transmission grid in 2002 and a fault in the Swedish grid in 2003 – the general picture is that the vast majority of outage minutes are due to faults in the distribution grid.

Major faults at the transmission level are rare, but affect a large numbers of consumers when they do occur. This was the case in 2002 and 2003. The average outage level should therefore be defined over a number of years.

In Denmark, outages at the distribution level are relatively stable at around 20-30 minutes per average consumer per year. However, these outages have seen a slight downward trend due to conversion of the distribution grid to underground cables.

2.2 Electricity system incidents in 2016
Incidents of significance to the security of electricity supply occur at the market, system, IT and component levels.

2.2.1 Wholesale market
There were no incidents related to power shortages in the Danish electricity system in 2016. As has been the trend historically, there were thus no market-related shortages in 2016 which led to failure to reach a market price.

The last time spot prices hit the price cap was on 7 June 2013 in Western Denmark – but this did not lead to consumer outages.
However, there were a few operating situations in which the potential loss of the largest unit in the system could have led to a power shortage due to maintenance work and breakdowns in the electricity system.

2.2.2 Use of brownout
Controlled disconnection of consumers (brownout) to handle strained operating situations has not been necessary in 2016 or in recent years.

2.2.3 Daily operations
Daily operation of the electricity system must ensure that electricity generation and electricity consumption balance at all times. Through active monitoring and ongoing updates of forecasts and operational planning

OPERATING STATUS TYPES

During **normal operation**, the electricity system follows the normal operating conditions, including being able to handle an outage of the largest unit (the N-1 principle).

If incidents in the electricity system threaten normal operation and there is a risk of operation disruption, the operating situation changes to an alert state. In an alert state, the market can be suspended and Energinet can pull all the levers at its disposal to maintain the electricity supply.

If operation becomes unstable and there are also local/regional outages, the operating situation is changed to emergency state. In an emergency state, Energinet calls in extra crisis staff and preparations are made to handle extended system disturbances.

FIGURE 8: ILLUSTRATION OF THE LINK BETWEEN THE INCIDENTS CLASSIFICATION SCALE (ICS) AND THE IMPACT OF THE INCIDENT.

ICS	›	Scale 0	Scale 1	Scale 2	Scale 3
In-fluence	›	Locally	Neigh-boring TSO's	Synchro-nously area	Blackout

up to the individual delivery hour, it is possible to minimise imbalances before they occur at the moment of delivery. Energinet's control centre operates with three different operating status levels: normal operation, alert state and emergency state.

The electricity system mostly runs in normal operation. Occasionally, the operating situation is in an alert state, but the market is very rarely suspended. In 2016, an alert state was registered once in April. This was caused by an IT incident which temporarily affected the control centre's monitoring of the electricity system and suspended the market. The problem was quickly solved, and close cooperation with neighbouring TSOs, among other things, ensured that there were no consumer outages in the intervening period.

TABLE 3: LIST OF DANISH INCIDENTS REPORTED TO THE ICS STATISTICS IN 2015 AND 2016. LOSS OF IT TOOLS IS ONLY REGISTERED FOR SCALE 1 AND SCALE 2 INCIDENTS IN THE ICS STATISTICS.

CRITERIA	Scale 0	Scale 1	Scale 2	Scale 3
Faults on elements in the transmission sytem	2015: 11 2016: 1	2015: 8 2016: 13		
Exceeding voltage levels	2015: 0 2016: 0	2015: 0 2016: 0		
Loss of IT tools		2015: 1 2016: 3		

An emergency state is declared extremely rarely, and there were no cases in 2016.

2.2.4 European incident reporting

The European electricity system is closely connected, and system disturbances in one country may impact neighbouring countries or, in a worst case-scenario, all of Europe. Therefore, European TSOs work together to ensure secure operation in a common electricity system.

ENTSO-E uses the Incidents Classification Scale (ICS) to improve joint European operations. ICS aims to provide an overview of incidents in the European electricity transmission system.

There were 13 incidents in the transmission grid in 2016 against eight the year before. Five of the incidents in 2016 occurred at Konti-Skan, five at Skagerrak, two at the Great Belt and one at Kontek.

Three incidents with loss of critical IT tools were registered in 2016 against one in 2015. The incidents in 2016 constituted a firewall problem due to software errors, problems with updating the SCADA system servers and, finally, a human error in connection with work being done on network equipment.

2.2.5 Incidents in the electricity transmission system

Knowledge of faults and outage rates is used to assess and plan future system security and in asset management. Faults in individual components or alarm systems rarely lead to failure to supply energy to the consumer. Disturbances and faults in the grid over 100 kV are reported each year. In addition, an annual report is prepared on

FIGURE 9: ILLUSTRATION OF THE PERCENTAGE DISTRIBUTION OF FAULTS IN THE HVAC GRID.

Source: DISTAC, Nordic and Baltic Grid Disturbance Statistics 2015.

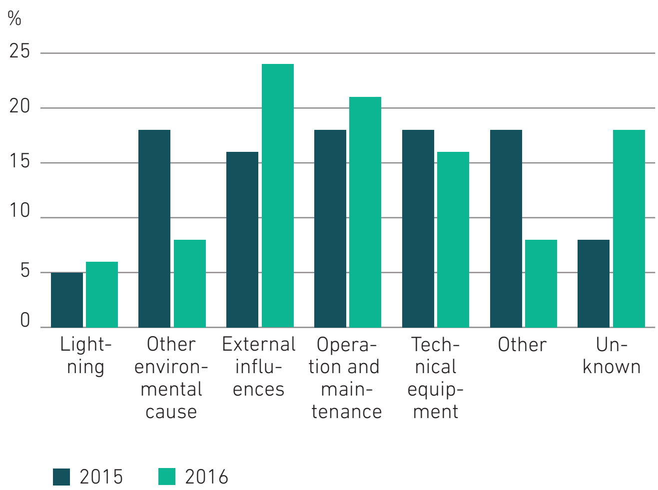
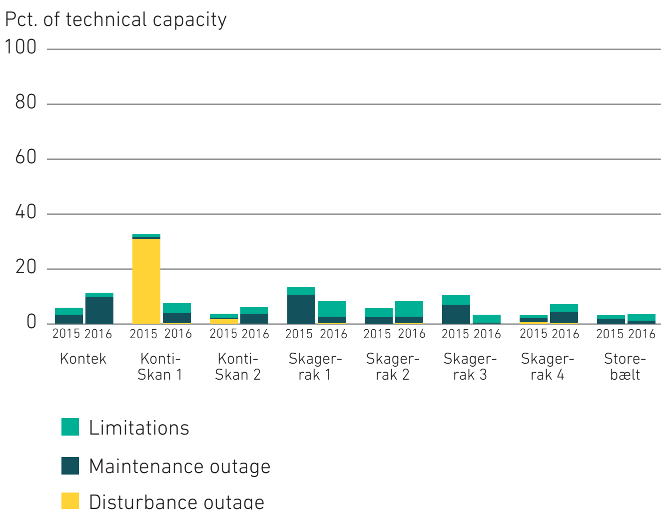


FIGURE 10: CURRENT RESULTS FOR CAUSES OF OUTAGE/ LIMITATIONS FOR DANISH HVDC CONNECTIONS.

