ENERGINET

LONG-TERM DEVELOPMENT NEEDS IN THE POWER GRID

The green transition will require new initiatives in the power grid above 100 kV.

CONTENTS

INTRODUCTION

The green transition entails the need for new initiatives in the power grid

This report shows that there will be a need to transmit more energy in the power grid in the coming years. This is due to the significant increase in renewable energy production far from consumers, and increased electrification. As 2040 approaches, it will therefore be necessary to develop the power grid and the way we use it.

All scenarios analysed point to significant changes. However, depending on which direction the future development actually takes, there will be significant differences in the scope and type of the necessary initiatives, and how quickly the needs arise.

Early dialogue and informed decision-making basis

With this report on the long-term development needs in the power grid, Energinet aims to create a qualified basis for an early and informed dialogue with citizens and stakeholders about the electricity system during the green transition, and the infrastructure that may accompany it.

Based on the identified needs for initiatives, a possible long-term grid structure is presented that can handle the needs, if they are to be addressed through infrastructure. It is important to focus on the long term in order to ensure due diligence, when projects have to be carried out based on uncertain assumptions. There may be other types of solutions, particularly in the market, that need to be brought into play in order to handle grid overloads, thereby reducing the need for infrastructure.

How we forecast the future trend

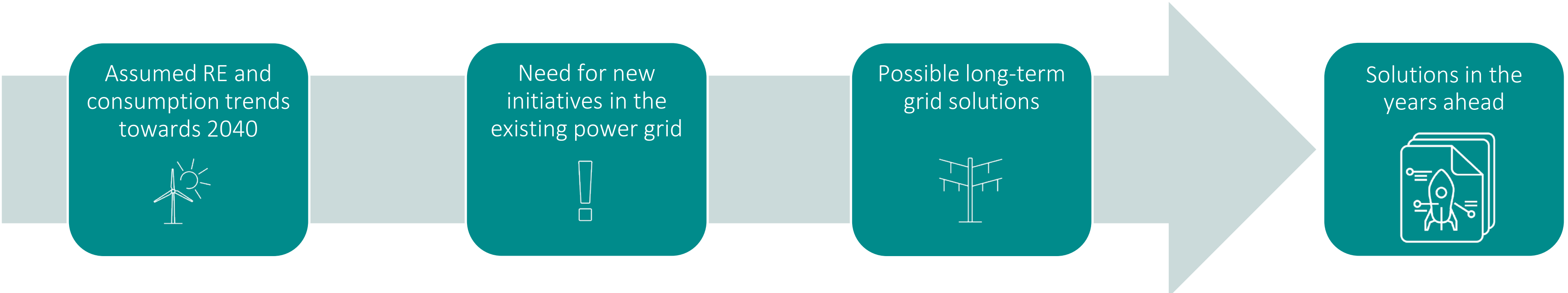
Energinet has based its calculation models and analyses used in this report on the Danish Energy Agency's analysis assumptions for Energinet from 2019 (AF19), supplemented by two scenarios. These two scenarios aim to capture the development of more onshore and offshore RE production, and especially hydrogen and power-to-X. These are likely to be part of the ongoing long-term green transition, and are reflected in the latest political agreements, including the climate agreement of June 2020.

The Danish Energy Agency's analysis assumptions for 2020 (AF20), which incorporate the latest climate agreement, were published in August 2020. The overall estimates for energy production and consumption from AF20 have been included in this report to show the general direction, while data from AF19 and the scenarios have been used to calculate the detailed impacts on the power grid. Specific investment decisions will be based on the most recent assumptions available at the time.

Read more about analysis assumptions and scenarios on pages 6 and 35.

Where can you find out more?

Please note that this is a condensed version of two more in-depth reports on the development needs of the power grid and possible solutions in the form of physical power infrastructure. A similar report has been prepared on the long-term development needs in the gas grid. These reports can be read here (in Danish): www.energinet.dk/udviklingsbehov2020. See also the Glossary on page 35.



The long-term development needs presented in this report are part of Energinet's overall planning process. Furthermore Energinet continuously works with market participants on other types of solutions – see p. 10. Based on the long-term analyses, specific projects will be launched in which the final solution to address the needs is determined. In this work, both grid solutions and other types of solutions will be examined.

LONG-TERM DEVELOPMENT NEEDS IN THE POWER GRID – FIVE CORE MESSAGES

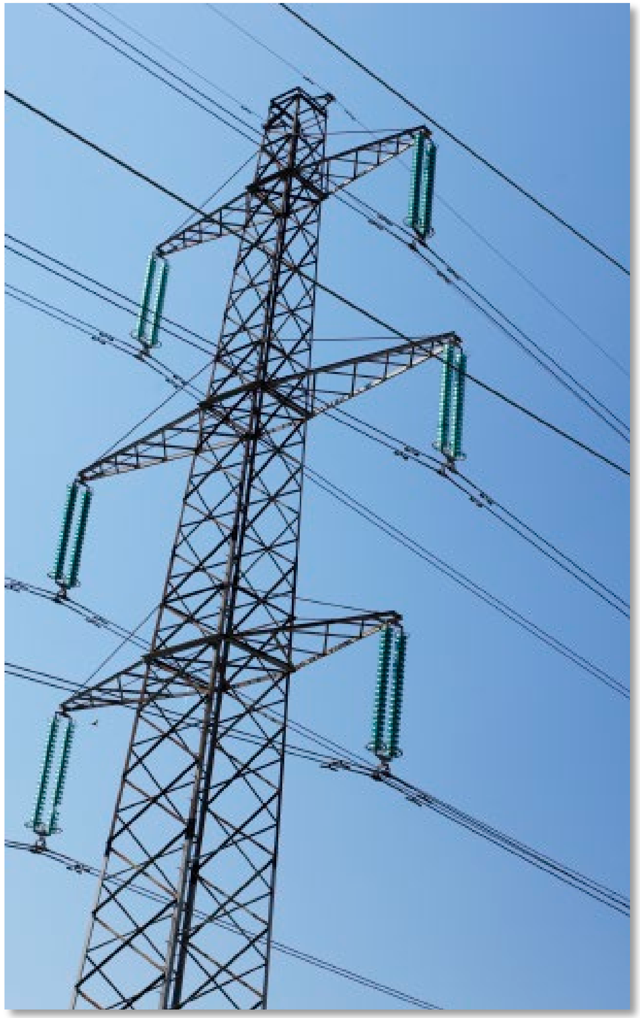
1. **Production and consumption of renewable energy will increase significantly towards 2040**
   In 2040, the total production capacity from solar and wind power plants in Denmark will be able to supply twice the maximum electricity consumption. Electrification, particularly in the form of heat pumps, electric vehicles and power-to-X, will entail that electricity consumption will grow significantly as well.

2. **The green transition will result in the existing power grid being overloaded**
   The existing power grid will become overloaded, irrespective of which paths the transition takes. However, the degree to which the grid becomes overloaded, and where this particularly happens, will be dependent on exactly which paths eventuate.

3. **Power grid overloading will result in a need for measures that can relieve the load on or increase the capacity of the power grid.**
   The green transition makes it imperative that we get started on the right solutions in a timely manner. Expansion of the power grid can increase its capacity, while market measures or the use of RE for green hydrogen can relieve the load on the power grid.

4. **The green transition will result in the need to expand the power grid, but when and how much is uncertain**
   It is very likely that the green transition will require the establishment of new power grid infrastructure – including new transmission lines. But when and how much will depend on how the market evolves and the solutions we choose as a society.

5. **The need to expand the power grid can be reduced by solutions that create better simultaneity or geographic balance between production and consumption**
   The better consumption and production can be matched in time and place, the less need will be to transmit green electricity in the power grid – e.g. if some RE production can be converted to storable energy (such as hydrogen). Energinet is working with market participants in the energy sector on a number of solutions and new initiatives.



THE POWER GRID IN 2040 – THE BIG PICTURE

The following pages give you an overview of probable trends in the electricity system towards 2040, the associated needs for development and possible solutions.

LARGE GROWTH IN RENEWABLE ENERGY AND INCREASED ELECTRIFICATION TOWARDS 2040

The goal is a climate-neutral society

The Danish Parliament adopted the Danish Climate Act (*Klimaloven*) in 2019, with the ambition of a 70% reduction in Danish climate gas emissions compared to the 1990 level. Together with the goal of a climate-neutral society in 2050, these objectives set the general direction for development of the energy system. In June 2020, a climate agreement for energy and industry was also adopted - a step towards specifying how the ambition will be met.

Rapid development

The capacity of installed solar and wind power plants exceeded the maximum electricity consumption in 2019, but this capacity will increase to approximately twice the size of the maximum electricity consumption in 2040 (see Figure 1). There are however major differences, between different geographical areas. Put briefly, over just a few years, we are moving from a situation where all RE capacity can be used for known electricity consumption, to a situation in which the increased capacity has to find an outlet in the form of new electricity consumption or RE exports.

