ENERGINET

SECURITY OF

ELECTRICITY SUPPLY REPORT 2019

This report is comprised of translated extracts from *Redegørelse for elforsyningssikkerhed 2019*. The full report can be found in Danish on Energinets webpage. The extracts includes the summary, status on the security of electricity supply in Denmark and the expected trend of the security of electricity supply. Together, the status and the expected trend of security of electricity supply explains the current level of security of supply, challenges and where that leads the security of electricity supply. The summary describes Energinet first recommendation to the Minister for Climate, Energy and Utilities based on an assessment taking account of the national economy, comparison with security of supply in other European countries and maintaining a high level of security of electricity supply.

Summary

In June 2018, an amendment to the *Danish Electricity Supply* Act gave the Minister for Climate, Energy and Utilities responsibility for the security of electricity supply and the duty to determine the level hereof. Under the *Danish executive order on transmission system operation*[1], Energinet must prepare an annual report on the security of electricity supply that includes a recommendation on whether to change the level. The report and recommendation both underpin the Danish Minister for Climate, Energy and Utilities' determination of a level of security of electricity supply. In this *Security of electricity supply report 2019*, Energinet recommends a future level of security of electricity supply. Energinet must also include forward projections of the security of electricity supply. Here, Energinet has consulted the Danish grid operators that handle supply at low voltage levels (below 100 kV).

A high level of security of electricity supply is at the core of Energinet's recommendation. Energinet's stated primary objective is the best possible accommodation of all aspects of the energy trilemma; maintaining a high level of security of electricity supply, taking account of the national economy as well as ensuring a successful green transition by integrating renewable energy.

The joint objective of Energinet and grid operators is to maintain a high level of security of electricity supply for the benefit of electricity consumers and society as a whole. However, a socio-economic prioritisation dictates that the cost of maintaining a certain level of security of electricity supply must correspond to the electricity consumers' willingness to pay for security of electricity supply. In the long term, grid operators would prefer to determine the level of security of electricity supply in the electricity distribution grids based primarily on a socio-economic approach, rather than a traditional approach based solely on the importance of a high level of security of electricity supply. Moreover, the recommendation in this report emphasises the importance Energinet attaches to Denmark maintaining a competitive advantage by being in the European top in terms of security of electricity supply.

Energinet recommends a planning objective for the overall level of security of electricity supply of 35 minutes without electricity (outage minutes) in 2030, which means that Danish electricity consumers can expect to have electricity 99.993 per cent of the time. In comparison, Danish electricity consumers had electricity 99.996 per cent of the time on average in 2018, meaning that Danish electricity consumers experienced just under 22 outage minutes on average. Disturbances in the electricity transmission grid caused approximately 0.2 outage minutes, while the remaining approximately 21.7 outage minutes originated in the distribution grids. In 2018, no outage minutes owed to generation inadequacy.

Planning objective in 2030	
Planning objective (outage minutes)	35
Additional costs (DKK million /year)	100-300
Benchmarking (Europe, 2016)	Top 5

Security of electricity supply in 2018 was on a par with the preceding 10 years (20 outage minutes, also corresponding to 99.996 per cent), serving to make Danish electricity consumers' security of electricity supply one of the highest ranking in Europe. With the recommendation of an increase to 35 outage minutes as the planning objective for 2030, security of electricity supply in Denmark is expected to continue to be among the best in Europe.

Denmark has maintained its high level of security of electricity supply over the past 10 years while increasing the share of fluctuating wind and solar energy. In 2018, wind and solar energy made up just under 44 per cent of the total Danish

1 Danish executive order no. 1217 of 15 October 2018 on the amendment of Danish executive order on transmission system operation and the use of the electricity transmission grid, etc.

electricity consumption. Denmark maintains a high level of security of electricity supply because the electricity grid is still relatively new, and age-related faults therefore remained at a relatively low level in 2018. In addition, many overhead lines have been replaced with cables and undergrounded, and the electricity grid is not affected by, for example, strong winds.

Energinet's recommendation of a planning objective with an increase in outage minutes compared to the previous 10 years is primarily based on socio-economic considerations as well as grid operators' assessment that the number of outage minutes originating in the distribution grids alone will rise to approximately 28 minutes in 2030. Grid operators base their assessment on their current reinvestment plans. Add to this Energinet's planning objective of seven outage minutes. These are primarily made up of five outage minutes owing to both generation inadequacy, which matches Energinet's current objective and therefore is not a change, and, to a lesser extent, circumstances relating to the electricity transmission grid. These electricity transmission grid circumstances are made up of one outage minute linked to robustness, remaining at the current risk level, and one outage minute linked to grid adequacy, caused by an increased case-by-case risk willingness when carrying out planned reinvestments.