Source: DISAC, Nordic and Baltic HVDC Utilisation and Unavailability Statistics 2016.



the utilisation of the HVDC connections with faults, limitations, accessibility etc. The analyses and statistics are published via ENTSO-E and prepared by the Nordic and Baltic countries. The aim is to develop a uniform method for classifying and calculating the number of disruptions and faults for the entire Nordic and Baltic region.

Reporting on the HVAC grid

The 'Nordic and Baltic Grid Disturbance Statistics' for the HVAC grid is a technical incident report providing insights into fault rates, causes, components subject to multiple faults and security of supply.

There were 51 faults in the Danish grid over 100 kV in 2016, compared to 79 in 2015. The 10-year average from 2007 to 2016 is 58 faults. The number of faults causing consumer outages was 13 in 2016, compared to seven in 2015.

Of the three largest faults in the grid over 100 kV in 2016, two were age-related, where a disconnector and busbar broke in connection with switching. The most serious fault led to consumers in the area having no electricity for approximately 26 minutes.

The second-largest fault was caused by salt deposits on insulators as a result of the storm Urd. Consumers in the area were without electricity for approximately 24 minutes.

Reporting on HVDC connections

In Denmark, the HVDC report covers a number of international connections and the Great Belt Power Link. The "Nordic and Baltic HVDC Utilisation and Unavailability Statistics" report contains information on how the Nordic HVDC connections are impacted by technical limitations in the grid or by faults and maintenance work.

In 2015 and 2016, there were 24 faults

on connections to/from Denmark. There were no long-duration faults in 2016.

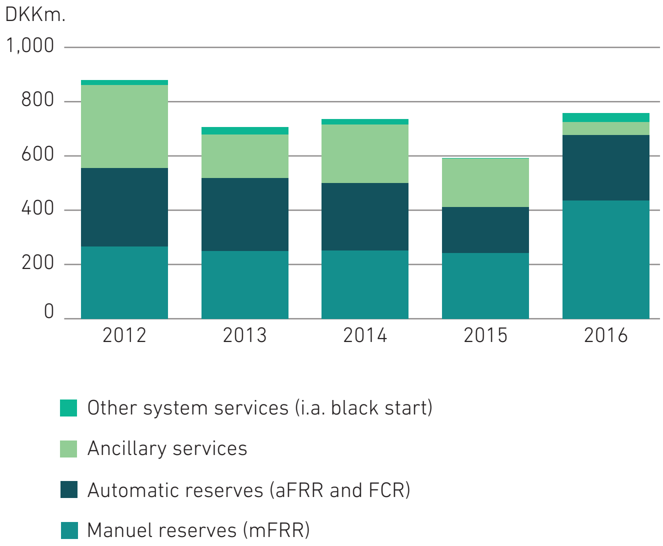
2.2.6 Ancillary services

Ancillary services is a general term for the production and consumption resources which Energinet pays to have available during the delivery hour and which are activated automatically or manually to ensure balance in the electricity system. Ancillary services consist of reserves, balancing power and properties required to maintain power system stability.

Their purpose is to maintain balance and stability in the electricity system. Energinet works continuously to develop the markets for ancillary services to ensure sound competition and appropriate procurement of the necessary ancillary services in socio-economic terms.

In 2012 to 2016, ancillary services were purchased at between DKK 600 million and DKK 900 million per year. Overall, costs increased by approximately DKK 150 million from 2015 to 2016.

FIGURE 11: TOTAL COSTS OF ANCILLARY SERVICES IN 2012-2016 COVERING PURCHASES OF BOTH RESERVES AND PROPERTIES REQUIRED TO MAINTAIN POWER SYSTEM STABILITY.



PROPERTIES REQUIRED TO MAINTAIN POWER SYSTEM STABILITY

THE PROPERTIES REQUIRED TO MAINTAIN POWER SYSTEM STABILITY ARE THOSE SERVICES NECESSARY TO MAINTAIN A SECURE AND STABLE OPERATION OF THE ELECTRICITY SYSTEM WHICH ARE NOT PROCURED ON THE ELECTRICITY MARKETS.

- **Frequency stability:** Maintaining a stable frequency in addition to what balancing in the active power markets is capable of. Inertia is the relevant property.
- **Voltage stability:** Maintaining a stable voltage with as little transport of reactive power as possible and maximisation of the active power transport. Dynamic voltage control is the relevant property.
- **Short-circuit power:** Maintaining a suitable short-circuit power level which permits operation of the electricity system, so both the classic HVDC connections and relay protection can function properly.

Properties required to maintain power system stability are provided by thermal plants in operation and synchronous condensers, and the power is reduced over long distances. For example, an ancillary services unit in North Jutland can provide 'strong' properties for system stability in North Jutland, but 'weaker' properties in South Jutland.

The largest change from 2015 to 2016 is a considerable increase in the cost of manual reserves. This is due to replacement purchases in connection with the maintenance of a unit at Kyndby Power Station, which normally supplies manual reserves. During the maintenance period, Energinet had to order a power plant into operation to procure adequate reserves, and the auction prices were very high. The reserves supply increased during the first week of the auction, which led to a significant price drop and meant that it was not necessary to order power plants into operation for the rest of the maintenance period.

Costs of purchasing properties required to maintain power system stability was down approximately DKK 120 million from 2015 to 2016. The reduction primarily owed to the updated analyses of the need for properties required to maintain power system stability, which have considerably reduced planned orders.

TABLE 4: DISTRIBUTION ON MARKET CONTRACTS AND ORDERS OF COSTS OF PURCHASING PROPERTIES REQUIRED TO MAINTAIN POWER SYSTEM STABILITY.

COST FOR PROCUREMENT OF PROPERTIES TO MAINTAIN POWER SYSTEM STABILITY				
DKK million	2013	2014	2015	2016
Planned				
• Market contracts	104	164	171	18
• Ordered under the Danish Electricity Supply Act	0	0	0	30
Unplanned				
• Ordered under the Danish Electricity Supply Act	57	54	6	0
Total	161	217	177	48

Note: "Planned" refers to an order having been announced typically several weeks in advance. The underlying 'Market contracts' refer to purchasing during the summer period when there has been competition. Conversely, 'Ordered under the Danish Electricity Supply Act' refers to situations without competition or a very specific need which has not made competition possible but only bilateral negotiations.

