ENERGINET

SECURITY OF

ELECTRICITY SUPPLY REPORT 2020

Under the Danish Electricity Supply Act[1], the Minister for Climate, Energy and Utilities is responsible for the security of electricity supply and determines the level hereof. Under the *Danish executive order on transmission system operation and the use of the electricity transmission grid etc.* (Executive Order on transmission system operation (Systemansvarsbekendtgørelsen))[2], Energinet must prepare an annual report on the security of electricity supply that includes a recommendation on whether to change the level hereof. The report and recommendation both underpin the Danish Minister for Climate, Energy and Utilities' determination of a level of security of electricity supply.

In the *Security of electricity supply report 2020*, Energinet recommends a future level of security of electricity supply. The report also includes forward projections of the security of electricity supply. The recommendation and forward projections have been prepared following a dialogue with the grid enterprises which are responsible for the supply at the lower voltage levels in the electricity grid.

The following comprises translated extracts from the Danish Security of electricity supply report 2020 (Redegørelse for elforsyningssikkerhed 2020). The full report can be found in Danish on Energinet's website. The extracts include the recommendation from Energinet to the Minister for Climate, Energy and Utilities and the status of security of electricity supply in Denmark.

1 Danish Electricity Supply Act, Act no. 119 dated 06/02/2020.

2 Danish executive order on transmission system operation and the use of the electricity transmission grid etc., Executive order no. 652 dated 18/05/2020.

CONTENTS

1. Recommendation

1.1 Energinet's recommendation on the level of security of electricity supply

Energinet aims to maintain a high level of security of electricity supply, while also taking into account socio-economic aspects and ensuring the green transition by integrating more renewable energy.

In this report, Energinet presents its recommendation for a planning objective for the overall level of security of electricity supply in Denmark in 2030. The planning objective is expressed as an average number of outage minutes for the Danish electricity consumer in 2030. For the past 10 years, the average Danish electricity consumer has experienced approximately 20 outage minutes per electricity consumer annually.

Energinet recommends an overall planning objective for 2030 of 35 outage minutes in total. The planning objective consists of two elements:

- Energinet's recommendation on generation adequacy and the electricity transmission grid totalling seven outage minutes in 2030, which matches the planning objective set by the Danish Minister for Climate, Energy and Utilities in January 2020.
- The grid enterprises' projection of 28 outage minutes in 2030 at the electricity distribution grid level, which matches the grid enterprises' projection from 2019.

The current level is approximately 20 outage minutes per year, and the planning objective of 35 outage minutes per year in 2030 reflects a balance between Energinet's persistent focus on maintaining a high level of security of supply and the challenges expected in the overall electricity system. Updated analyses confirm the type of challenges identified last year and point to a greater risk of long-term pressure on generation adequacy in particular. Thus, Energinet still sees the increasing risk of a lack of generation adequacy over the coming years and an ageing electricity grid, both at the electricity distribution and transmission level, respectively, as two important points of focus when it comes to maintaining a high level of security of electricity supply towards 2030.

Since the publication of the 2019 report, a political decision has been made to reduce Danish emissions of greenhouse gases by 70 per cent in 2030 compared to 1990, which will also impact the electricity sector. Moreover, this decision may potentially also change the framework for the security of electricity supply. It has not yet been decided exactly how the 70 per cent objective will be accomplished. Therefore, assessments of the derived consequences for the electricity system and security of electricity supply are still subject to uncertainty. In this report, however, Energinet presents some initial assessments, which indicate that generation adequacy will be further challenged. The uncertainty about the specific translation into actions of the 70 per cent objective calls for a quick resolution, allowing Energinet and other stakeholders to act in due time. Energinet closely monitors developments in the security of electricity supply to be ready to initiate the necessary initiatives to meet the planning objective set.

Analysis assumptions for Energinet 2019 underpin the basic analyses in this report, but do not reflect the realisation of the total Danish climate actions and the 70 per cent objective. Energinet has added a number of sensitivities and alternative forecasts to the report's basic analysis of the development in generation adequacy towards 2030. Overall, these underline the long-term generation adequacy issues. Please note that the exact level of such long-term projections is uncertain, and that the details of the realisation of the 70 per cent objective have not been finalised, meaning that it is not possible to assess the consequences yet.