In recent years, grid adequacy has come under pressure due to the incremental probability of faults that an ageing electricity grid brings. Energinet has launched measures to reduce the probability of faults in the electricity transmission grid, but the risk cannot be completely eliminated. In addition, the transition from adjustable power generation to fluctuating solar and wind power generation is challenging generation adequacy. To meet the challenges and uncertainties related to this trend, grid operators and local authorities are already making the necessary reinvestments and implementing automation in electricity system operation in order to be able to react quickly to sudden fluctuations. Moreover, Energinet has begun to implement a number of market reforms which, among other things, aim to ensure greater flexibility in the electricity system.

Energinet has also opted to launch a major reinvestment programme, upgrading components in the electricity transmission grid, in order to counter the increasing fault rate that an ageing electricity transmission grid would otherwise produce. An increasing fault rate could have a negative impact on grid adequacy and thus result in an increase in outage minutes for electricity consumers. Following the completion of this reinvestment programme, Energinet does not see a socio-economic benefit of working to reduce the number of outage minutes in the electricity transmission grid further. Grid operators expect to see a reduced security of electricity supply at the electricity distribution grid level towards 2030 based on the current investment plans, which are expected to be implemented within their current financial regulation framework. However, this remains a subject of considerable uncertainty.

Furthermore, Energinet predicts that electricity consumers may have to bear additional costs if it becomes necessary to initiate further measures, such as temporary strategic reserves, to ensure generation adequacy.

Energinet's key recommendation is to respond to the challenge of generation adequacy using market reforms already introduced. In recent years, a number of market reforms have been introduced in Europe, which are only now beginning to take effect. The overall impact of these reforms cannot be determined yet, and particularly generation adequacy is difficult to predict in challenging situations. Despite this uncertainty, Energinet still finds that it is may be necessary to introduce an option to disconnect demand or increase electricity generation capacity, for example with temporary strategic reserves. Moreover, if market reforms do not sufficiently boost generation adequacy or the power situation worsens, Energinet finds that the socio-economically most cost-effective solution is to establish temporary strategic reserves in Eastern Denmark after 2025.

Energinet is therefore working to prepare a possible decision on temporary strategic reserves in Eastern Denmark to place a 'safety net' underneath generation adequacy. Specifically, Energinet will work together with the Danish Energy Agency, continuing the work on developing scenarios and sensitivities for generation adequacy to be used as a basis for an assessment of the need for temporary strategic reserves. The first results of this work will be available in 2020, after which they are expected to form part of the basis for future releases of the Security of electricity supply report. Any strategic reserve requires the prior approval of both the Danish Energy Agency and the European Commission.

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1. Status on security of electricity supply

This section provides insight into the security of electricity supply in 2018 and the related costs for Energinet.

ELECTRICITY SYSTEM KEY FIGURES 2018

OUTAGE MINUTES IN THE ELECTRICITY SYSTEM, TOTAL

2018, minutes:	22
2017, minutes:	25

WIND AND SOLAR ENERGY SHARE

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

COSTS OF ANCILLARY SERVICES

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

FOCUS ON THE ELECTRICITY TRANSMISSION GRID

2018, sec.:	11
2017, sec.:	92
Objective, sec.:	60

Outage minutes caused by Energinet.

EMERGENCY INCIDENTS

2018, number:	1
2017, number:	1

IT INCIDENTS

2018, number:	1
2017, number:	0

ALERT STATE

2018, number:	2
2017, number:	1

EMERGENCY STATE

2018, number:	0
2017, number:	0

1.1 Security of electricity supply in 2018

Danish electricity consumers have enjoyed very high levels of security of electricity supply for many years, which was also the case in 2018. The security of electricity supply is calculated as the average number of outage minutes per electricity consumer, but does not take into account the number of disturbances experienced by electricity consumers.

On average, electricity consumers have experienced just under 22 minutes of outage, corresponding to a security of electricity supply of 99.996 per cent, with just under 22 minutes of outage originating in the distribution grids and 11 seconds in the electricity transmission grid. This makes Danish consumers' security of electricity supply one of the highest in Europe.