"The work to ensure security of electricity supply is undergoing major changes due to the green transition, which involves much more wind and solar power. "

The increase in costs for planned orders under the Danish Electricity Supply Act is attributable to a significantly higher number of monopoly situations due to geographical constraints in the summer supply in 2016 which meant that market contracts were not possible. Consequently, the cost of purchasing market contracts was also down.

Plans to close power plants and cancelled maintenance applications

A maintenance plan is prepared each year, listing central power plant maintenance. The maintenance plan is coordinated by Energinet with input from power plants, neighbouring TSOs and Energinet. Once the maintenance plan has been approved, Energinet cannot deviate from it without compensating the affected power plants. Energinet did not cancel any maintenance included in the 2016 plan.

In 2016, there have been several applications for longer start-up warning times ('mothballing') for thermal power plants. In each situation, Energinet has assessed any security of supply-related consequences.

In a number of cases, Energinet found that the proposed start-up warning times would mean an unacceptable deterioration of the security of supply, only granting permission for shorter start-up warning times than those applied for.

2.2.7 Availability at central power plants

Average availability of central power plant production in Denmark is based on previous years' levels. The average availability of central power plant production was 79% of technical capacity in 2015 and 73% of technical capacity in 2016. An availability percentage below 100% primarily owes to maintenance work and breakdowns. Availability is expected to be significantly higher than average when faced with situations of high prices on the electricity market.

2.2.8 Emergency incidents

Incidents occur regularly in the electricity system. Most of these are handled by the normal duty operator structure and are therefore not viewed as emergency incidents. Emergency incidents are rare but can have a major impact on the security of supply.

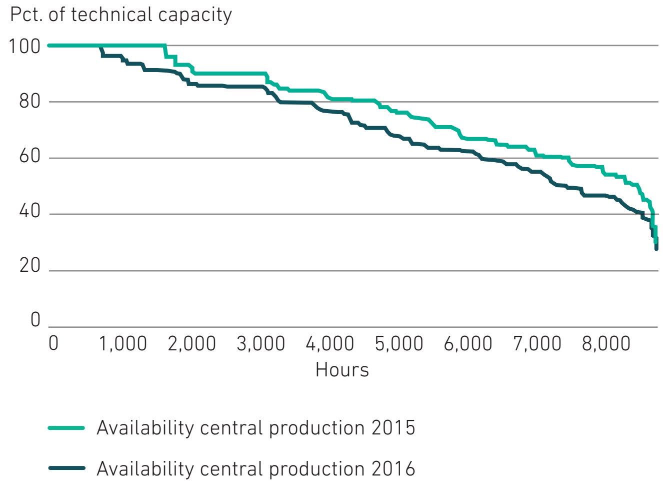
Emergency incidents are often complex and require several functions and companies to work together. Therefore, an incident often requires cooperation with players outside the sector – such as the police, fire department and emergency response services.

There were no major emergency incidents in the electricity system in 2016 which threatened supplies to consumers.

In 2016, Energinet's emergency response apparatus was only activated to a lesser extent. It was not necessary to prepare incident reports for the Danish Energy Agency.

FIGURE 12: DURATION CURVES FOR AVAILABILITY OF CENTRAL POWER PLANT CAPACITY IN 2015 AND 2016.

Source: Extract of UMMs (Urgent Market Messages) from ENTSO-E's Transparency Platform.



3. FORWARD-LOOKING RISK ASSESSMENTS

FIGURE 13: ILLUSTRATION OF SECURITY OF ELECTRICITY SUPPLY CONSISTING OF SYSTEM SECURITY AND SYSTEM ADEQUACY.

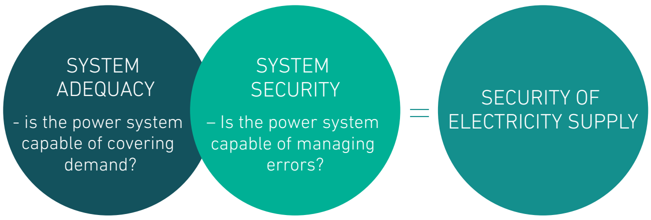
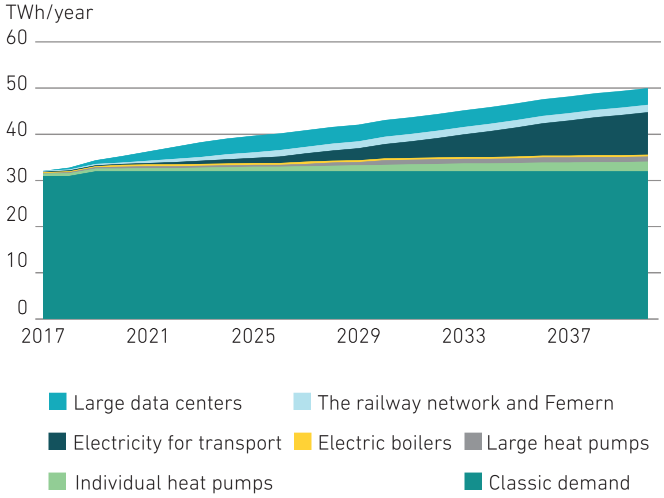


FIGURE 14: EXPECTED TRENDS IN DANISH CONSUMPTION BROKEN DOWN BY CATEGORIES.

Source: Energinet's analysis assumptions 2017.



Risk assessments for the electricity system are divided into two categories – system adequacy and system security – which in reality are two partially overlapping elements.

Assessing system adequacy means assessing the electricity system's ability to meet total consumer demand, and can be subdivided into generation adequacy and grid adequacy. Generation adequacy is the system's ability to generate sufficient electricity for consumers when it is needed. Grid adequacy is the transmission and distribution system's ability to transport sufficient electricity from where it is produced to where it is needed. Insufficient system adequacy will typically result in announced disconnections of consumers in limited areas.

Assessing system security means assessing the electricity system's ability to handle sudden system disturbances caused by electrical short circuits, power plant or transmission line outages etc. without this affecting the electricity supply or resulting in power outages. System security is the biggest threat to the Danish electricity system, as the consequence in a worst-case scenario is an extensive blackout in Western and/or Eastern Denmark.