Recommendation at electricity transmission and electricity distribution level, respectively

Towards 2030, an increase in the average number of outage minutes experienced by customers is expected at both the electricity transmission and electricity distribution level, i.e. a certain decline in the security of electricity supply. The main cause is an ageing electricity grid, which is expected to lead to an increase in outage minutes, especially at the distribution level. However, the challenge of an ageing electricity grid is faced at both the electricity transmission and electricity distribution level, where there is still a considerable need for reinvestments. Projections in this report are based on the continuation of reinvestments in both electricity transmission and distribution grids as planned. In addition to an ageing grid, Energinet finds that there is an increasing risk of power shortage due to, among other things, growing electricity demand and reduction of capacity at thermal power plants. The analyses in this report show a greater risk of power shortage than last year's analyses. Energinet's recommendation is still to meet the challenge of generation adequacy by using market initiatives and by keeping up capacity on international connections. However, the situation also requires close monitoring and focus on the electricity market's flexibility and continued support for generation adequacy. Energinet is therefore planning to introduce close monitoring of market flexibility with a view to initiating the necessary mitigation measures if necessary.

Energinet also sees a risk of reduced robustness as more inverter-based facilities are connected to the electricity system while conventional plants, such as central power plants, are decommissioned. However, the potential consequences of this risk are categorised as special incidents and are not included in the planning objective.

The planning objective is set for a 'normal year', and the electricity grid is not dimensioned to avoid 'special incidents' altogether. However, it should be emphasised that Energinet focuses on the security of electricity supply in a broad sense of the word, and that Energinet is continuously working to optimise the operation of the electricity grid in order to ensure robustness, and also that Energinet uses operating incidents to learn how to improve the electricity transmission grid. Chapter 2 of the full report (Danish only) specifies the various elements of security of electricity supply.

Risk of special incidents

The risk of special incidents is a factor not included in the recommended planning objective. In 1999 and 2003, two examples of special incidents resulting in major outages were seen, caused by a hurricane and a special incident (fault combination) in the Swedish electricity system, respectively.

Special incidents are incidents that are not considered in the criteria used for electricity grid dimensioning.

It is not possible to predict and consider all possible combinations of incidents when planning the electricity system without incurring very high socio-economic costs.

The overall recommendation of 35 outage minutes is distributed on the electricity transmission grid and the distribution grids as follows:

Generation adequacy and the electricity transmission grid: 7 minutes:
This objective is based on Energinet's analyses and projections of generation adequacy, grid adequacy and grid robustness.

- 5 outage minutes related to a lack of generation adequacy, i.e. inability to meet total demand for electricity.
- 1 outage minute related to grid adequacy, which is the electricity transmission grid's ability to provide electricity for consumers.
- 1 outage minute related to robustness, which is the electricity transmission grid's ability to withstand sudden disturbances or trips.
- 0 minutes related to lacking IT security.

Over the past 10 years, there has been less than one outage minute a year on average in the electricity transmission grid.

Electricity distribution: 28 minutes:
This objective is based on the electricity distribution enterprises' projection of outage minutes. Over the last 10-year period, there has been an average of approximately 20 annual outage minutes in the electricity distribution grids.

In accordance with the Danish Executive order on transmission system operation and the use of the transmission grid etc., Energinet has consulted the grid enterprises about their expectations for the security of electricity supply in the distribution grids. Energinet has received data from the grid enterprises via Danish Energy, including a background memo on data and methodology in the grid enterprises' projection of outage minutes.

In this report, Energinet presents the grid enterprises' projection of an expected level of 28 outage minutes in 2030. Energinet remarks that the grid enterprises' projection is based on a continuation of the current reinvestment level of DKK 1.7 billion a year and an assumption of unchanged electricity demand towards 2030. The latter is likely to lead to an underestimation of the number of outage minutes.

The projection of the year for the electricity distribution grids matches the projection level in the security of electricity supply 2019 report. Energinet finds that the grid enterprises' projection is based on a more systematic approach than last year. However, Energinet is also of the opinion that there is still some uncertainty associated with the projection as not all component types in the grid are accurately assessed in relation to future fault risks, and that the data basis is primarily based on input from three major grid enterprises and not all grid enterprises. Moreover, as mentioned above, an increase in electricity demand is not factored into the projection. However, Energinet also finds that the method development seen is a good starting point for building a sound basis for projections in the reports going forward.