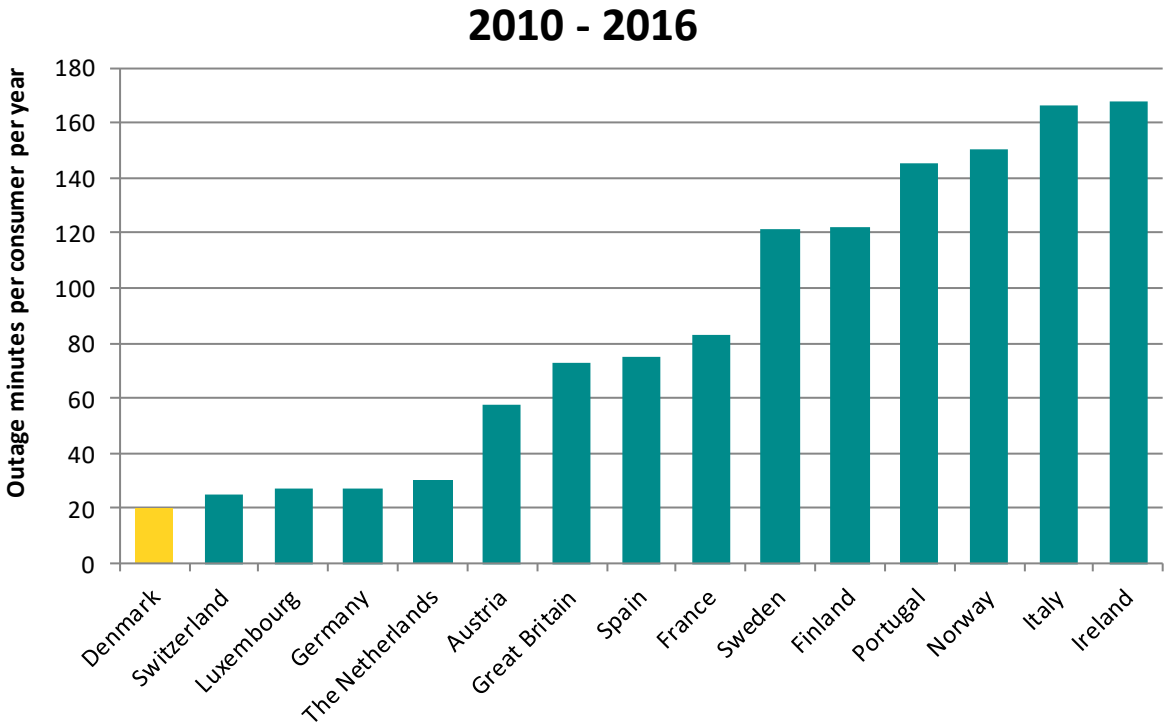


Figure 1 Average outage minutes in European countries with the fewest outage minutes in the 2010-2016 period. Source: CEER's Benchmarking Report 6.1 on the Continuity of Electricity and Gas Supply.

The 11 seconds originating in the electricity transmission grid in 2018 is a reduction compared to the 92 seconds recorded in 2017. An important reason for this reduction is increased focus on the prevention of procedural errors, in particular in connection with connection and disconnection of installations. The 11 seconds were caused by three system disturbances in the electricity transmission grid and three system disturbances on islands, where Energinet has reserve supply obligations.

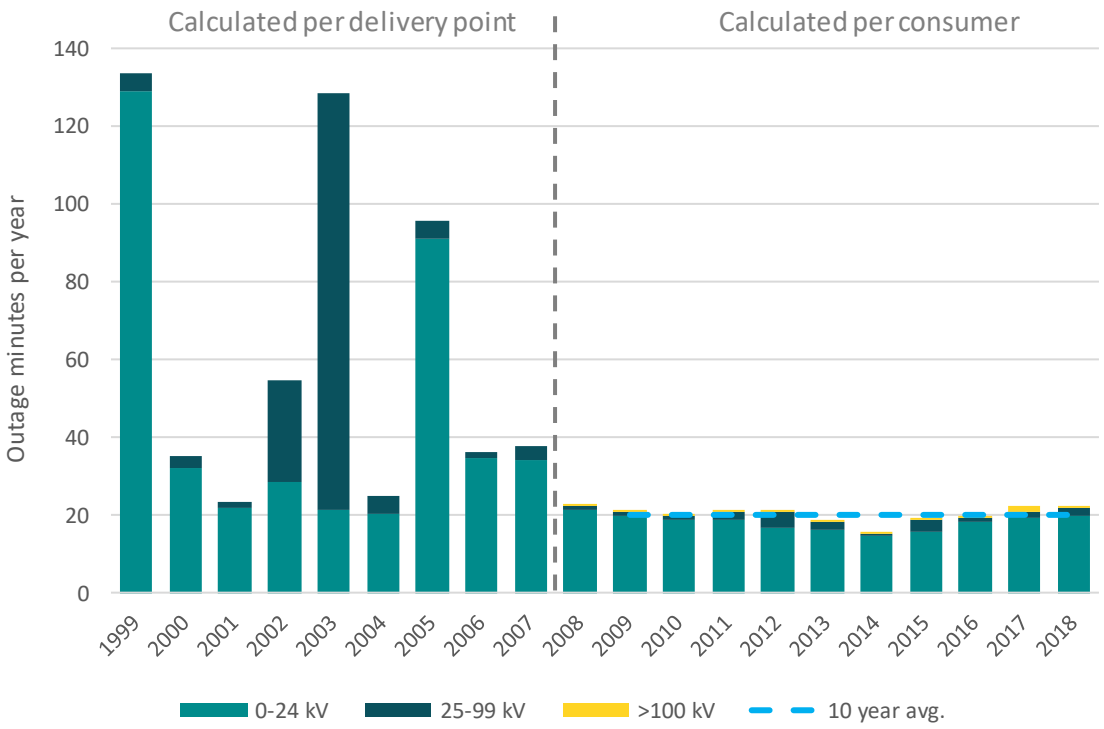
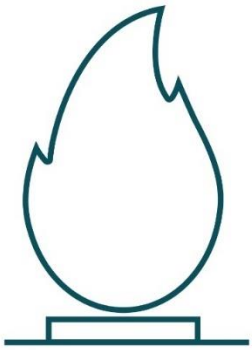