Forward-looking risk assessments primarily focus on:

- Generation adequacy
- Market trends
- Grid adequacy
- System security
- Daily operations
- Information security

Risk assessments are used to evaluate whether mitigating initiatives should be effected to meet Energinet's target of 20 minutes of outage overall in the transmission grid.

Generally speaking, the Danish security of supply is very high and will remain high in the years ahead, albeit not necessarily at the current level.Consequently, future challenges must be taken into account, for example in connection with the green transition in the coming years.

FIGURE 15: EXPECTED TREND IN MAXIMUM HOURLY POWER CONSUMPTION (10-YEAR WINTER).

Source: : Energinet's analysis assumptions 2017.

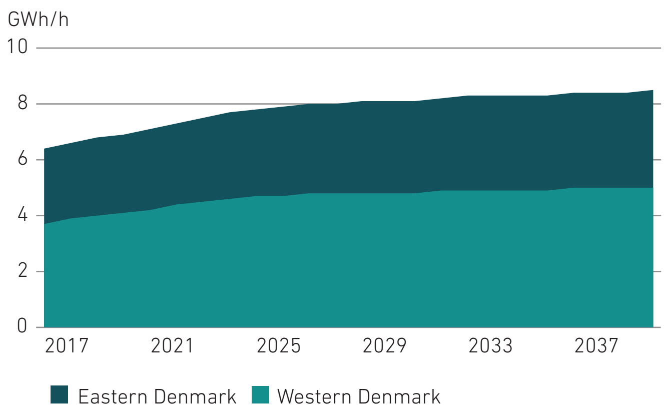
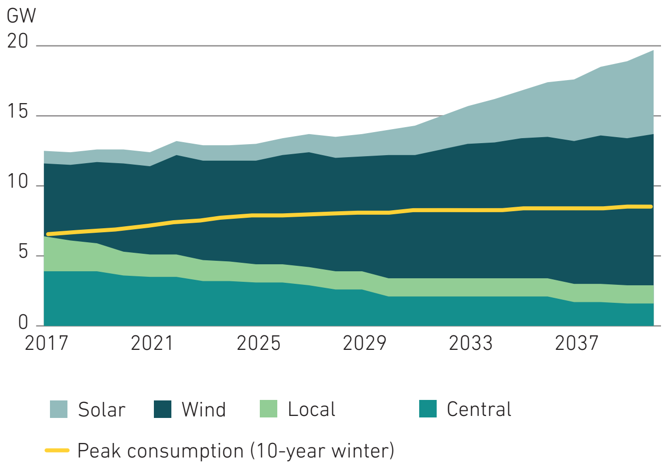


FIGURE 16: EXPECTED TRENDS IN INSTALLED DANISH PRODUCTION CAPACITY AND EXPECTED MAXIMUM HOURLY CONSUMPTION IN A 10-YEAR WINTER.

Source: Energinet's analysis assumptions 2017.



3.1 Assessment of future assumptions

The development in the Danish electricity system is essential to analyses of security of supply. Expectations for the future assumptions are used to assess the extent to which the electricity system will be able to handle security of supply towards consumers. It is therefore important to regularly assess the expectations for development in the electricity system.

Every year, Energinet therefore prepares its best estimate of the development of key parameters within the electricity and gas sectors, called the analysis assumptions. The analysis assumptions are drawn up on the basis of involvement of and input from the industries. The assumptions are used across analyses, forecasts, budgets and business cases etc.

3.1.1 Electricity consumption

Electricity consumption is expected to increase in the coming years. Classic electricity consumption is expected to be roughly constant in the long term, but a considerable increase is expected in other consumption categories, such as data centres, heat pumps and electric vehicles. To a large extent, the expected increase in consumption up until 2024 is due to regular connections of large data centres.

The increasing number of data centres also entails an expectation of a market increase in the expected maximum power consumption in the years ahead. Expected trends for both energy and power place growing demands on the production and exchange capacities in the future.

3.1.2 Production capacity
These years, the trend in Danish production capacity shows a move away from thermal capacity towards renewable energy sources such as wind and solar power. The total installed production capacity is increasing, but may still pose a challenge for the security of supply because the energy production will fluctuate more.

3.1.3 Exchange capacity
Denmark has a significant exchange capacity in relation to the size of the consumption, and this capacity is expected to grow in the coming decade. Based on the expected projects, exchange capacity will increase by approximately 4 GW until 2025.

New capacity comes from four projects (first full year with commercial operation):
- Expansion of capacity between Western Denmark and Germany in two stages up to 3,500 MW from 2023
- A new 400 MW connection between Eastern Denmark and Germany from 2019 via the Kriegers Flak offshore wind farm
- A new 700 MW connection between Western Denmark and the Netherlands (COBRAcable) from 2020
- A new 1,400 MW connection between Western Denmark and the UK (Viking Link) from 2023 (this connection is in the planning stage).

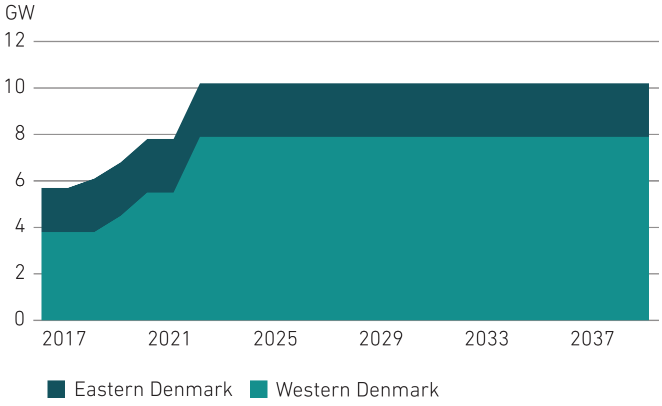
3.2 Generation adequacy
Generation adequacy refers to the system's ability to procure sufficient electricity to satisfy consumption needs at all times. Generation adequacy is closely linked to the electricity market. Power shortages may occur in the market if there is a risk of insufficient electricity generation to meet consumption needs.

Energinet's objective is for the risk of power shortages to not exceed current levels. This corresponds to a target of maximum 5 minutes of outage for an average consumer in an average year caused by lack of power in the Danish system.

Forward-looking risk assessments are made using Energinet's FSI model. This model estimates the power shortage

FIGURE 17: EXPECTED NOMINAL IMPORT CAPACITY OF DENMARK'S INTERNATIONAL CONNECTIONS.

Source: Energinet's analysis assumptions 2017.



GOALS FOR GENERATION ADEQUACY

- **EUE (Expected Unserved Energy)** indicates unserved energy per year, including the risk of blackout, i.e. the total energy consumption need which cannot be met by production.
- **Weighted minutes** indicates the number of hours with a power shortage irrespective of the extent of the shortage.
- **LOLE (Loss Of Load Expectation)** indicates the number of hours with a power shortage irrespective of the extent of the shortage.
- **LOLP (Loss Of Load Probability)** indicates the probability of a power shortage in a given hour (LOLE=8760 x LOLP).