Difficult trends to forecast

What new types of electricity consumption will gain ground, and which sources of renewable energy will meet them? Each year, the Danish Energy Agency prepares new analysis assumptions (AF), which present key figures for the production and consumption of energy based on political objectives and expected market and technology developments. These serve as the primary basis for Energinet's work. AF19 does not incorporate the 70% target or the climate agreement for the energy sector from June 2020. AF20 includes the new political goals, but has not yet been incorporated into Energinet's calculation models.

On that basis, Energinet has, in consultation with stakeholders, prepared an initial assessment of the consequences of the 70% target, by supplementing AF19 with two scenarios – a yellow and a blue. This assessment will be updated next year based on AF20, but Energinet does not expect major changes in the possible long-term grid expansions presented on page 9. However, further analysis is required. Read more about analysis assumptions and the scenarios on page 35.

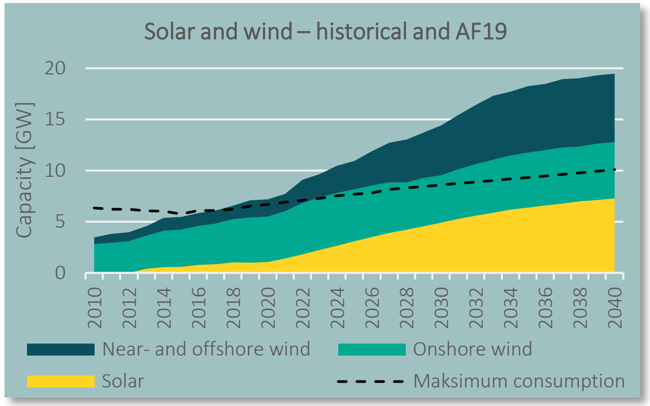


Figure 1: From 2020, the electricity system is entering a new era, where the installed renewable energy capacity exceeds the maximum electricity consumption and will grow markedly towards 2040. Read more about analysis assumptions and the scenarios on page 35.

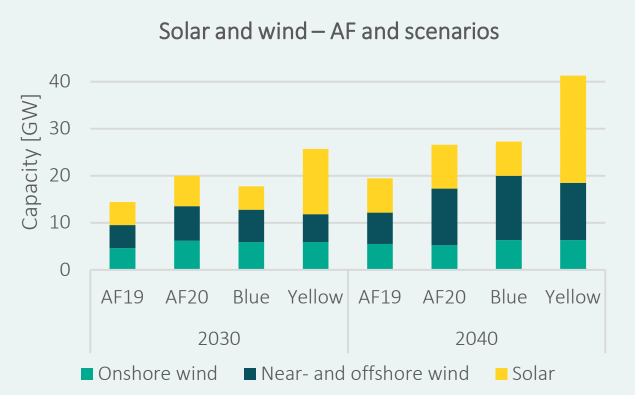


Figure 2: The blue and yellow scenarios supplement AF19 with the same trends as AF20. In the blue scenario, increased electricity consumption is met by offshore wind power, while it is met by a combination of offshore wind power and large numbers of solar panels in the yellow scenario. The yellow scenario is an extreme solar scenario. Read more about analysis assumptions and the scenarios on page 35.

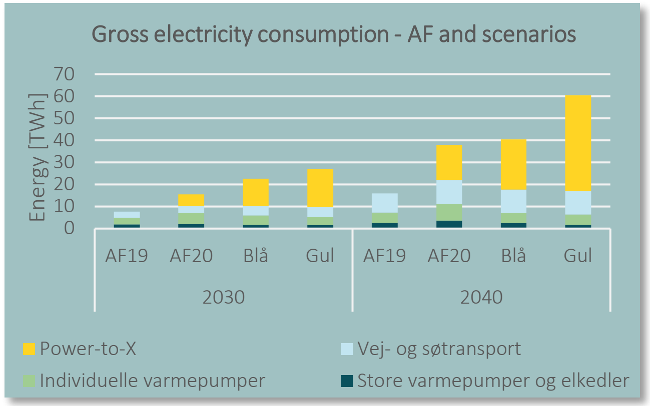
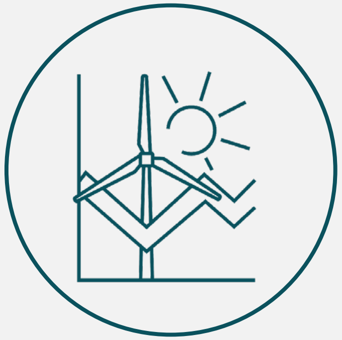


Figure 3: The blue and yellow scenarios supplement AF19 with the same trends as AF20. The blue and yellow scenarios contain power-to-X for Danish consumption of RE fuels and generally increased electrification. In 2030, AF20 forecasts more electrification from individual heat pumps, while electric vehicles are on par with the blue and yellow scenarios. Read more about analysis assumptions and the scenarios on page 35.

FOUR FACTORS CAN PARTICULARLY IMPACT THE NEED TO DEVELOP THE POWER GRID

New initiatives are required if the power grid is to support the green transition all the way to a climateneutral society in 2050. In other words changes, reinforcements and grid expansions are required. However, there are four factors in particular which will have a significant impact on the scope, type and location of the measures that will be necessary in the overall power grid.



RE ON MARKET TERMS

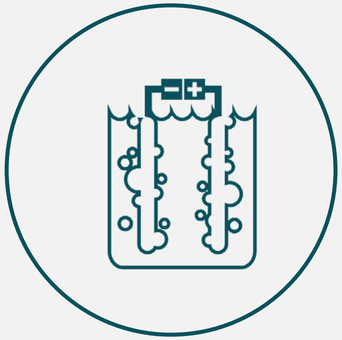
There is rapidly growing interest in installing solar power plants, in particular, across most of Denmark. How much and how fast this market will grow is difficult to predict, but both factors will significantly impact the long-term needs in the power grid.

South Zealand and Lolland-Falster are clear examples of regions where these factors will have a major impact. See page 28.

ENERGY ISLANDS

A political majority has decided to investigate the possibility of two energy islands – one in the North Sea and one near Bornholm. Precisely where these energy islands are connected to land will have a major impact on the long-term needs of the power grid. It will also be a key factor whether some of the RE production is converted to hydrogen on the island, or all the electricity has to be fed into the onshore power grid.

The energy islands could impact the entire 400 kV grid, but see west Jutland and Copenhagen for clear examples on pages 12 and 31.



POWER-TO-X

The development of electrolysis plants and power-to-X is underway, and the topic receives much attention in the June 2020 climate agreement. When power-to-X plants become widespread, their location, size and conditions of connection to the power grid will have a major impact on the needs of the grid.

In areas with excess RE production, electricity consumption from power-to-X plants can help reduce these needs (see page 12). In areas with an electricity supply deficit, special conditions for connection will be necessary to avoid power-to-X leading to greater needs for the grid (see page 15).

GEOGRAPHICAL BALANCE BETWEEN CONSUMPTION AND PRODUCTION

The higher voltage power grid (> 100 kV) is used to transmit electricity between regions. The relationship between production and consumption in defined geographical areas may therefore be the most important determinant of the needs in the high-voltage grid.

This is a key factor across the country, but a clear example is central and west Zealand. More production south of this region would increase the needs in the area, while more production north of the region would reduce them. See page 25.

POWER GRID OVERLOADING ENTAILS THE NEED FOR NEW INITIATIVES – BUT THERE ARE GEOGRAPHICAL DIFFERENCES

Identifying the needs

AF19 and the scenarios described on the previous page offer a preliminary first estimate of the needs in the power grid resulting from the Climate Act, the climate agreement and the green transition in general. 'Needs' refer here to overloading in the power grid due to existing capacity not being sufficient to transmit the energy through the system which the analyses predict will be necessary.

South Jutland

The needs here are driven by the expansion of offshore wind power. This region is largely a transport area for offshore wind power, including the energy island, for consumption in other parts of Denmark and for export.

Triangle Region and Horsens area

The needs are primarily driven by changes in consumption, specifically electrification. The scope and speed of electrification will be important, as will changes in electricity consumption from data centres in the region.

West and east Jutland

The needs are driven by RE expansion – onshore and offshore wind power and solar power. The energy island in the North Sea is a key factor, as connecting this will increase the load on 400 kV connections out of the area in which it is connected. Increased electrification will also strain transmission lines, especially in and around Aarhus.

South Zealand and Lolland -Falster

The needs are primarily driven by expected major growth in onshore solar and wind power.

Central and west Zealand

The needs are primarily driven by the greater requirement in the future for transmitting RE-based electricity from the southwest to the northeast towards Copenhagen.