Figure 2 *Outage statistics for Denmark, 1999-2018. Calculations for 1999-2007 are per delivery point (fictitious point in the 10 kV grid), and calculations for 2008-2018 are per electricity consumer. Source: Grid operators' fault and outage statistics (Elselskabernes Fejl- og Afbrudsstatistik (ELFAS)), Danish Energy.*

Note (for the figure above):
The figure illustrates the average number of minutes per electricity consumer per year in Denmark when electricity could not be supplied. Historically, generation inadequacy and IT security breaches have not caused disconnection of electricity consumers in Denmark, and faults in the electricity distribution grids are primarily attributable to grid inadequacy, while faults in the electricity transmission grid are due to a lack of robustness. Introducing a new approach, Energinet will begin to use outage statistics calculated per customer (which has been calculated since 2008). On average, outage minutes calculated per delivery point are approximately 2 minutes higher than outage minutes calculated per electricity consumer, owing to a higher data basis resolution.

In 2018, several significant incidents occurred in the electricity transmission grid, but these did not, however, lead to disconnection of electricity consumers. The most important of these was a fire at Hovegård substation. This incident could potentially have led to outages in many areas of Zealand. Consumer disconnection was avoided, among other things, because Amager Power Station, unit 3, was already ordered into service for another reason.



Fire in reactor at Hovegård substation on 13 July 2018

One major near-miss incident in 2018 was a fire at Hovegård substation and the subsequent operating situation.

Around 17.00 on 13 July 2018, a component caught fire at Energinet's Hovegård substation near Smørum west of Copenhagen. The fault occurred in a cable lead-through, which exploded, igniting the oil in the component.

Hovegård is a critical substation. It electrically connects Northern Zealand to Sweden and, from here, the rest of Eastern Denmark. In addition, the substation is one of two primary substations which can lead electricity to Copenhagen. It is also important for the delivery of certain reserves and start-up of the electricity transmission grid after a blackout.

The incident, including follow-on faults, is not covered by the dimensioning criteria used by Energinet. Therefore, the incident had the potential to cause disconnection of electricity consumers in all or in large parts of Eastern Denmark. Even though the security of electricity supply was under severe pressure during the hours when part of Hovegård substation was out of commission, this did not lead to disconnection of electricity consumers. The low electricity consumption in the summer period and the possibility of quickly regulating power stations upward were contributing factors to electricity consumers not being disconnected.

1.2 Energinet's costs of safeguarding the security of electricity supply

Energinet incurs a number of costs from maintaining its obligations under the *Danish Electricity Supply Act*. Energinet's costs can be divided into operating expenses, depreciation and financing. Selected costs and investments to safeguard the security of electricity supply are shown in Table 1. It is difficult to define the exact costs of safeguarding the security of electricity supply, as the entire value chain in principle contributes to this.

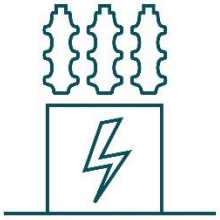
Energinet's costs (million DKK) (2018 prices)	2018
Operating expenses	
Energinet Electricity System Operator and Electricity Transmission operating costs	800
Ancillary services	800
Investments	
Reinvestments	200
Grid reinforcements	200
Ordered projects	900
Cable action plan and visual enhancements	200
Interconnectors	1,500

Table 1 Selected, rounded costs in 2018, which contribute fully or partially to safeguarding the security of electricity supply.

Operating expenses comprise, among other things, costs relating to the operation and maintenance of the electricity grid, control centre operation and market and system development activities as well as staff costs. Energinet's investments in transmission installations totalled DKK 3 billion in 2018. Investments are depreciated and financed over the installations' useful life.