1.2 Trends and the planning objective

Security of electricity supply is high in Denmark. This fact has been true for many years, and the same is true when making an international comparison. Danes have access to electricity 99.996 per cent of the time on average. This corresponds to an annual number of outage minutes per electricity consumer of around 20. The planning target of 35 outage minutes corresponds to a security of electricity supply of 99.993 per cent.

Depending on the duration of outages and on how, where and when outage minutes occur in specific cases, this may have greater or lesser impact on individual, affected electricity consumers. An outage may be extra troublesome for specific customer groups with certain geographical or consumption-related characteristics. However, as an overall average, the security of electricity supply will only decrease relatively modestly from the current 99.996 per cent to 99.993 per cent in general in Denmark.

The main reason for international variations in the security of electricity supply is the degree of underground cabling in the electricity distribution grids. In many countries, underground cabling is significantly more expensive than in Denmark, and therefore, Energinet's assessment is that not many countries will be able to reach the same level of security of electricity supply that Denmark has. At the same time, Energinet finds that the rest of Europe, and in particular the Nordic countries, are also facing the challenges of having ageing electricity grids that require massive investments merely to maintain the status quo of security of electricity supply. Moreover, several other European countries are also found to be looking into a future with an increasing risk of lack of generation adequacy due to the phasing out of thermal capacity and electrification. Owing to this concurrence between European countries, Energinet expects the level of security of electricity supply in Denmark to remain among the highest in Europe, even with 35 outage minutes per year from 2030.

This expected increase in the number of outage minutes requires more stringent attention to the security of electricity supply. Energinet focuses on maintaining a continued high level of security of electricity supply and will continue to develop and adopt measures to meet the expected challenges, including not least the risk of a lack of generation adequacy.

Analyses in this report show a greater risk of power shortage than last year's analyses (35 output minutes in 2030 in this year's report versus 8 output minutes in 2030 in last year's report), which primarily owes to an assumption of higher electricity consumption in Denmark compared with last year's analyses. However, distinct power shortage challenges are not expected until after 2025. Energinet still recommends that the risk of power shortages be met by implementing market-based initiatives. The uncertainty of the projections combined with the fact that any impact of measures designed to underpin the security of electricity supply will only be seen over time are both part of the reason for Energinet maintaining last year's recommendation for the planning target for 2030. With increasing prices in situations with pressure on generation adequacy, the market is expected to respond with greater flexibility, and maintaining the objective must be seen in the context of the importance of monitoring and underpinning the electricity market's capacity to promote generation adequacy. Energinet thus maintains the ambition expressed in last year's recommendation of the planning objective for 2030 and also believes that keeping a certain degree of continuity in the recommendation from year to year is a natural starting point for further planning.

In addition, Energinet still finds that a temporary strategic reserve may be an appropriate tool if initiatives in the electricity market, despite the implementation of market reforms, prove incapable of promoting acceptable generation adequacy in the long term.

In respect of ensuring grid adequacy, Energinet believes that it is still necessary to focus on reinvestments to upgrade an ageing electricity grid and recommends, as a minimum, to continue reinvestments at the planned level.

In general, it must be noted that projections for both electricity transmission and electricity distribution levels involve some degree of uncertainty. Energinet and the grid enterprises will continue to improve both the data basis and projection methods.