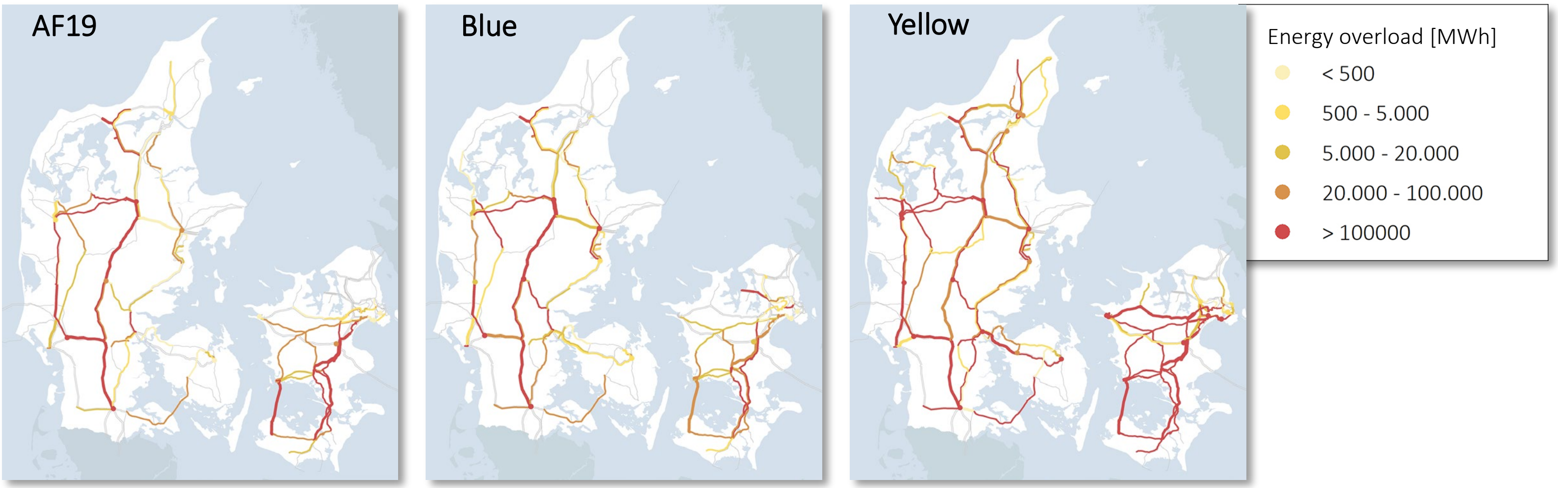
Copenhagen area

The needs are driven by increasing consumption in the form of increased electrification and urban development.

Figure 4: Power grid overload in 2040

The load of the power grid in 2040 is roughly the same whether the trend follows AF19 or the blue scenario, although the latter has more offshore wind power, a higher degree of electrification and incorporates growth in power-to-X.

It is the yellow scenario, involving a huge expansion in solar power plants, that stands apart. The yellow scenario includes a major expansion in solar panels, and the increased electricity consumption is largely located in different areas of the grid to production. There is therefore a great need to transmit energy. The yellow scenario is considered to be a relatively extreme solar scenario.



NOTE: Read more about AF19, AF20 and the scenarios on page 35.

POSSIBLE EXPANSION OF THE POWER GRID TOWARDS 2040

What does the map show?

The map to the left shows an overview of the possible changes up to 2040 in relation to the existing and already planned power grid – see the appendix on page 36. According to Energinet's analyses, these changes would be able to handle the identified needs, if these are to be addressed through infrastructure.

Below, we only describe the largest possible expansions – new 400 kV-connections. More details about other types of expansions can be found in the next chapter (starting on page 11), which details the need and possible grid solutions per geographical area in Denmark.

Possible 400 kV-connections on existing tower rows

As the map shows, there are two places in Jutland where it may be necessary to establish new 400 kV-connections on existing towers. In other words, the transmission capacity of these sections can be increased considerably by simply installing new cables on the towers, or operating existing cables at a higher voltage level. In the western part of Jutland, the need for a possible new 400 kV-connection is primarily due to increased RE production in the North Sea. In the northern part of Jutland, it is primarily the more uncertain RE expansion that results in a need for expansion, and it is therefore less certain.

Possible 400 kV-connections on new tower rows

As the map shows, there are three places in Jutland where possible 400 kV-connections would have to be established on new tower rows. On Zealand, there are two places where new 400 kV-connections may be required. The connections in Jutland are due to increased electricity consumption in the Aarhus area, the integration of offshore wind power from the North Sea and the need to transmit energy to south Jutland and Germany. On Zealand, the issue is increasing consumption in Copenhagen, and transmitting RE surplus from south Zealand and Lolland-Falster towards consumption areas around Copenhagen and export connections in north Zealand.

Figure 5: The map to the left shows a number of proposals for new physical plants which, according to the analyses, would be able to meet the requirements for integrating more renewable energy and new, greener energy consumption towards 2040. It is extremely important to note the following conditions:

1. This is an early, best assessment based on current goals and scenarios. The intention is to provide ongoing information about possible solutions in the form of physical infrastructure, long before the decision to implement might be made.

2. Based on current policy guidelines, new 400 kV-connections would be established as overhead lines. At Energinet, we are aware that physical plants, and especially overhead lines, are not always very welcome. We are therefore working to minimise the scope of overhead lines and are continually investigating alternative options – physical, in the form of cables, but also market and operational solutions etc. (see page 10).

ALTERNATIVE SOLUTIONS THAT CAN REDUCE THE NEED TO EXPAND THE POWER GRID

Energinet continually works with many types of solutions to meet the development needs in the power grid – including market solutions, operational solutions and adjustments to the regulatory frameworks etc. This is done in close cooperation with sector authorities and market participants.

The solutions will often be general products or rules, disseminated across the entire power grid and not just at local sites. New rules and frameworks are incorporated into the planning process as they are developed and approved, and they can effect the development needs and thus the long-term grid structure.

The solutions may affect the conditions that determine whether there is a need for an expansion, and will often interplay with possible infrastructure solutions by reducing or delaying the need for grid expansions.

Possible solutions include better incentives to place new consumption or production close together, or to act more flexibly in the market. Other solutions could be to optimise operation of the system.

Six examples of solutions Energinet is involved in, which can reduce the need for grid expansion to varying degrees, are presented below.

LOCAL FLEXIBILITY

Energinet and the DSOs have a pilot project on Lolland which aims to investigate the possibility of a market for local flexibility. If the pilot project achieves good results and is disseminated across Denmark, it will give Energinet a market-based option for relieving internal congestion, and a way of pricing this, which can be compared to the costs of grid expansion.

LIMITED GRID ACCESS

Energinet is working on a 'Limited grid access' product, which will allow large consumers directly connected to the high-voltage grid to choose to be interruptible, in exchange for a reduced tariff. Energinet and the DSOs are also investigating whether a similar product could be offered to large customers in the DSO grid. Dissemination of these products would potentially be able to reduce local expansion needs.

COMPENSATION OBLIGATION

Following a recommendation from the inter-ministerial tariff report, the climate agreement states, that legislation must be implemented to change Energinet's obligation to compensate RE plants in the event that full production cannot be accommodated due to limitations in the high-voltage grid. This could send a signal to RE developers, encouraging them to choose locations that take limitations in the high-voltage grid more into account.

FEED-IN TARIFFS AND CONNECTION CONTRIBUTIONS

The inter-ministerial tariff report and the climate agreement indicate that the legislation must be changed to permit the introduction of a geographically differentiated connection contribution and feed-in tariffs for generators. Geographical differentiation will provide a price signal to RE developers that encourages more appropriate locations in the grid.

BIDDING ZONES

In accordance with the EU regulations, Energinet must periodically consider whether the existing division into bidding zones (price areas) in the electricity market (east and west Denmark) is the most optimal. Dividing into more bidding zones could provide market participants with a clearer price signal, so they take limitations in the power grid into account when choosing locations for new production or consumption. This could reduce the need for grid expansions.

NEW TARIFF MODEL

Energinet is working with the DSOs to develop a new tariff model. The model is expected to include a capacity payment element, which could provide an incentive for customers to reassess their capacity needs. Time-differentiated tariffs could also help move consumption away from peak periods, which can be the determining factor for grid capacity, thereby reducing the need for expansion.

POWER GRID IN 2040 – NEEDS AND POSSIBLE GRID SOLUTIONS BY AREA

This section details the power grid's needs and potential infrastructure solutions towards 2040, by geographical area.

WEST JUTLAND – NEEDS AND POSSIBLE GRID SOLUTIONS

WEST JUTLAND: GREATER RE PRODUCTION FROM OFFSHORE AND ONSHORE WIND AND SOLAR POWER

The west Jutland area will have a significant need for new initiatives, irrespective of which of the investigated paths towards a more climate-neutral society become reality.