From 2014 to 2018, Energinet spent approximately between DKK 600 to 800 million on ancillary services. Costs increased approximately DKK 180 million from 2017 to 2018.

This increase in ancillary services costs is mostly attributable to generally high prices for frequency reserves in both the Nordic countries and Western Denmark during the summer and a one-off, long-term ordering of Amager Power Station, unit 3.



Ancillary services
Ancillary services is the collective term for the electricity generation and consumption resources used to maintain electricity system balance and stability. Energinet procures ancillary services that can be activated automatically or manually in the delivery hour. Ancillary services consist of reserves, regulating power, properties required to maintain power system stability and other system services such as black start services.

The ordering of Amager Power Station, unit 3, ended in March 2019, following an extension owing to the delayed commissioning of a new 132 kV cable. Up until the end of September 2019, no new ordering had taken place in 2019.

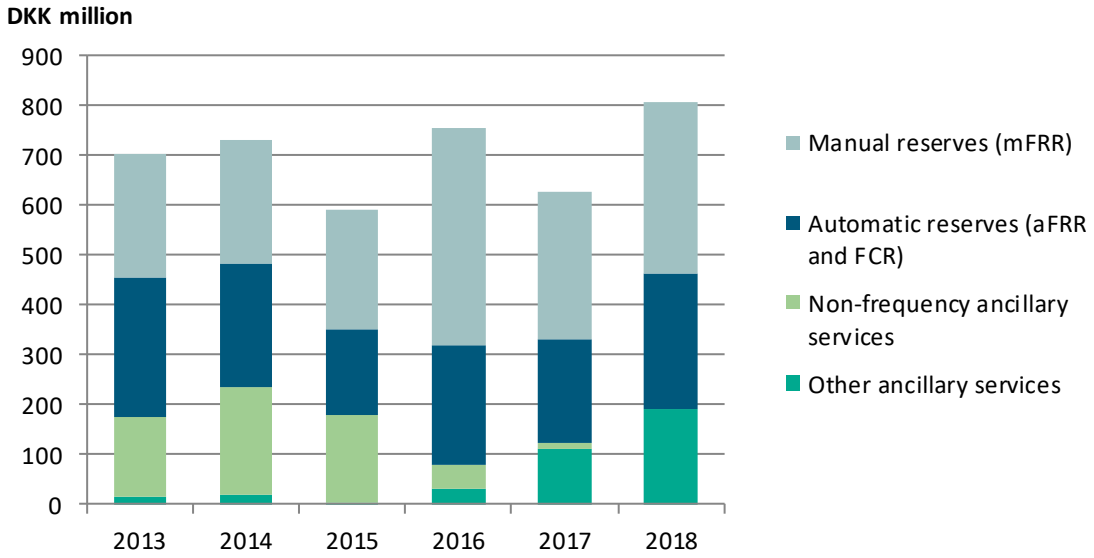


Figure 3 Costs of procuring ancillary services. Costs incurred by Energinet related to synchronous condensers are not included in this comparison.

2. Expected trend of security of electricity supply

Energinet estimates the future security of electricity supply on the basis of *Analysis assumptions for Energinet*[2], prepared by the Danish Energy Agency and based on a 'best guess' approach. This is included in Energinet's analyses of generation adequacy and its *Reinvestment, expansion and restoration plan*[3].

The estimation of the expected trend in generation adequacy is made using simulations of the electricity system. In addition, Energinet estimates the outage minute trend based on historical data and expected development in terms of grid adequacy, robustness and IT security.

Energinet estimates that, all things being equal, there is an increasing risk of electricity consumer disconnection in the electricity transmission grid towards 2030. This is primarily attributable to the phasing out of adjustable thermal electricity generation in favour of fluctuating solar and wind power generation, increasing electricity consumption levels and an ageing electricity transmission grid with an inherent increasing probability of faults. Grid operators finds that the current reinvestment plans will result in an increase in the number of outage minutes in the electricity distribution grids.

2.1 Analysis assumption for Energinet

Analysis Assumptions for Energinet 2018 underpin Energinet's prediction of the expected trend in the Danish electricity system. Changes to these assumptions may have a significant impact on the expected outage minute trend.

The energy agreement from 2018 is the reason for the most significant changes compared to Energinet's previous analysis assumptions. The energy agreement includes three major offshore wind farms, new technology-neutral tenders and tax reductions on electricity and electrical heating. Measures from the energy agreement were incorporated into the analysis assumptions 2018 report.