TABLE 5: GENERATION ADEQUACY ASSESSMENT IN EASTERN DENMARK. BASIC RESULTS.

EASTERN DENMARK 2018-2025				
	EUE (MWh/year)	Weighted minutes (min./year)	LOLE (hours/year)	LOLP (%)
2018	186	7	0.5	0.01
2019	97	3	0.2	0.00
2020	316	11	0.7	0.01
2025	1,002	33	1.8	0.02

risk in the Danish electricity system. The results are calculated separately for Eastern and Western Denmark.

3.2.1 Generation adequacy analyses
Generation adequacy analyses in Denmark towards 2025 show that Eastern Denmark faces the greatest risk of power shortages. This can be ascribed, among other things, to increased domestic production capacity as well as more high-capacity international connections in the Western Denmark system than in the Eastern Denmark system.

With Energinet's analysis assumptions, all the analysis results for Western Denmark show a risk of less than one output minute per year, thus complying with Energinet's generation adequacy objective. Therefore, only results for Eastern Denmark are presented in the following.

Basic results, where maintenance and outage probabilities are based on historical data, show that the risk of power shortages in Eastern Denmark generally increase in the long term. The power situation will improve in 2019 following the commissioning of the Kriegers Flak offshore wind farm. The seven calculated minutes equates that the average consumer is expected to have 99.9987% of the demanded energy supplied, while 33 minutes correspond to 99.9937%.

The overall more strained power balance owes to changed expectations in the analysis assumptions. Firstly, less wind capacity than previously is forecast for Eastern Denmark,

FSI MODEL

The Forsyningssikkerhedsindeks (FSI) model is Energinet's tool for analysing expected future generation adequacy situations. The model is stochastic and simulates incidents in the electricity system which can lead to power shortages on an hourly basis.

A number of calculation runs (typically 300) are performed for each year being analysed, to represent possible incident combinations. Thus the model results illustrate an average of all calculation runs for a single year.

The FSI model is based on historical time series on an hourly basis for consumption and fluctuating production (wind and solar power). Production from thermal power plants and imports via international connections are stochastic. The stochastic element is represented using probabilities of breakdowns or maintenance. Thermal generation plants and international connections will therefore be unable to supply energy to meet the consumption needs for a number of hours in each calculation run. Which and for how many hours are decided at random. During the hours when large generation plants and/or international connections drop out, consumption needs must be met by fluctuating production from wind and solar power or the remaining thermal plants and international connections.

The model estimates the risk of outages in the Danish system due to power shortages. Since the model operates on an hourly basis, variations within each hour of delivery are not covered. The FSI model is best suited to perform calculations on the basis of assumptions resembling the current situation, as it is based on historical time series and without the derived effects of shortage situations, such as flexible consumption. The FSI model will tend to overestimate the risk of power shortages in a future electricity system which is significantly different from today's system in terms of both physics, the market and international operational cooperation (e.g. in 2025).

as well as declining thermal capacity. Secondly, electricity consumption is higher in this year's analysis assumptions. As from 2020, the risk of power shortages therefore exceeds Energinet's 5-minute target.

TABLE 6: SENSITIVITY RESULTS FOR AVAILABILITY OF INTERNATIONAL CONNECTIONS IN EASTERN DENMARK.

AVAILABILITY OF INTERNATIONAL CONNECTIONS				
	EUE (MWh/year)	Weighted minutes (min./year)	LOLE (hours/ year)	LOLP (%)
2020 - outage doubled	1,442	51	3.3	0.04
2020 - outage halved	119	4	0.2	0.00

TABLE 7: SENSITIVITY RESULTS FOR DATA CENTRE CAPACITY IN EASTERN DENMARK.

DATA CENTRE CAPACITY				
	EUE (MWh/ year)	Weighted minutes (min.year)	LOLE (hours/ year)	LOLP (%)
2020 – 100 MW extra data center capacity in both DK1 and DK2	542	18	1.1	0.01
2025 – 100 MW extra data center capacity in both DK1 and DK2	1,725	53	3.1	0.04
2025 – Data center capacity doubled in DK1 relative to analysis assumptions, no data centers in DK2.	1,051	34	1.9	0.02

Note that the expected number of hours with power shortages in the model simulations is low, indicating that power shortage situations are rare incidents, also in DK2. Even though the results are subject to uncertainty, they indicate that a few brownout situations should be expected over the next 10 years.

The risk of brownouts may be reduced by, for example, maintenance planning, market solutions (e.g. strengthened efforts to ensure flexible consumption), a new production capacity framework and the establishment of new infrastructure for new areas.

More specifically, a project has been initiated to assess whether an additional electricity connection to Western Denmark is a socio-economically attractive solution for strengthening the power balance in Eastern Denmark.

3.2.2 Generation adequacy sensitivity

Risk assessments of the future power situation are highly impacted by input data, which is illustrated in the following sensitivity analyses. The various parameter variations are examples and do not reflect Energinet's assessment of the input parameters.

Availability of international connections

As Denmark is well-connected to the electricity grids in our neighbouring countries, the availability of these connections is important when assessing generation adequacy. The availability of international connections directly impacts import options – no cable, no energy.

The results show that reduced availability of international connections increases the risk of power shortages significantly. Doubling the outage time on all international connections significantly increases the risk of power

TABLE 8: SENSITIVITY RESULTS FOR POWER PLANT CAPACITY/AVAILABILITY IN EASTERN DENMARK.

POWER PLANT CAPACITY/AVAILABILITY				
	EUE (MWh/year)	Weighted minutes (min./year)	LOLE (hours/year)	LOLP (%)
2018 – 200 MW extra power plant capacity	46	2	0.1	0.00
2019 – 200 MW extra power plant capacity	47	2	0.1	0.00
2020 – 200 MW extra power plant capacity	116	4	0.2	0.00
2025 – 200 MW extra power plant capacity	452	15	0.8	0.01
2020 – Outage probability for central power plants doubled	613	22	1.4	0.02

shortages in Eastern Denmark. This means that the risk of outages increases significantly in years with extra-long outage times due to maintenance work or breakdowns. Conversely, the risk also decreases in years without long-term maintenance work or breakdowns.

Increased data centre expansion
Interest in locating large data centres in Denmark has been high in recent years. Data centres are significant energy consumers with expected high continuous power usage. As a result, the establishment of additional data centres, in addition to already known or similar energy consumers, will possibly impact general generation adequacy in the Danish electricity system to a great extent.