This area will be highly impacted by a number of new plants producing renewable energy. These include offshore wind power (the Thor offshore wind farm, the Vesterhav Nord and Syd near-shore wind farms and an energy island in the North Sea) and expected growth in large solar power plants.

West Jutland will thus be an area in which the production of renewable energy increases markedly, while energy consumption does not increase correspondingly. The need to transmit renewable energy away from the area will thus increase, and the current power grid does not have the capacity to meet the future need.

The maximum flow of energy out of the area will vastly increase from approx. 1.2 GW today to between 4.5 and 6.5 GW in 2040, based on the assumptions in AF19 and the two scenarios.

The expansion of onshore wind and solar power will strain the existing 150 kV grid, and measures will be required to address this, while the expansion of offshore wind power, in particular, will strain the 400 kV grid.

If an energy island in the North Sea or other offshore wind power is connected within the west Jutland area, it will further increase the load on the 400 kV grid in the area. Conversely, a connection outside the west Jutland area would reduce the load on the power grid in this area.

The establishment of power-to-X would also reduce the load on the power grid, as this would increase electricity consumption in the area. Electricity which is used to produce hydrogen and which is not transmitted in the power grid.

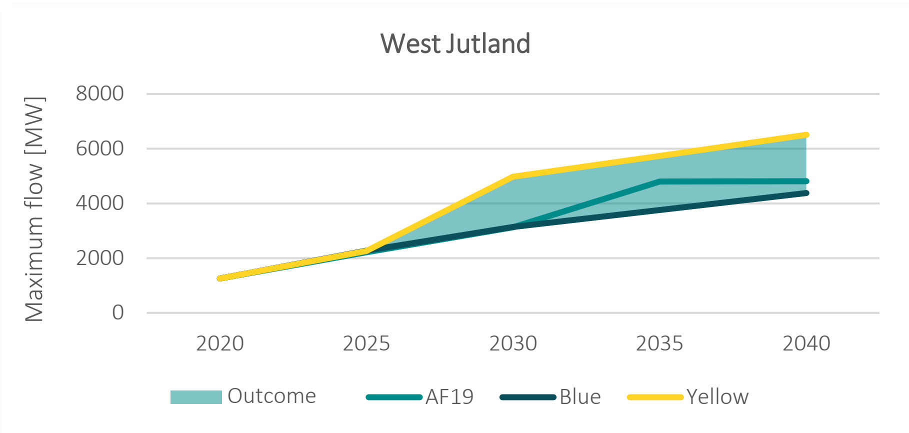


Figure 6: Maximum flow of electricity across west Jutland shown in Figure 7. High growth in RE production will require development in all scenarios. The establishment of power-to-X (blue scenario) will reduce the need. The yellow scenario is based on very large growth in onshore solar power plants, and will particularly lead to more pronounced overloading locally. Read more about analysis assumptions and the scenarios on page 35.

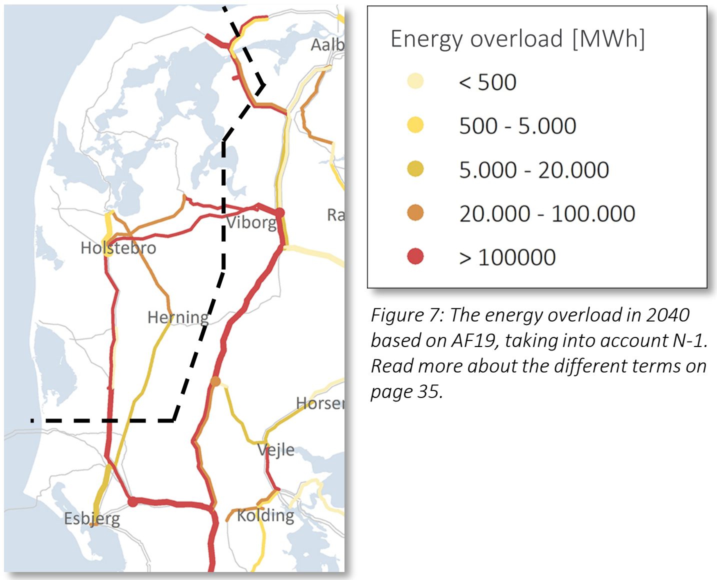


Figure 7: The energy overload in 2040 based on AF19, taking into account N-1. Read more about the different terms on page 35.

WEST JUTLAND: POSSIBLE NEW 400 KV-CONNECTION AND GENERAL REINFORCEMENT OF THE 400 KV- AND 150 KV-GRIDS

As the needs analysis shows (see page 13), the power grid in west Jutland will become significantly overloaded when large volumes of renewable energy production have to be integrated in the area in the coming years.

This page presents solutions based on physical changes to the grid which could address the challenges if grid solutions are the path taken.

Changes to the 400 kV-grid

An additional 400 kV-line will be needed between Endrup and Idomlund (see Figure 8) to carry renewable energy away from the area when the Thor offshore wind farm is connected to the high-voltage substation in Idomlund. This can be achieved without erecting new towers, as one cable system on the new 400 kV-connection for the given segment, which is expected to be in operation from 2024, will be operated at 150 kV initially, but can be operated at 400 kV.

A brand new dual-system 400 kV-connection between Askær and Stovstrup (see Figure 8) would relieve the grid overload that will otherwise result from greater RE expansion, including the 1.8 GW of offshore wind power that AF19 assumes will be connected in Stovstrup and Idomlund.

Two factors could reduce the need for this connection. Firstly, the connection point for an energy island in the North Sea could entail more flexible connection options for the expanded offshore wind power. If power from the energy island is connected in central or east Jutland instead of west Jutland, the need for this connection will be reduced.

Secondly, increased electricity consumption in the area, for example from power-to-X, could help reduce the need, as less RE would have to be transmitted out in the form of electricity.

Cable laying and reinforcement of the 150 kV-grid

A political decision has been made to remove 150 kV overhead lines in all municipalities affected by the new 400 kV overhead line between Endrup and Idomlund, and run this part of the grid as underground cables instead. The requirement of cable laying makes it possible to rethink the structure of the 150 kV-grid in order to accommodate RE expansion in the area, and allow both overhead line systems to be operated at 400 kV. The map on the right (figure 8) shows which cable sections can meet the need.

The yellow scenario is based on the projection that developers establish far more onshore RE production plants than previously predicted (especially large solar power plants), due to increasingly mature market conditions. Enquiries from developers (to municipalities, grid companies and Energinet) reveal that a larger portfolio of RE plants may be connected to the grid than has been assumed in the analyses. This trend could result in the need for more reinforcements to the 150 kV grid, in particular, than are presented here.

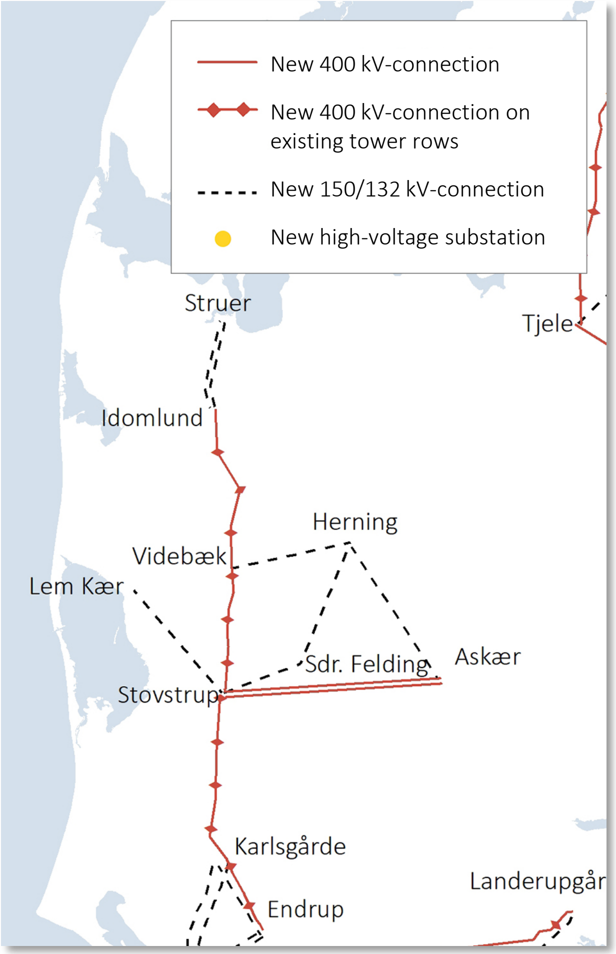


Figure 8: Possible grid solutions in west Jutland towards 2040.