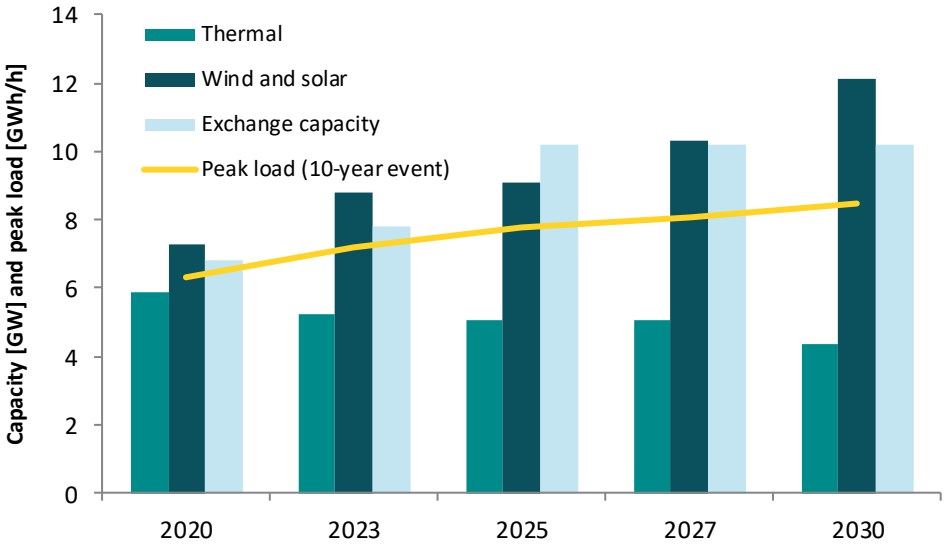


Figure 4 Electricity generation and exchange capacities as well as maximum electricity consumption in case of a 10-year incident for Denmark as stated in the Analysis assumptions for Energinet 2018 report.

2 Webpage: Analysis assumptions for Energinet.

3 Reinvestment, expansion and restoration plan 2018

In addition, the analysis assumptions include updated expectations about the expansion of large data centres, a one-year delay to the establishment of the planned interconnectors in the Viking Link project scope and new projections of, among other things, land-based wind turbines, solar cells and transportation by road.

Overall, the analysis assumptions show a considerable increase in wind and solar-based electricity generation capacity. Thermal electricity generation capacity is expected to be phased out at a lower speed than stated in previous analysis assumptions. At the same time, there is an increase in electricity consumption, primarily driven by data centre expansion, but the long-term trend also owes to the electrification of the heating and transport sectors.

Projections are associated with considerable uncertainty, and the Danish Energy Agency's *Analysis assumptions for Energinet 2018* report presents one possible outcome for the Danish electricity system. Naturally, the speed of the green transition and the trend of increasing generation capacity from wind and solar sources, declining thermal generation capacity and increased electricity consumption due to electrification are all associated with considerable uncertainty. It is therefore relevant to analyse the sensitivities of the generation adequacy assessments made in relation to any changed assumptions. Especially changes to thermal generation capacity and electricity consumption have an impact on the security of electricity supply. Based on input from a wide range of participants in the electricity sector, Energinet has prepared a *realistic worst-case* (RWC) scenario for Danish generation adequacy. This RWC presents an accelerated development process for the electricity system in Denmark, and it clarifies and incorporates the considerable future uncertainty associated with the green transition.