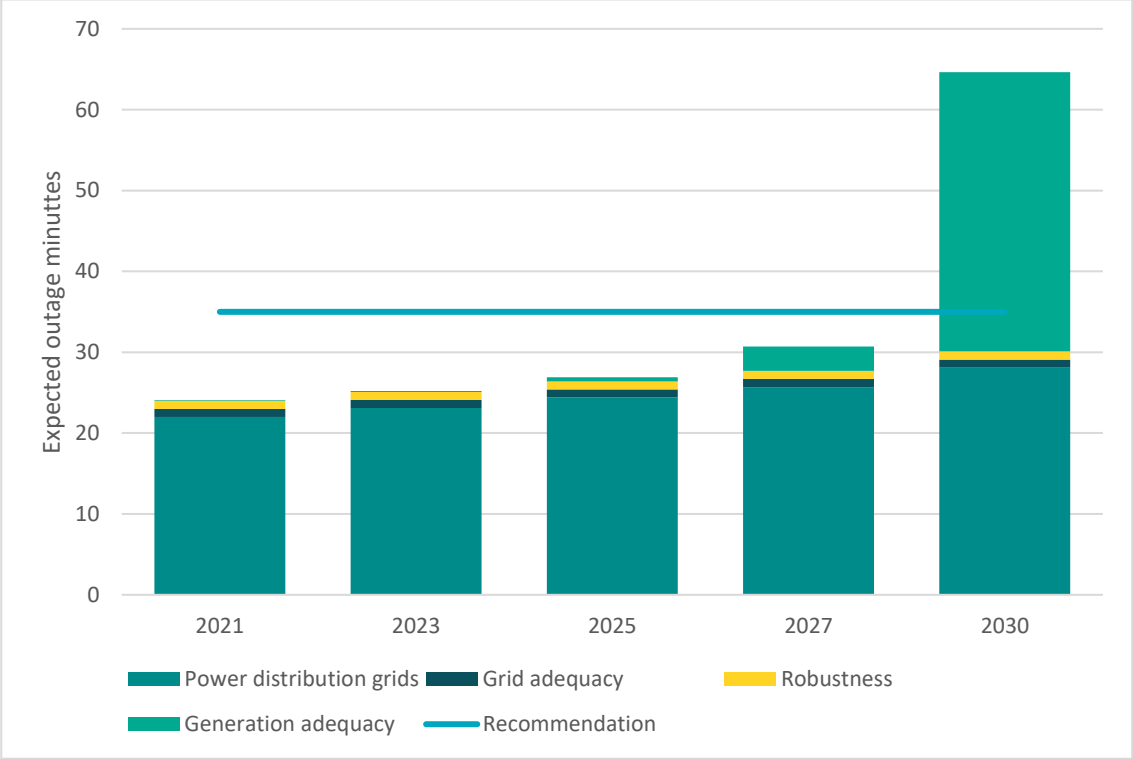


Figure 1 *Expected number of outage minutes in the Danish electricity system until 2030, cf. the basis analysis of the report. See section 4.2 of the full report (Danish only) for further details. In addition to the projection, the figure also shows the recommended planning objective. Please note that the recommended planning objective represents a "normal year", meaning that special incidents are not included. However, the projection of expected trends in generation adequacy includes all likely outage incidents in combination with, for example, extreme climate years.*

1.3 Method and planning objective

Energinet continues to attach great importance to the security of electricity supply when determining its recommendation while economic optimisation and the green transition also remain central focus areas. In other words, focus is on maintaining a very high level of security of electricity supply, even though the framework, such as the advanced age of the electricity grid and the green transition of the electricity system, is expected to pose a challenge to the currently low number of outage minutes.

Moreover, Energinet's overall assessment is that it may be disproportionately expensive to maintain a level of security of electricity supply as high as seen over the past ten years, but also that the economy and Danish gross domestic product will not be significantly affected by a decrease in the security of electricity supply from approximately 99.996 per cent today to 99.993 per cent in 2030, cf. the planning objective for 2030.

In the interest of socio-economic optimisation, ideally no measures should be implemented to improve the security of electricity supply, if such measures cost more than an interruption of electricity supply would. Value of Lost Load (VoLL) is an economic indicator that expresses the costs of interrupted electricity supply and can be used for comparison with the costs of securing the electricity supply. There is no unique fixed value for VoLL for Denmark. Energinet does not use a specific value of VoLL as a fixed decision parameter, but instead uses calculations of VoLL to get a perspective of

whether the socio-economic benefits of measures exceed the costs when operating and developing the electricity system.

Value of Lost Load (VoLL)

Value of Lost Load, abbreviated VoLL, is an economic indicator that states the cost of interrupted supply.

VoLL can be seen as the total socio-economic and private/corporate costs of an interrupted electricity supply. Depending on the specific context, the private/corporate economic angle is most often used in studies estimating VoLL. Energinet uses the economy as an important criterion when making investment decisions.

VoLL is not one single value. The value depends on a number of factors, for example who is interrupted (industry, service, households, etc.) and the characteristics of outages (duration; time of day, week, year; forewarned or not; etc.).

There are a number of uncertainties associated with VoLL, and different studies can produce very different results. Estimates of VoLL can thus only give a rough approximation of what the expected socio-economic value of security of electricity supply is, based on the particular assumptions set for the specific studies.