EAST JUTLAND – NEEDS AND POSSIBLE GRID SOLUTIONS

EAST JUTLAND: INCREASED RE PRODUCTION NORTH OF AARHUS AND GREATER ELECTRICITY CONSUMPTION IN THE AARHUS AREA

In east Jutland, the integration of greater volumes of renewable energy from onshore solar and wind power north of Aarhus, and the possibility of significantly increased volumes of renewable energy from offshore wind power – depending on where an energy island in the North Sea is connected to land – will determine the grid needs.

At the same time, greater electrification in the form of electric vehicles, electrification of the heating sector etc. will lead to increased electricity consumption in the Aarhus area, overloading the power grid.

The grid's capacity is exceeded from 2025 onwards in all scenarios (see Figure 9 below). The yellow scenario entails a very large expansion of solar power plants, in particular. Although this scenario is unlikely to be fully realised, it reveals, as in west Jutland (see page 13), that the grid load in the area will be very sensitive to a boom in onshore RE.

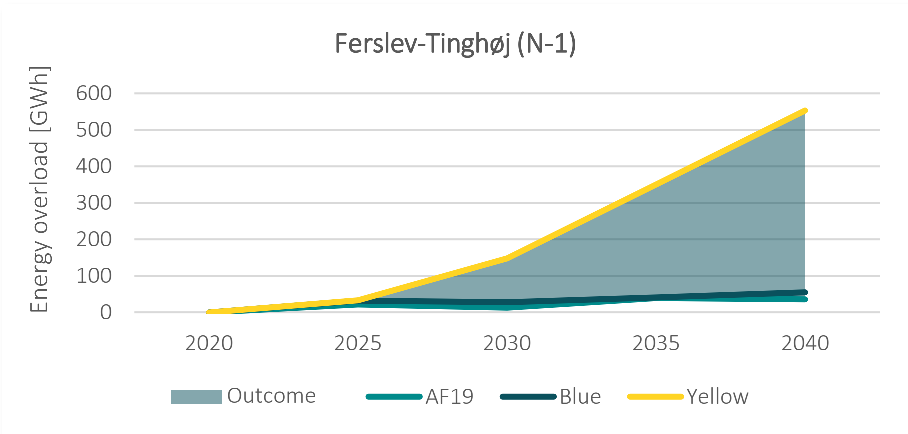


Figure 9: Energy overload in the 150 kV-connection Ferslev-Tinghøj, taking into account N-1. The capacity of the connection is exceeded from 2025 and onwards in all analysed scenarios, as a result of the renewable energy expansion in the area north of Aarhus. The yellow scenario represents an extreme solar scenario and is unlikely to be fully realised. Read more about analysis assumptions, the scenarios and other terms on page 35.

In all analysed scenarios, it is assumed that 500 MW of offshore wind power from a new wind farm will be connected to Ferslev. Since the political climate agreement of June 2020, this offshore wind farm has potentially been superseded by the decision to establish an energy island in the North Sea. Whether there will be load on the area's power grid from the assumed volume of offshore wind power will therefore depend on whether there is a connection to Ferslev from the energy island or other offshore wind.

Electricity consumption in Aarhus will increase. The analysis can be expected to be a cautious estimate in this regard, as the aspirations regarding the scope and speed of electrification have increased in the climate agreement of June 2020.

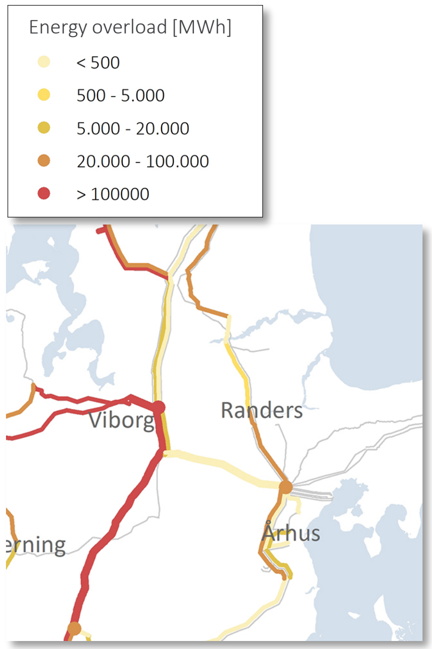


Figure 10: The energy overload in 2040 based on AF19, taking into account N-1. Read more about the different terms on page 35.

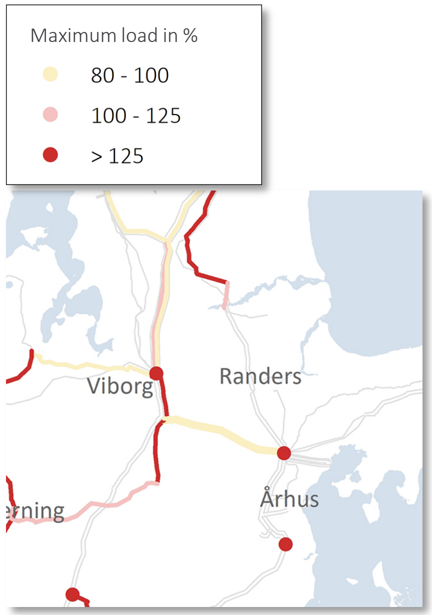


Figure 11: Overloading in 2040 based on AF19 and supplying consumption in the N-2 case. Read more about the different terms on page 35.

EAST JUTLAND: UPGRADES AND POSSIBLE NEW 150 KV- AND 400 KV-CONNECTIONS

As the needs analysis shows (see page 16), the power grid in east Jutland is likely to become overloaded under all analysed scenarios, primarily due to already known and likely future growth in the number of RE production plants north of Aarhus, and the possible connection of offshore wind power from an energy island. A moderate increase in electricity consumption is also seen in Aarhus, as a result of general electrification (electric vehicles, electrification of the heating sector etc.).

This page presents solutions based on physical changes to the grid which could address the challenges if grid solutions are the path taken.

New possible 400 kV-connections

The analyses show heavy overloading on the 150 kV grid between Ferslev and Tjele. This can be addressed by establishing an extra 400 kV-system on the existing towers, if possible, or replacing the towers with a type capable of handling two 400 kV-systems (figure 12). This will involve moving the 150 kV overhead line underground in this segment, which has not been addressed here.

The grid will also be overloaded with high consumption in the Aarhus area in situations where the existing 400 kV connection between Ferslev and Trige trips, as well as with one further outage (power grid capacity is determined based on the N-2 criterion when dealing with security of supply, see page 35). This can be addressed by adding a new 400 kV connection between Tjele and Trige (figure 12).

The need for a 400 kV-connection between Tjele and Trige only arises in the longer term. It will therefore be prudent to wait and see how consumption develops in the Aarhus area.

One of the greatest uncertainties is power-to-X plants. The establishment of power-to-X plants in the Aarhus area could increase the need for grid expansion. However, if power-to-X plants are connected under terms that mean that they can be operated with a lower security of supply than ordinary electricity consumption, such plants might not increase the need for grid expansion, even in an area dominated by consumption.

150 kV-grid reinforcements

Several large potential projects involving onshore renewable energy production are expected to be connected in the years ahead. The RE expansion will primarily raise the need to relieve the 150 kV-overhead line between Hornbæk and Trige. This can be addressed by establishing a 150 kV-cable between Hornbæk and Moselund (figure 12), resulting in two parallel connections between Hornbæk and Trige.

Further expansion in renewable energy production in the area will subsequently result in a need to relieve the section between Ferslev and Katbjerg. This can be done using a 150 kV-cable from Tjele to the area around Katbjerg (figure 12).

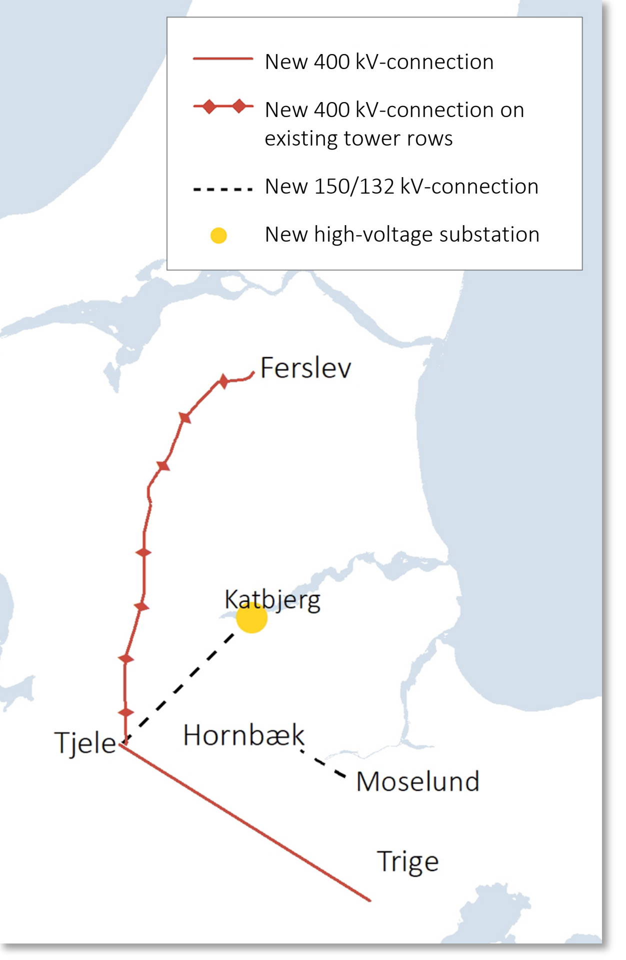


Figure 12: Possible grid solutions in east Jutland towards 2040.