Results show that data centres located in Eastern Denmark will increase the risk of power shortages in the Eastern Denmark system. The location of several data centres in Western Denmark alone will only have a marginal impact on the power situation in Eastern Denmark via the Great Belt Power Link. A doubling of the data centre capacity in Western Denmark in 2025, for example, will not significantly increase the risk of power shortages in Eastern Denmark. As the FSI model does not take local conditions into account, there may still be local challenges in connection with the commissioning of large energy consumers.

Availability of central power plants
The availability of thermal production capacity is material to risk assessments of the power situation.

Additional power plant capacity of 200 MW in Eastern Denmark will probably reduce the risks in 2018 and 2020 to a level within Energinet's objective as well as more than halving the risk in 2025. In contrast, reduced availability of power plants, for example via a

TABLE 9 : RESULTS OF THE GENERATION ADEQUACY ASSESSMENT IN THE MAF FOR EASTERN DENMARK 2020.

	EUE (MWh/year)	LOLE (hours/year)	LOLP (%)
Eastern Denmark 2020 & 2025 (base case)			
2020	0	0	0.00
2025	8	0.37	0.00
Eastern Denmark 2020 (sensitivity)			
2020	0	0	0.00

doubling of the outage probability at central power plants, will somewhat double the risk of power shortages in 2020.

3.2.3 Common Nordic and European generation adequacy assessments

Energinet cooperates with other European and Nordic TSOs on common generation adequacy assessments. The method used is based on probabilistic principles.

The method is suitable for evaluating how international connections contribute to generation adequacy and add other types of risk.

In 2016, ENTSO-E published its Mid-Term Adequacy Forecast (MAF) for the first time. The purpose of the MAF is to assess the risk of power shortages in the European price areas in the medium term (up to 10 years ahead). The assessment is made on the basis of a common European analysis, where four different market models are simulated based on the same data set.

In the first edition of the MAF, the method did not yet include outage probabilities for HVAC connections (such as the Øresund cables from Zealand to Sweden), and the results in Table 10 therefore underestimate the generation adequacy risk for Denmark.

Outage probabilities for HVAC connections will be included in the 2017 edition. The work on MAF 2017 is still ongoing, and the first draft is expected to be published in the summer of 2017.

The results of Energinet's market simulations for MAF 2016 included a base case and one sensitivity analysis. In the base case, reserves and outage probabilities for international connections are not included in the calculations. Reserves and outage probabilities for HVDC connections have been added in the sensitivity analysis. The sensitivity analysis focuses on 2020.

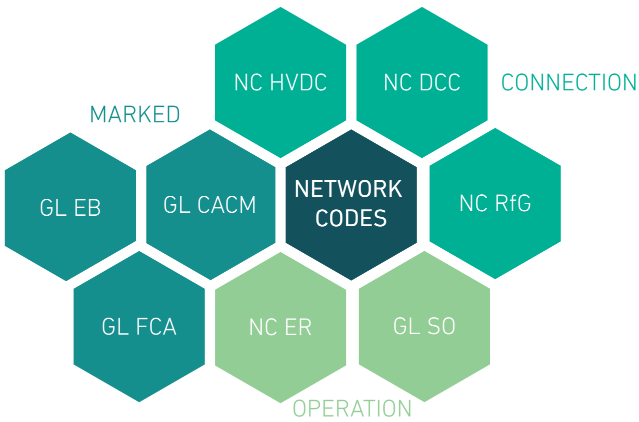
The results from MAF 2016 do not paint quite the same picture of a strained power situation in the Danish system as the FSI model. This may partly be attributable to differences in methodology and input parameters (e.g. outage times on international connections), but may also indicate that the FSI assumptions about international data and international availability are too pessimistic.
In the long term, Energinet expects to replace the FSI model with the European model.

TABLE 10: SHARE OF HOURS WITH CONSUMPTION EXCEEDING PRODUCTION CAPACITY IN DENMARK.

	SHARE OF HOURS IN ONE YEAR (%)
2018	7.7
2019	9.7
2020	18.3
2025	30.2

FIGURE 18: ILLUSTRATION OF NETWORK CODES AND THEIR INTERRELATIONSHIP.

Note: Follow the network code work at http://networkcodes.entsoe.eu/.



3.2.4 Longer periods with imports meeting consumption needs

In line with the green transition and the phase-out of thermal capacity, imports from international connections increase. Increased cross-border trading means that there are more hours when we import but also hours when we export more.

Periods during which imports are necessary in order to meet consumption needs are expected to increase to approximately 30% towards 2025. Conversely, this means that Denmark is expected to be able to cover its own consumption needs approximately 70% of the time in 2025. During the same 70% of the time, Denmark will therefore be expected to have export capacity at its disposal.

3.2.5 Strategic reserve in Eastern Denmark

As one step towards ensuring generation adequacy in Eastern Denmark, Energinet wanted to create a strategic reserve in Eastern Denmark in the 2016-2018 period to contribute to supply in highly critical situations However, Energinet decided to cancel the call for tenders in December 2015. The tender was called off because Energinet did not expect to be able to implement it, as the European Commission saw the reserve as being in breach of the EU rules on state aid.

Since then, the European Commission has carried out a sector inquiry into capacity mechanisms. Based on this, Energinet still finds that it is not possible to make a call for tenders for a strategic reserve in the 2016-2018 period. Energinet will reduce the risk of disconnecting consumers in the event of shortages in Eastern Denmark through improved coordination of maintenance work on international connections, power plants and own installations as well as by rewarding shorter outage times in connection with construction projects and using shorter start-up warning times at power plants. In addition, Energinet has ensured a shorter start-up warning time at a single power plant.

3.3 Market trends

The current market model has contributed to optimising the use of existing generation plants and to ensuring balance between consumption and production. There are currently two key developments within market trends:

- Development of European network codes for the electricity market. Network codes contribute to the security of supply by harmonising market regulations and thereby the possibility to better utilise production capacity and transmission capacity across borders.
- Development of the future market model based on the energy-only market, where clear price signals must ensure sufficient flexibility and capacity, as concluded in the Market Model 2.0 project.

Market Model 2.0

As initiatives for the three issues identified in the Market Model 2.0 project from 2015, three development areas were identified:

- **Capacity:** Mechanisms are needed that allow Energinet to meet its security of supply objective. These should primarily be based on clear price signals using an energy-only market approach, e.g. a higher price cap.

- **Flexibility:** There is a need for more flexibility among consumers and incentives for greater flexibility among producers and consumers. Therefore, market rules must be adapted and new business models introduced to the market.
- **Critical properties:** There is a need to determine future demands and whether new ways to obtain and pay for critical properties can be designed.