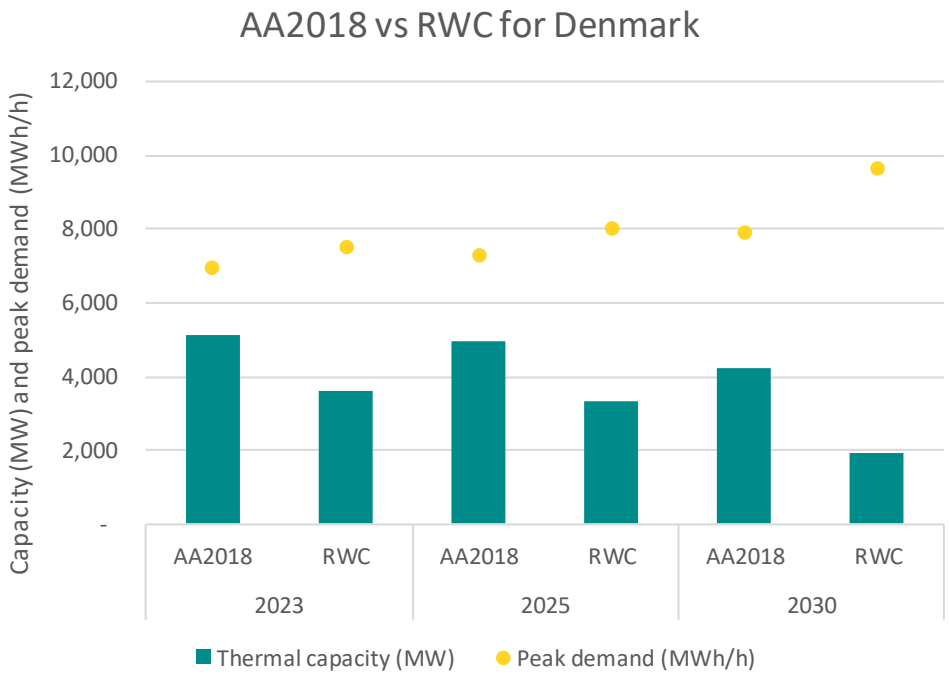


Figure 5 Thermal electricity capacity and maximum electricity consumption for Denmark based on Analysis assumptions for Energinet 2018 and the RWC scenario.

The most significant changes to the RWC compared with *Analysis assumptions for Energinet 2018* are reduced thermal generation capacity, greater generation capacity from wind and solar sources as well as an elevated electricity consumption.

2.2 Electricity system trends

In the years ahead, the electricity system will face a number of significant changes, bringing both resulting challenges and opportunities. The next phase of the green transition will introduce significant and rapid changes to the electricity system. Technological developments mean that renewable energy facilities are installed without subsidies, and that the electricity supply is based on fluctuating, renewable energy sources at an increasing rate. Consequently, the traditional subsidy-based planning logic, which has driven the green transition until now, is being replaced by market forces to a greater degree, making it necessary to bring new planning approaches into play.

Developments in computing power, sensors and machine learning in combination with developments in renewable energy technologies and storage possibilities create a basis for new business models and break down the traditional value chain.

In future, the market participant segment will be different and, for example, consist of both existing and new interest groups, data-based enterprises, service providers and transnational consortia. Some will be familiar, but take on new roles, and completely new types of participants will join them.

Therefore, it is necessary to prepare the electricity grid for a future far more changeable, in order to create the right foundation necessary to achieve a risk-free green transition.

Energinet is making the necessary reinvestments and implementing automation in the operation of the electricity system in order to be able to respond quickly to sudden changes. Moreover, Energinet has begun to implement a number of market reforms which, among other things, aim to ensure greater flexibility in the electricity system. Outage minutes are expected to increase after 2025 due to power generation inadequacy, primarily in Eastern Denmark.

As for the transmission grid, outage minutes caused by grid inadequacy are expected to remain at approximately the same level as today. However, increased risk willingness is accepted during reinvestment periods. Grid operators also find that the current reinvestment plans will result in an increase in outage minutes towards 2030 that will continue into the mid-2040s. This increase is expected to stagnate as reinvestments are made in outworn components.

Figure 6 shows the expected outage minute trend in the Danish electricity system towards 2030. The figure groups expected outage minutes for the distribution grids and electricity transmission grid, respectively, with the latter further divided into generation adequacy, grid adequacy, robustness and IT security.