It is very difficult to define a precise socio-economically optimum level for the planning objective. However, Energinet's overall assessment is that a socio-economically optimum level of security of electricity supply is at a lower level (measured in per cent of security of supply) than the current level of security of electricity supply, as the current level has primarily been driven by a historical and political desire for a high level of security of electricity supply.
Energinet aims to continue to develop the methods and data basis together with the stakeholders in the industry to improve socio-economic assessments.

1.4 Determination of level and initiatives to reach the recommended level

The uncertainty of the projections made means that assessments and results are expressed in sample spaces, which are then specified into a certain number of minutes. A planning objective is an overall objective which is to be realised through follow-up decisions. The effect of development trends and measures that may affect the security of electricity supply only becomes apparent over time. No major changes to the actual security of electricity supply can be expected from one year to the next unless special incidents occur.

Energinet and the grid enterprises use the 2030 target in their planning, and projection fluctuations may therefore lead to changes to initiatives. In addition, short-term projections are based on the physical conditions of the electricity grid. Schemes for reinvestments and new investments in the electricity grid and infrastructure have relatively long time frames and cannot change expected development scenarios significantly in the short run.

In relation to the planning objective for generation adequacy and the electricity transmission grid, Energinet will primarily focus on the development of electricity market initiatives and the implementation and prioritisation of reinvestments in the electricity grid. In relation to reducing the risk of special incidents, Energinet also has several activities related to robustness in play.

Initiatives introduced to meet the more serious challenge of generation adequacy must be closely coordinated with the efforts and time schedule of the work to fulfil the Danish 70 per cent objective. Energinet expects increased flexibility in

electricity consumption to form part of the green transition, which may counteract the challenges of insufficient power. On the other hand, CHP capacity may be phased out more quickly than previously predicted.

Current and planned initiatives to achieve the level recommended are described in Table 1.

Grid enterprises	
Grid adequacy and robustness	- Reinvestment plans. - Intelligent components and remote control will be installed in grid substations. - Implementation of asset management systems and digitalisation, which can help with resource optimisation in relation to maintenance and reinvestments.
Energinet	
Generation adequacy	- Initiate, implement and develop market reforms: o Flexible settlement (prepared via, among other things, the implementation of hourly-read meters and hourly settlement in 2020) o Implementation of aggregator role in the electricity market o Increase of price caps in the electricity market (day-ahead, intraday and regulating power markets) o Market coupling of reserve markets to support generation adequacy - Promote demand-side response. - Continued assessments of the possible introduction of a temporary strategic reserve. - Focus on reinvestments/service life extension for ageing international connections.
Grid adequacy	- Make reinvestments to counter the impact of the ageing electricity grid. - Increased willingness to take risks by deviating from the N-1 principle in local situations for short periods of time, for example during reinvestments and auditing, if this is deemed the best socio-economic solution. - Expand the electricity grid so that the electricity grid can receive and move generation from new electricity generation units to electricity consumers.
Robustness	- Clarify risks of more inverter-based facilities and less conventional facilities as well as implement measures to reduce these risks. - Utilise automation to be able to operate the grid closer to the edge. - Increase emergency preparedness and maintenance for critical components to prolong service life.
IT security	- Continue regular quality assurance of IT systems.

Table 1 List of current and planned initiatives to maintain a high level of security of electricity supply. Initiatives are described in further detail in chapters 4 and 5 of the full report (Danish only).

Additional possible measures are described in further detail in chapter 5 of the full report (Danish only), including different levels of reinvestment efforts in both the electricity transmission grid and the electricity distribution grids, the introduction of a scarcity price for imbalance settlement in cases of power shortage and a temporary strategic reserve.

Other possible measures may also be implemented if there is a request to use a different planning objective than the one recommended. The description in chapter 5 of the full report (Danish only) also includes gross cost estimates and consequences for outage minutes of the expected development.

Energinet estimates that initiatives already initiated and those planned, combined with the necessary underpinning of generation adequacy in the electricity market, will ensure that the recommended planning objective is met in 2030. Further possible measures may add to the efforts. These possible measures can strengthen the security of electricity supply, but they are also limited by socio-economic aspects which require that costs must be balanced with the planning objective.