TRIANGLE REGION AND HORSENS –
NEEDS AND POSSIBLE GRID SOLUTIONS

TRIANGLE REGION AND HORSENS: INCREASED CONSUMPTION FROM ELECTRIFICATION AND DATA CENTRES CAUSES A NEED FOR NEW INITIATIVES

The Horsens area and the Triangle Region is an electricity consumption centre, and consumption is expected to increase in the future. The rise in consumption will be due to a general increase in electrification and the connection of large consumers (data centres) to the transmission grid. A partnership is also working on establishing electrolysis in Fredericia, which could significantly increase electricity consumption in the area as well.

Electricity consumption in the area is thus growing, without a corresponding increase in electricity generation from renewable energy in the area. This gives rise to a need to transmit greater volumes of electricity to the area – a need that the current power grid is not fully geared to handle.

Overloading in the local power grid is forecasted in all scenarios from 2025 onwards, and the strain is greater in the blue and yellow scenarios than in AF19. In both scenarios, the greater load is due to the assumption of greater electrolysis and power-to-X expansion – 100 MW and 1,200 MW, respectively – in the blue and yellow scenarios in 2040.

A key point regarding electrolysis and power-to-X expansion in the area is that the location of electrolysis plants will have a major impact on grid load. Another crucial factor is whether the plants can be connected with a lower security of supply, since electrolysis plants can operate with interruptible consumption. If this is the case, the grid load will be less than the blue and yellow scenarios show.

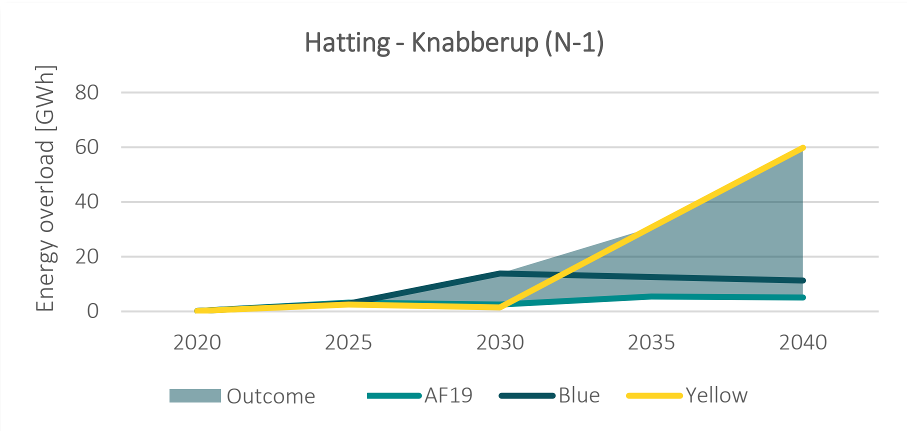


Figure 13: Energy overload in the 150 kV-connection Hatting-Knabberup, taking into account N-1. For all three scenarios analysed, the connection will be overloaded from 2025 onwards, but with a greater increase in the blue and yellow scenarios than in AF19. Some of the difference is due to the general increase in electrification in the scenarios, and some is due to power-to-X expansion. The final interpretation of the needs will depend on whether power-to-X plants are connected under special conditions. Read more about analysis assumptions, the scenarios and other terms on page 35.

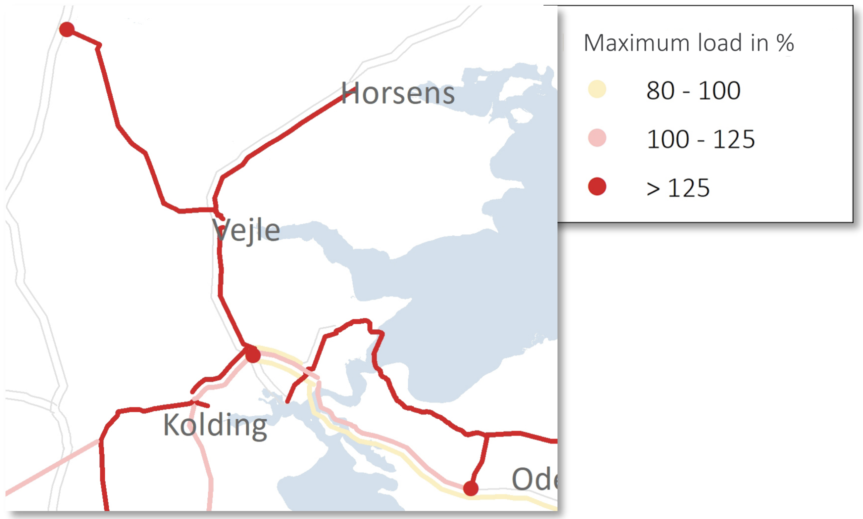


Figure 14: Overloading in 2040 based on AF19 and supplying consumption in the N-2 case. Read more about the different terms on page 35.

TRIANGLE REGION AND HORSENS: POSSIBLE NEW 400 KV-CONNECTION AND 150 KV-CONNECTION

As the needs analysis shows (see page 19), the power grid in the Triangle Region and Horsens area will be overloaded in all analysed scenarios as a result of increasing electricity consumption, particularly from electrification and data centres.

This page presents solutions based on physical changes to the grid which could address the challenges if grid solutions are the path taken.

Possible new 400 kV-connection partially using existing towers

The transmission grid in and around the Triangle Region is impacted by increasing consumption in east Jutland and on Funen, and by transit with neighbouring countries. There will therefore continue to be a need to develop the grid in the area, depending on future changes in consumption and changes in electricity exchange with other countries.

A new 400 kV-connection in the area (figure 15) would be able to transmit more electricity to the Triangle Region, while also increasing the total capacity in the 400 kV-grid in south Jutland. In particular, if large volumes of electricity generated from renewable energy sources on an energy island in the North Sea are connected onshore in Revsing, Tjele or Ferslev, this 400 kV-connection or something similar may be necessary to relieve existing export routes to Germany etc.

The connection can be established by operating the existing 150 kV-connection between Bramdrup and Landerupgård at 400 kV, and extending it to the Revsing substation. A new 150 kV-cable between Bramdrup and Landerupgård can be established to replace the existing 150 kV connection.

New 150 kV-connection

To meet the increasing electricity consumption in the area, the 150 kV-grid can be reinforced with a new cable connection between Hatting and Ryttergården (figure 15). To secure the supply in the event that the high-voltage substation at Hatting trips, the connection can be prepared for connection to a new high-voltage substation at Hedensted with a 150/60 kV transformer (figure 15).

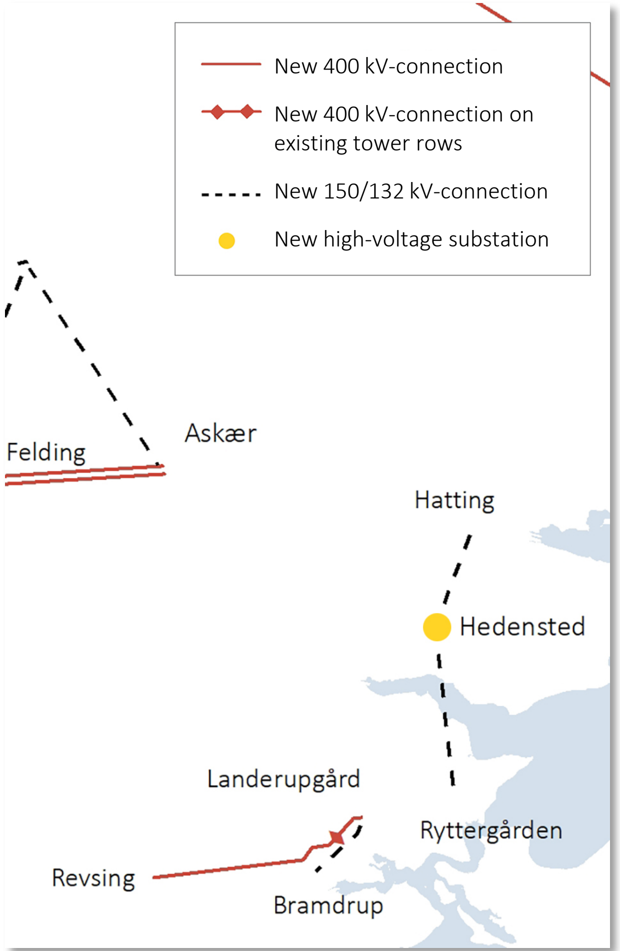


Figure 15: Possible grid solutions in the Triangle Region and Horsens towards 2040.