The challenge to ensure correct flexibility incentives in the market has been addressed with a number of initiatives which Energinet is working to realise.

3.4 Grid adequacy

The grid's ability to transport electricity from where it is generated to where it is demanded is called grid adequacy and is a crucial element in the calculation of the total security of electricity supply.

Most of the 132 kV and 150 kV grids were established from the 1960s and up until the 1990s, and large parts of this asset pool are facing reinvestment over the next 10-15 years.

The green transition and urban population growth also mean that major reinvestment in and expansion and restoration of the transmission grid must be expected over the next many years.

To effectively complete the overall planning, Energinet prepares a RUS plan.

3.4.1 Expansion

To ensure an appropriate level of grid adequacy, there is a need in the years ahead to expand the transmission grid in most of Jutland as well as on Southern Zealand and Lolland-Falster due to the integration of electricity generation from renewable energy facilities.

In addition, the need for grid reinforcements may arise over time as a consequence of the large data centres in the pipeline near Viborg and Odense.

Finally, there is a need for reinvestment and expansion in Copenhagen, see section 3.4.3.

3.4.2 Reinvestment

Energinet gives higher priority to maintenance and reinvestment based

RUS plan

(REINVESTMENT, EXPANSION, RESTORATION)

In some cases it may take several years from a problem being recognised until the necessary facilities have been established to solve the problem. Coordination helps to optimise planned grid outages and identify project synergies.

The RUS plan is an important part of the basis for Energinet's efforts to ensure the security of supply in the most cost-effective way possible.

The RUS plan will be prepared every other year. Energinet's first RUS plan was published on 28 February 2017.

The RUS plan shows the need for expansion and reinvestment 10 years ahead. The RUS plan is based on the trends indicated in Energinet's analysis assumptions, reinvestment analyses of the existing transmission grid and other factors.

on a plant's specific state and criticality rather than sticking to defined time intervals as was previously the case.

Plants which are in a poor state and at the same time critical to the operation of the electricity system are given the highest priority. This contributes to a greater extent than previously to ensuring a continued high level of security of supply, but in a more cost-effective way.

Currently, reinvestment projects account for approximately 20% of the total planned investments in grid adequacy. Going forward, reinvestment projects are expected to make up an increasing share of the total reinvestment, expansions and restorations.

3.5 System security

System security is the electricity system's ability to handle sudden system disturbances. The system has to be robust and able to handle outages of important internal connections, power plants and international connections without the overall system becoming unbalanced or breaking down. System security relates to the system's dynamics at the moment a fault occurs and in the seconds after.

In recent years, Energinet – in cooperation with the German TSO TenneT – has activated a significant volume of special regulating from the Nordic regulating power market with suppliers in Western Denmark to remedy grid problems in the North German transmission grid. The grid problems typically occur in connection with handling large-scale wind power generation in Northern Germany.

Future need for properties required to maintain power system stability

More wind turbines, less capacity at power plants, changes in the CHP industry, additional and more powerful international connections. The electricity system is undergoing significant changes, and more, less or new components lead to changing needs. Since 2015, Energinet has analysed the present and future needs for properties required to maintain power system stability in Western and Eastern Denmark. In 2015, focus was on analysing Western Denmark. Since then, Energinet's analyses have mainly focused on needs in Eastern Denmark.

COPENHAGEN SUPPLY AND REINVESTMENT

The expected increase in electricity consumption in Copenhagen combined with thermal power plants being decommissioned or operating for fewer hours has entailed that a new supply structure for Copenhagen and the surrounding area is under consideration. In addition, some of the cables into the city are reaching the end of their service life and have to be taken out of operation for long periods of time due to faults.

In many situations, it will be necessary to meet a large part of Copenhagen's electricity consumption demands with production capacity from outside Copenhagen. At the same time, there must be capacity for planned outage times and force majeure situations on important supply lines.

Energinet is working on several projects that focus on both reinvestment in the Copenhagen area as well as supply from the rest of Zealand into Copenhagen. The reinvestment project consists of a step-by-step replacement of the 132 kV cables into Copenhagen, prioritised on the basis of criticality and state. To ensure long-term security of supply for Copenhagen, Energinet expects to establish new infrastructure in Copenhagen.

Today, Energinet already continuously assesses the need for local production in Copenhagen and when needed Energinet initiates measures such as orderings to ensure continuous high security of supply in Copenhagen.

As was the case in Western Denmark, the analysis for Eastern Denmark showed that the need for properties required to maintain power system stability, in addition to the system's own contribution, primarily concerns sufficient possibilities of dynamic voltage control. The analysis also showed that the need in Eastern Denmark in normal operating situations is met when one ancillary services unit is in service, for example a central power plant or one of Energinet's two synchronous condensers in Eastern Denmark.

A precondition for covering the new need is smarter use of existing components in the electricity system through automation. Previously, it was found necessary to have three active ancillary services units, for example both synchronous condensers and at least one power plant, with an additional ancillary services unit ready for start-up.

3.5.1 Risk assessment of incidents which could impact system security

At times, we have had blackouts in Denmark, and it is impossible to keep this from happening again. During unfortunate circumstances, there will always be a risk of a system breakdown. The key is taking preventive measures and limiting the impact when it does happen.

Risk assessments of system security are based on comprehensive analyses and selected critical situations. There are an endless number of critical situations that could lead to power outages. However, most of these situations are very unlikely and/or lead to minor outages only.

Assigning probabilities to all outage risks is not practically feasible. Therefore, definitions of minimum requirements for the electricity system are necessary in order to make a probability-based risk approach useful in practice.

Prevention is mainly achieved through continuous improvements to the existing framework for the operation of the electricity system, such as effective operating criteria, good management of reserves and properties required to maintain power system stability, rapid restoration following outages, smooth international cooperation and the underpinning of decisions with dynamic analyses and risk assessments.

3.6 Maintenance planning

Careful maintenance planning plays an important role in maintaining security of supply. The importance of maintenance planning will only increase in future due to fewer units with high output levels which are not currently obligated to report maintenance work.

"In future, cooperation across national borders, cooperation throughout the entire value chain, more IT support and flexibility in electricity consumption will come to play a far greater role than today"

Going forward, an increased level of detail will be needed in maintenance planning to ensure, among other things, optimum interactions between central and local production in a future with increasingly non-centralised production.

Due to the expectation of reduced generation adequacy in Eastern Denmark, socio-economic principles must also be applied in future to determine what should be done when the maintenance plan cannot uphold generation adequacy, making it necessary to secure this in another manner, e.g. by moving power plant maintenance periods.