1.5 Perspectives for the Danish electricity supply in a green and international framework

An important parameter in the development of both the Danish and European electricity supply is the green transition and, consequently, a continued major expansion of renewable energy and increased electrification of, for example, the transport and heating sectors. The reduction of thermal capacity for electricity production is, among other things, driven by renewable energy expansion, and both Denmark and our neighbouring countries are looking into a future where increasing electricity consumption must be covered by generation from renewable energy technologies with output that fluctuates more than the output of the thermal power stations of yesterday.

To fulfil the 70 per cent objective, more price-sensitive electricity consumption is required because this may, if necessary, counteract both the challenge to generation adequacy and the need for large-scale expansions of infrastructure. However, technology development and the cost of demand-side response involve great uncertainty which translates into uncertainty about the net effect on generation adequacy.

Denmark will continue to have a high level of security of electricity supply with an even higher share of renewable energy than today. However, increased electrification will certainly result in an increased demand to be met, meaning that the electricity grid must have more capacity to transport/deliver the required electricity to consumers.

The Danish electricity transmission system is closely connected to the neighbouring countries' electricity transmission systems and is dependent on links to other countries that underpin the Danish security of electricity supply. The Danish electricity system is governed by European electricity market regulation.

Joint calculation methods for assessing generation adequacy have been developed in the EU based on the *Clean Energy Package* (in particular EU regulation 2019/943 on the internal market for electricity). These methods state that security of electricity supply is a national matter, and that the individual countries can set their own objectives for generation adequacy within the overall framework. A specific objective for generation adequacy must be expressed by a different indicator than outage minutes, and Energinet expects these requirements to be reflected in the recommended planning targets in the coming years' reports. Requirements for generation adequacy assessments must be met if a capacity mechanism, e.g. a strategic reserve, is to be approved for state subsidies[3]. These methods may potentially mean that the ministerially approved level of security of electricity supply in Denmark is more ambitious than the level set by the European Commission for approving strategic reserves for state subsidies, making the introduction of such a reserve more challenging to accomplish.

Energinet expects that a number of outstanding assumptions about the climate action plan, the implementation of a common European method for the determination of reliability standards as well as updates to expected developments

3 Read more in section 5.1.2 of the full report (Danish only).

in electricity systems abroad will be in place in 2021. These are all important elements that can impact the expected development of the security of electricity supply and thus Energinet's recommended planning objective in the Security of electricity supply report 2021.

2. Status on security of electricity supply

KEY FIGURES FOR THE ELECTRICITY SYSTEM

OUTAGE MINUTES ELECTRICITY SYSTEM TOTAL

(average number of outage minutes per electricity consumer)

2019, minutes:	20
2018, minutes:	21
2017, minutes:	22

OUTAGE MINUTES ELECTRICITY TRANSMISSION GRID

(consumption-weighted outage seconds)

2019, seconds:	13
2018, seconds:	11
2017, seconds:	92

WIND AND SOLAR ENERGY SHARE

2019, per cent:	50
2018, per cent:	44
2017, per cent:	46

COST OF ANCILLARY SERVICES

2019, million DKK:	665
2018, million DKK:	806
2017, million DKK:	626

EMERGENCY INCIDENTS

2019, number:	0
2018, number:	1
2017, number:	1

IT INCIDENTS

2019, number:	0
2018, number:	1
2017, number:	0

ALERT STATE

2019, number:	1
2018, number:	2
2017, number:	1

EMERGENCY STATE

2019, number:	0
2018, number:	0
2017, number:	0

Danish electricity consumers have enjoyed very high levels of security of electricity supply for many years. This was also the case in 2019. In 2019, Danish electricity consumers experienced an average of around 20 outage minutes per electricity consumer. Since 2008, the number of outage minutes in Denmark has been around 20. This makes the security of electricity supply for Danish electricity consumers one of the highest in Europe.