SOUTH JUTLAND – NEEDS AND POSSIBLE GRID SOLUTIONS

SOUTH JUTLAND TRANSIT OF RENEWABLE ENERGY FROM THE NORTH SEA

The future energy needs in south Jutland are characterised by a moderate increase in the local production of renewable energy, and increased consumption from data centres. However, it is primarily the realisation of an energy island in the North Sea and subsequent expansion of offshore wind power that will have the greatest impact on the needs of the power grid in the area.

The existing 400 kV-substations in the area are obvious connection points for an energy island in the North Sea. The blue and yellow scenarios therefore assume that a total of 1 GW of offshore wind power is connected to the Revsing high-voltage substation – significantly more than in AF19 (see figure 16).

The analysis of grid overloading based on the assumptions in AF19 primarily shows an increased flow in the 400 kV-overhead lines in the area (figure 17), while the power grid at lower voltage levels in the area is less affected. This is due to a general expansion in production plants for renewable energy in the area, but especially the transit of renewable energy from the North Sea.

The power grid in the area is very well-developed, and large parts of the assumed 150 kV-grid are only planned and not built yet. It will therefore be modern and robust.

Combined with the possible reinforcement of the 400 kV-grid between Landerupgård and Revsing in the Triangle Region, this means that the area is essentially deemed to be ready for both moderately increased electricity consumption and, in particular, increased transmission of renewable energy from the North Sea.

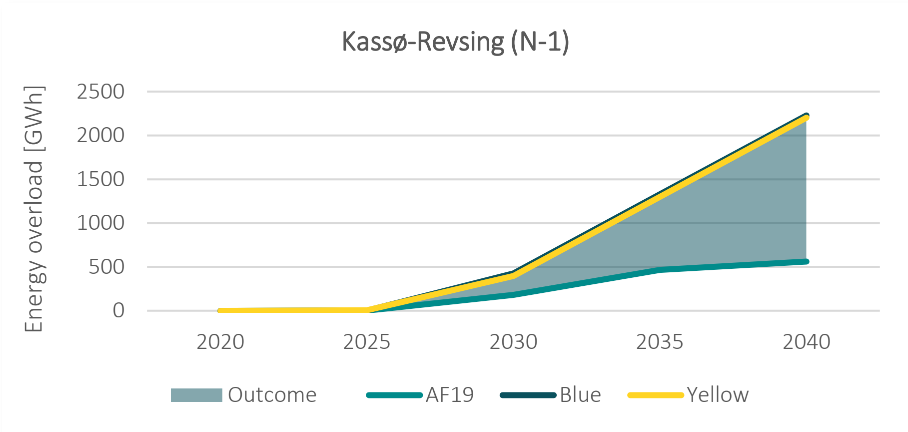


Figure 16: Energy overload in the 400 kV-system Kassø-Revsing , taking into account N-1. The connection will be overloaded after 2025 in all analysed scenarios. This is due to the expansion of renewable energy in both west and central Jutland, increasing the use of the connection as an export corridor to Germany. Connecting offshore wind power along the Jutland Ridge (yellow and blue scenarios) will further increase the use of the connection. Read more about analysis assumptions, the scenarios and other terms on page 35.

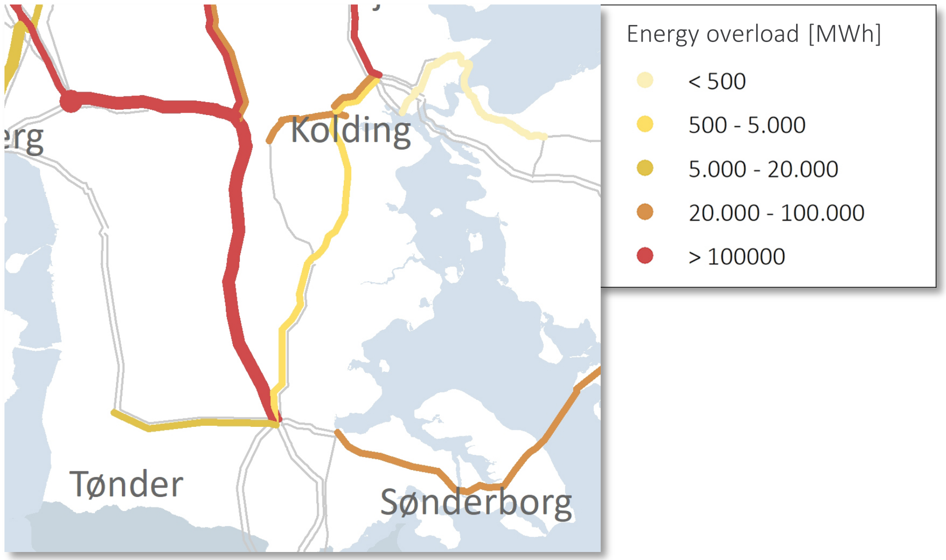


Figure 17: The energy overload in 2040 based on AF19, taking into account N-1. Read more about the different terms on page 35.

FUNEN –
NEEDS AND POSSIBLE GRID SOLUTIONS

FUNEN: INCREASED ELECTRICITY CONSUMPTION POSES ONLY FEW CHALLENGES IN THE POWER GRID

Funen is an area in which increased electricity consumption is expected, as in the rest of Denmark, as a result of electric vehicles, consumer heat pumps etc. Increased electricity consumption is also expected at the many horticultural nurseries in the area, at the new super hospital and new university hospital (OUH) and from the expansion of the University of Southern Denmark. The analyses based on AF19 also predict a significant increase in the local production of renewable energy from solar power plants.

The regional 150 kV-power grid in the area is well developed and, with a few reinforcements, will be able to handle the increased consumption.

Only few possible grid reinforcements needed

In addition to a new 150 kV-cable connection across a short section at Fraugde, east of Odense, greater transformer capacity will be needed. The transformer in Kingstrup in west Funen can be upgraded, and the transformer capacity near Odense needs to be increased. The latter can be achieved by installing a new transformer in a new high-voltage substation west of Odense. The substation will initially be established as 150 kV, due to general consumption increases in the local distribution grid. The substation can later be expanded to 400 kV with a 400/150 kV-transformer, to increase the 400 to 150 kV transformer capacity around Odense in general as a result of increases in consumption.

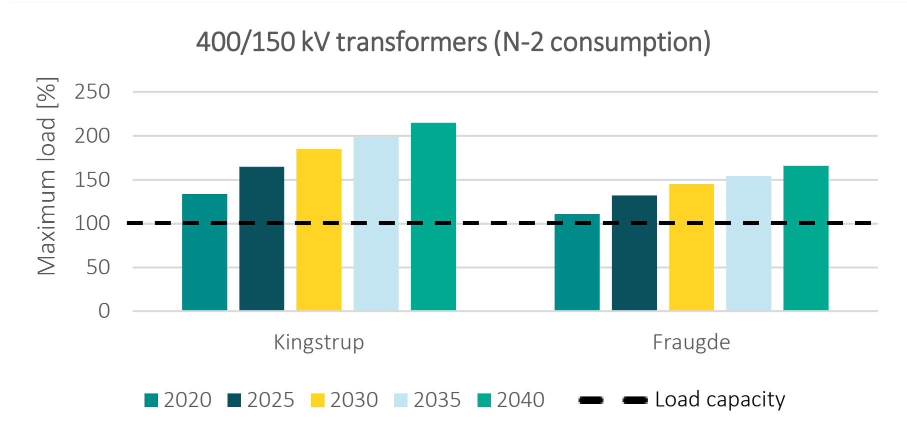


Figure 18: Maximum load for 400/150 kV-transformers on Funen when supplying consumption in line with AF19 in an N-2 situation (see page 35). The load is compared to the capacity of the transformers. The load will increase as a result of increased electrification. Given that the climate agreement's aims for faster electrification are not fully reflected in AF19, the estimated load is deemed to be on the conservative side. Read more about analysis assumptions, the scenarios and other terms on page 35.