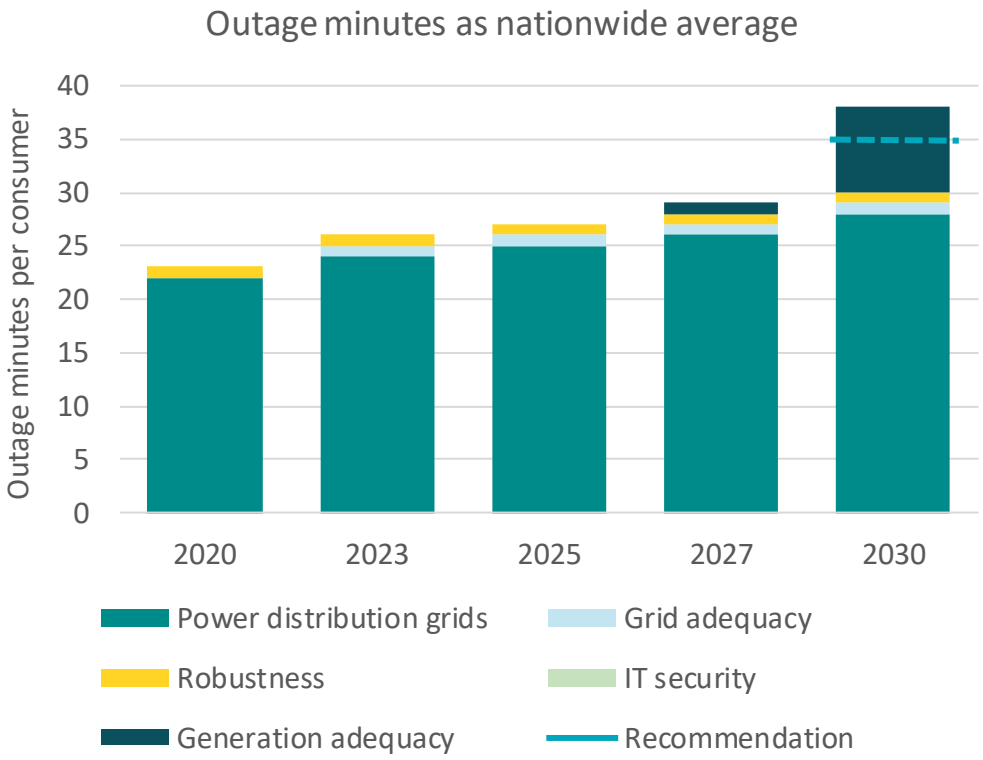
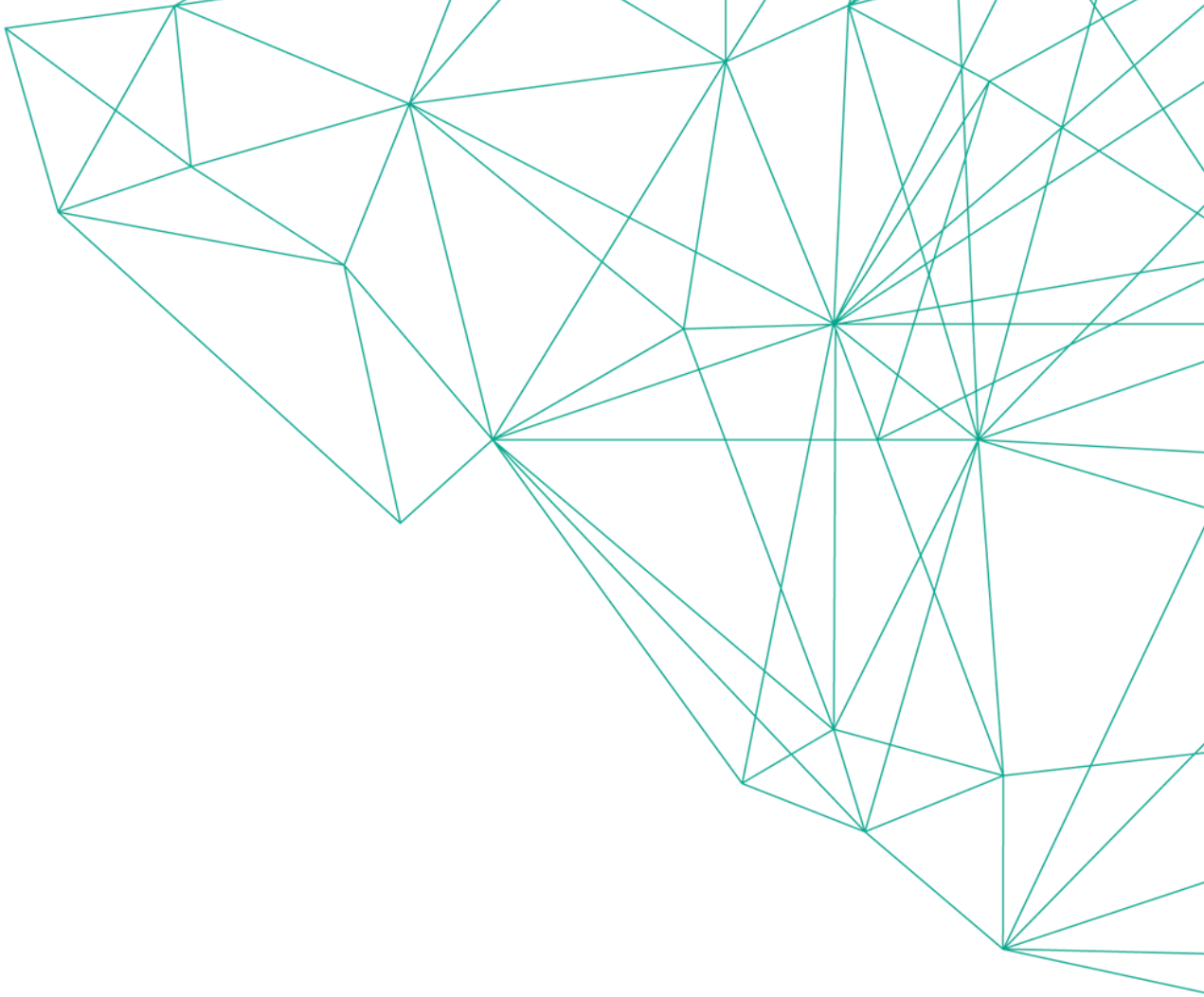


Figure 6 Expected outage minutes in the Danish electricity system in a normal year (without exceptional incidents).



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