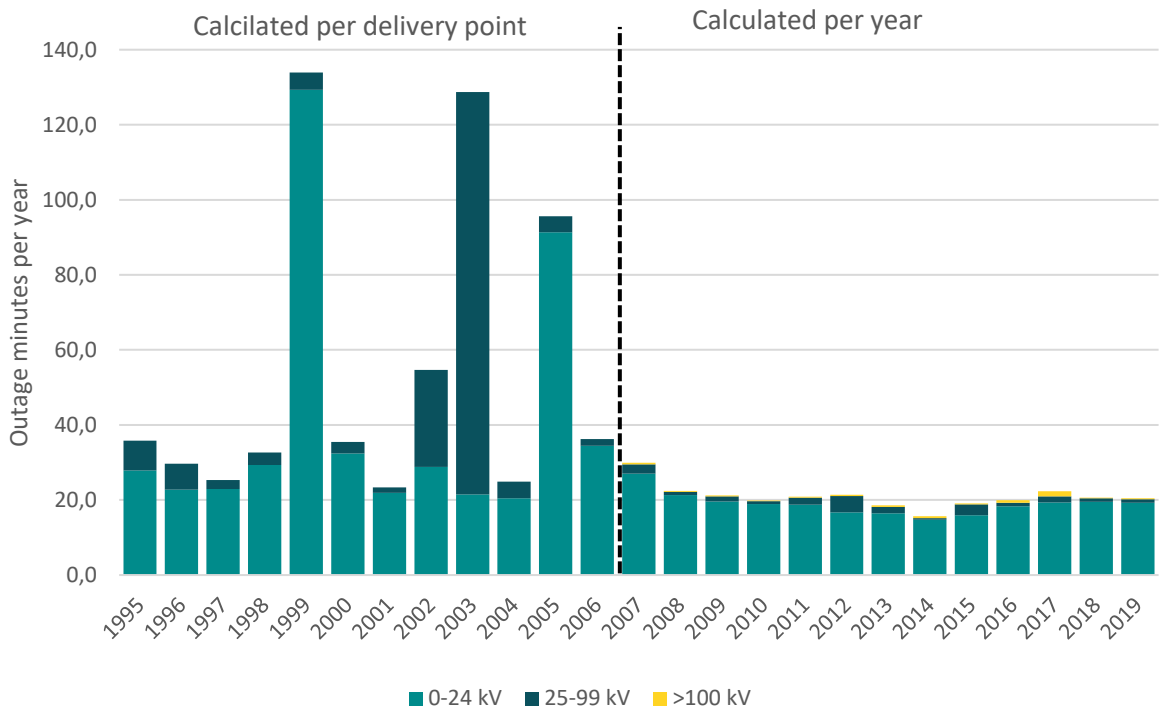


Figure 2 *Outage statistics for Denmark, 1995-2019. Calculations for 1995-2006 are per delivery point (fictitious point in the 10 kV grid), and calculations for 2007-2019 are per electricity consumer (SAIDI – System Average interruption Duration Index). On average, outage minutes calculated per delivery point are approximately 2 minutes higher than outage minutes calculated per electricity consumer for the period 2007-2019. Until 2007, outage statistics were only divided into the voltage levels 0-24 kV and 25-99 kV, with the electricity transmission grid included in the 25-99 kV statistics. From 2007 onwards, the electricity transmission grid has been shown independently in the category > 100 kV. Source: Grid operators' fault and outage statistics (Elselskabernes Fejl- og Afbrudsstatistik (ELFAS)), Danish Energy.*

Figure 2 illustrates the average number of minutes per year in which electricity could not be supplied for the past 25 years in Denmark. Historically, generation inadequacy and IT security breaches have not caused disconnection of electricity consumers in Denmark. Also, faults in the electricity distribution grids are historically primarily attributable to insufficient robustness and grid inadequacy, while faults in the electricity transmission grid are due to insufficient robustness.