Energinet is working to ensure more transparent maintenance planning to ensure both compliance with the future network codes and clearer socio-economic principles in maintenance planning.

3.7 Operational cooperation across borders

Denmark is dependent on well-functioning relations and operating agreements with our Nordic and European neighbours to secure a reliable and efficient operation of the Danish electricity system.

Visual enhancement project of Little Belt.

Energinet currently has operating agreements at the Nordic level, with the central European TSC, and bilaterally with all countries with which Denmark shares international connections. In addition, Energinet is also part of a close Nordic operational cooperation in the Nordic RSC (Regional Security Coordinator), which is expected to be in full operation by the end of 2017.

Going forward, Energinet sees a need for extra focus on the operational cooperation across borders, while also presenting Denmark as a regional rather than a national partner.

Regionalisation is high on the European agenda, making it a priority for Denmark as well. This trend is rooted in the belief that regional solutions are necessary to safeguard and benefit security of supply in an electricity system with increasing amounts of renewable energy.

The first steps towards establishing the Nordic RSC were taken in 2016. The Nordic RSC office is located in Copenhagen and has been manned since November 2016. Expectations are for the Nordic RSC to be fully up and running by the end of 2017. The Nordic RSC's main objective is to handle five specific tasks in relation to the Nordic national TSOs, which will help to promote coordination and, at the same time, optimise the entire Nordic electricity system.

NORDIC RSC HAS FIVE TASKS

1. COMMON GRID MODEL
   The Nordic RSC must establish a common grid model that provides an hourly overview of all significant assets in the grid in the entire Nordic region (in terms of production, transmission and consumption).

2. COORDINATED SECURITY CALCULATION
   The Nordic RSC must identify operational security risks and recommend preventive action to the individual TSOs.

3. COORDINATED CAPACITY CALCULATION
   The Nordic RSC must calculate cross-border transmission capacities and maximise the transmission capacity offered to the market.

4. COORDINATED OUTAGE PLANNING
   The Nordic RSC must keep a joint register of all planned outages for assets in the grid (high-voltage transmission lines, generators etc.) and streamline maintenance management.

5. COORDINATED CALCULATION OF AVAILABLE PRODUCTION CAPACITY
   The Nordic RSC must provide the market players with forecasts for production, consumption and the state of the grid up to several weeks in advance.

WHAT IS AN RSC?

The Nordic RSC is a cooperation between the TSOs in Norway, Sweden, Finland and Denmark (Statnett, Svenska Kraftnät, Fingrid and Energinet).

An RSC (Regional Security Coordinator) is managed and run by the TSOs taking part in the regional cooperation.

An RSC prepares advanced calculations and a regional grid model, which is to form the basis for more efficient cross-border grid operation.

An RSC does not have operational control of the individual TSO's grid.

Control Centre Electricity in Erritsø.

WHAT VALUE DOES THE NORDIC RSC ADD?

The Nordic RSC will carry out the same type of calculations of electricity grid capacity, production need forecasts, security in electricity grid operation, security of supply etc., which the individual TSOs prepare for their own areas today.

The difference is that the Nordic RSC will prepare these calculations and forecasts for the entire Nordic area, finding cross-border solutions. In the long term, this Nordic regional cooperation will strengthen security of supply in an electricity system with increasing amounts of renewable energy.

3.8 Information security

Increased use of IT has created major development opportunities in the electricity sector, both in terms of business and technology.

The use of IT is one of the key prerequisites for integrating large quantities of renewable energy in the electricity system and for making it possible to optimise the operation of the electricity grid at the moment of delivery using real-time data.

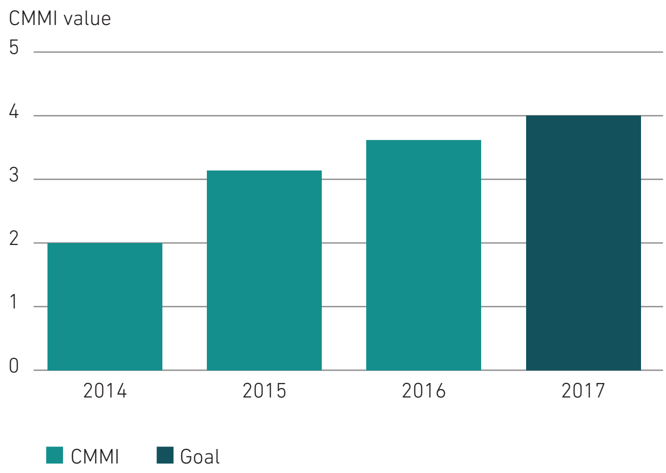
This increased dependence on IT means that the electricity system becomes more vulnerable if the IT systems are not available, or if there are errors in these. It is therefore relevant to expand the concept of system security to explicitly cover information security and IT system uptime.

Historically, information security breaches or IT uptimes have not had any serious impact on the Danish electricity supply.

For several years, Energinet worked intensively to secure supply-critical IT systems and train its staff in contingency situations where systems are unavailable. Various system tests, controlled hacker attacks and information campaigns have been regularly conducted internally at Energinet.

Energinet believes that there is a need to focus on information security throughout the value chain. This is because information technology is now vital to the operation of energy systems and because the threat situation has changed in recent years. This greater focus covers everything from system and server operation to culture and awareness among the companies' employees.

FIGURE 19: MATURITY FOR IT SECURITY INDICATED WITH CMMI VALUES FOR 2014-2016 AND THE TARGET FOR 2017.



ISO 27001

Energinet measures IT security based on the ISO 27001 IT security standard. Energinet had a target for the maturity of IT security of above average by year-end 2016, correspon-ding to an average Capability Maturity Model Integration value (CMMI value) of 3.5 on a scale from 0-5.

By the end of 2016, PWC found that:

- Energinet reached its target for 2016 of an average CMMI value of 3.62.
- If the current focus and activity levels can be maintained throughout 2017, Energinet will be able to reach the maturity target set for year-end 2017 of 4.0.

INFORMATION SECURITY GOALS

A MODERN ELECTRICITY SYSTEM MUST BE DESIGNED TO PREVENT AND WITHSTAND MALICIOUS ATTACKS WHICH COULD LEAD TO A CRITICAL SITUATION FOR THE ELECTRICITY SUPPLY.

The three main objectives for information security are to ensure availability, integrity and confidentiality:

- **Availability:** Ensuring that systems, data and information are available when needed.
- **Integrity:** Ensuring that data and information are complete and reliable and have not been distorted by unintended changes.
- **Confidentiality:** Data and information may be confidential and require protection from unauthorised access.

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