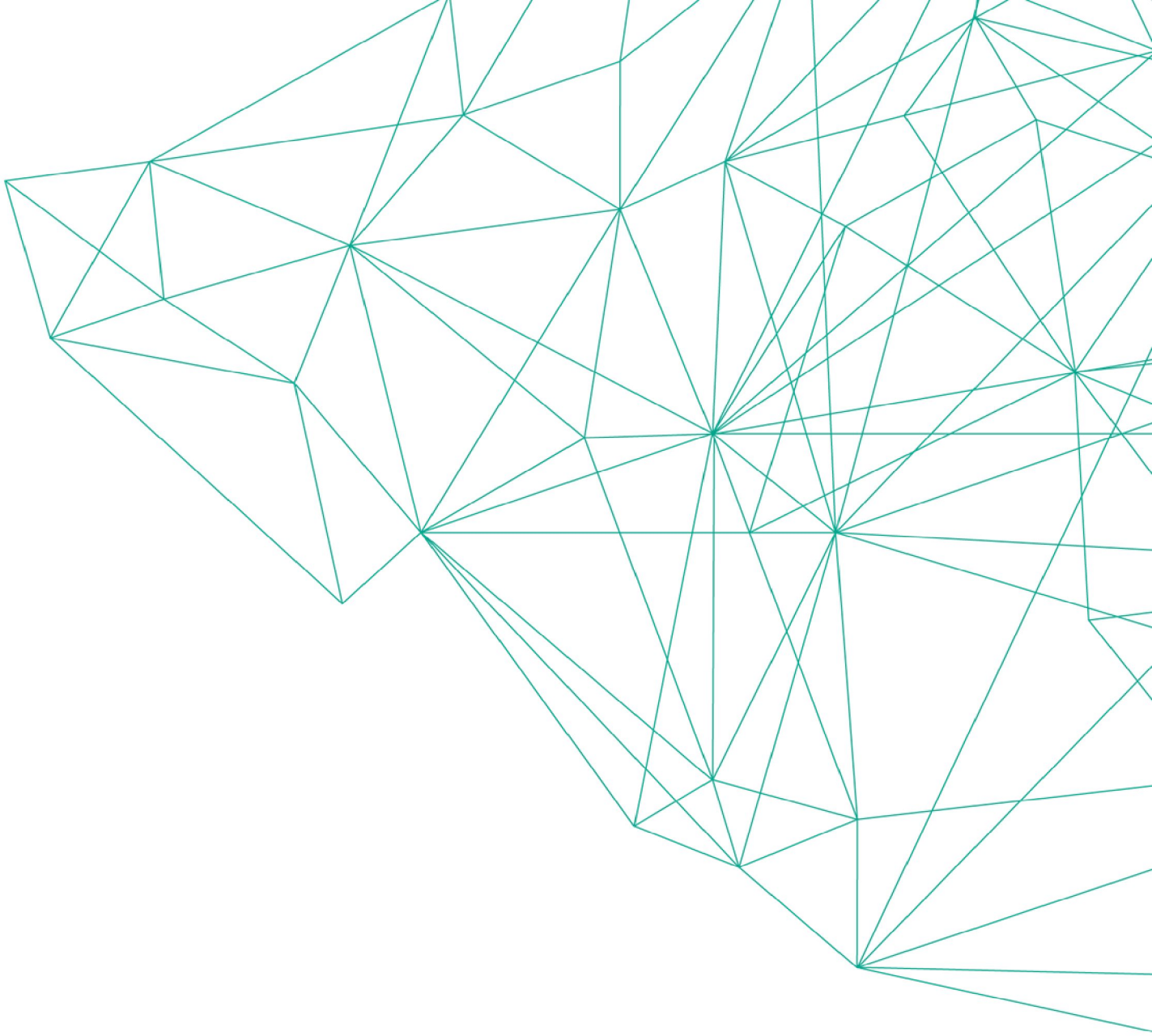
The historically high level of security of electricity supply in Denmark, especially in the past 10 years or so, is linked to, among other things, the considerable degree of underground cabling in the electricity distribution grids, which has made these more resistant to weather-related impacts. Similarly, the electricity grid has generally been well-developed and well-established in relation to the volume of electricity to be supplied and electricity production to be integrated.

Historically, the age of the electricity grid and the consequent state of operation have also played important roles. Generally, the electricity grid has been in a phase of its life cycle with a low probability of faults. The electricity grid is now reaching a new phase in its life cycle, where the probability of faults is found to be increasing.

Even though the security of electricity supply has been very high in recent years, there have also been incidents which could potentially have resulted in considerable outages of the electricity supply, but this did not happen. In 2019, for example, there was an incident in which the eastern Danish system lost approximately 1,100 MW of power in a very short period of time. In 2018, there was a fire at a central substation in Zealand, and in 2013, the Storm Allan came close to causing disconnection of a significant number of electricity consumers in eastern Denmark.

All these incidents resulted in trips of several components in the electricity transmission grid, i.e. incidents that the electricity transmission grid is not dimensioned to handle. The fact that these incidents did not lead to significant outages owes to favourable operating conditions at the time of each incident, the fact that Energinet's control centre managed to activate remedial actions as well as a generally high level of robustness in the Danish electricity transmission system.

The historical security of electricity supply, focusing mainly on trends in 2019, is described in further detail in Energinet's report on outage statictics 'Security of electricity supply 2019'.



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