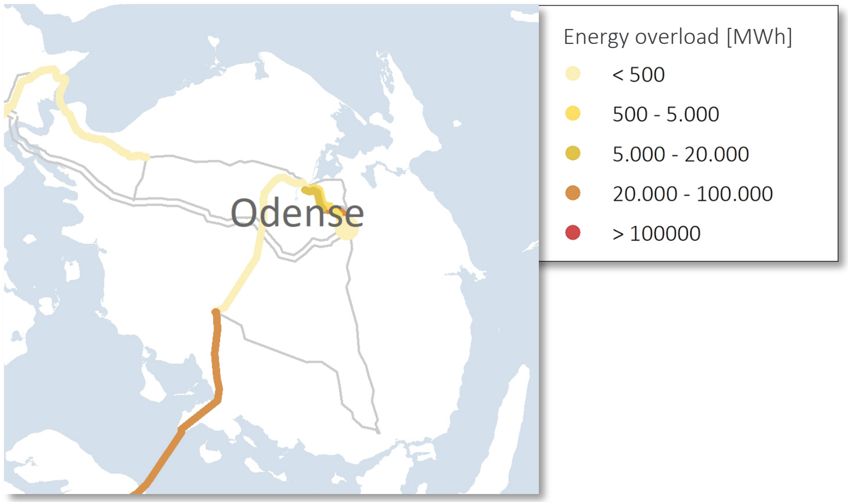


Figure 19: The energy overload in 2040 based on AF19, taking into account N-1. Read more about the different terms on page 35.

CENTRAL AND WEST ZEALAND – NEEDS AND POSSIBLE GRID SOLUTIONS

CENTRAL AND WEST ZEALAND: TRANSIT OF RENEWABLE ENERGY FROM SOUTH ZEALAND AND LOLLAND-FALSTER

Central and west Zealand is an area where the need for new initiatives will be fairly sensitive to which path is taken. This is because the so-called Køge-Roskilde cross section is located between an area with surplus of production (south Zealand and Lolland-Falster) and an area with a production deficit as well as export opportunities (Copenhagen and north Zealand).

In general, this cross section will experience more load if renewable energy production grows more than assumed to the south, or if consumption increases more than assumed to the north. Conversely, the cross section will experience less load if renewable energy production grows more than assumed to the north, or if consumption increases more than assumed to the south.

The exact need for new initiatives in this area is therefore also highly dependent on whether an energy island near Bornholm is connected to high-voltage substations that are located north or south of the Køge-Roskilde cross section.

The need for initiatives in the area will also be fairly sensitive to how much growth is seen in onshore RE, and where this is established. Finally, the development of power-to-X will also have an impact.

In any case, the safest assumption to base planning on in the area is that there will be surplus electricity generation from renewable energy, which will have to be transmitted north towards Copenhagen from south Zealand and Lolland-Falster.

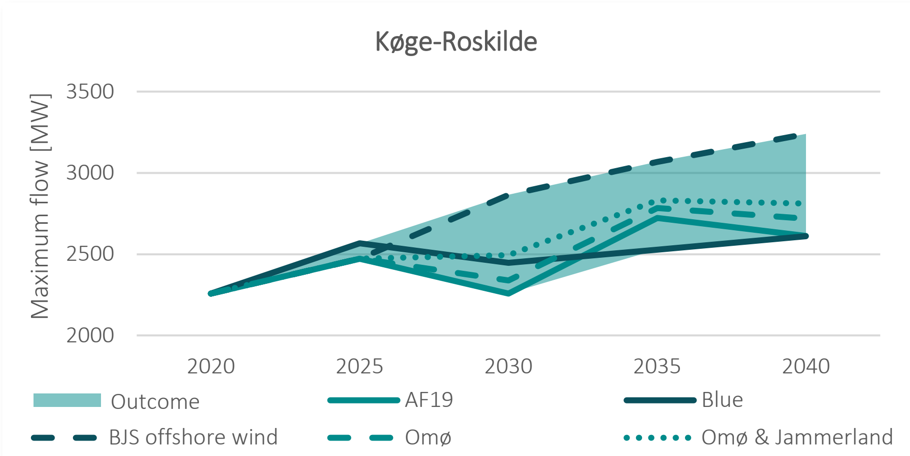


Figure 20: Maximum flow of electricity across the Køge-Roskilde cross section, shown in figure 21. The flow through the cross section will increase as a result of an increased production surplus to the south, which has to be transmitted towards the demand centre around Copenhagen and export options to the north. Full capacity at the Omø Syd and Jammerland Bugt near-shore wind farms will increase the flow relative to AF19. The same applies if more offshore wind is connected south of the segment (BJS offshore wind). Read more about analysis assumptions, the scenarios and other terms on page 35.

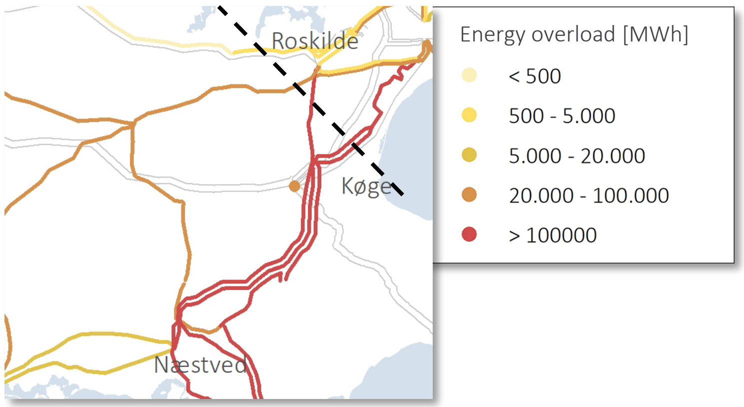


Figure 21: The energy overload in 2040 based on AF19, taking into account N-1. Read more about the different terms on page 35.

CENTRAL AND WEST ZEALAND: POSSIBLE NEW 400 KV- OR 132 KV-CONNECTION AND MODERNISATION OF THE EXISTING 132-KV GRID

As the needs analysis shows (see page 26), all scenarios forecast that the power grid in central and west Zealand will be overloaded, primarily because the area will serve as an energy transit area in which surplus RE production from the south is transmitted to the consumption centre in and around Copenhagen, and to export connections.

This page presents solutions based on physical changes to the grid which could address the challenges if grid solutions are the path taken.

Possible new 400 kV- or 132 kV-connection

As mentioned in the needs analysis, the development needs of the power grid in the area are relatively sensitive to a number of assumptions, including where an energy island in the Baltic Sea will be connected.

Even though the safest assumption is that more RE will have to be transmitted from production areas in south Zealand and Lolland-Falster towards the Copenhagen area, the data does not unequivocally support a new 400 kV-connection. Either a new 400 kV-connection or a new 132 kV-connection between Hovegård and Bjæverskov/Spanager could come into play (figure 22).

One alternative is to establish a 132 kV-connection from Hovegård to Spanager, the other is to establish a 400 kV-connection between Hovegård and a new Bjæverskov Vest substation. The final solution must be decided in connection with the planning, and will depend in part on how robust a solution is desired in relation to uncertainties in the future trend.

Modernisation of existing 132 kV-grid

The 132 kV-overhead line between Kamstrup and Spanager is often already the limiting factor for transmission capacity across the Køge-Roskilde cross section.

Replacing the existing 132 kV-overhead line with a 132 kV-cable (figure 22) would in itself increase the transmission capacity, primarily by replacing ageing plants with newer and more efficient technology.

A similar approach can be followed for a number of the 132 kV-overhead lines in the area, which are so ageing that they must soon be replaced and modernised. This would result in at least the same overall transmission capacity as now, but with fewer cable connections than there are existing overhead lines.

It will also be necessary to expand the transformer capacity in the area – by installing new transformers at existing high-voltage substations, and on the longer term, potentially by establishing a new high-voltage substation in Dianalund.

Figure 22: Possible grid solutions in central and west Zealand towards 2040.

SOUTH ZEALAND AND LOLLAND-FALSTER – NEEDS AND POSSIBLE GRID SOLUTIONS

SOUTH ZEALAND AND LOLLAND-FALSTER: SIGNIFICANT GROWTH IN SOLAR POWER PLANTS WILL ENTAIL A NEED FOR NEW INITIATIVES

Development in the south Zealand and Lolland-Falster area will be characterised by strong growth in onshore renewable energy, especially from large solar power plants. But the potential Omø Syd near-shore wind farm, which is being developed and is expected to be connected to the high-voltage substation at the Stigsnæs Power Station on south-west Zealand, is also expected to have an impact.

The production of renewable energy in the area will thus increase markedly, while energy consumption will not increase correspondingly. The need to transmit renewable energy away from the area will thus increase, and the current power grid does not have the capacity to meet the future need.

Figure 23 below shows, with the yellow scenario, that the biggest factor of uncertainty in the area is how much growth there will be in the establishment of new solar power plants. AF19 already includes growth in solar power plants, and it is presumably unlikely that the growth will be as much larger as the yellow scenario projects. However, it helps to clarify at which areas the trend will have the greatest impact on the need for new initiatives.

The establishment of power-to-X in the area (blue scenario), and thus increased local energy consumption which does not have to be transmitted further as electricity, will reduce the load on the power grid. Conversely, the load will increase if it is assumed that the Omø Syd offshore wind farm produces at full capacity (the dotted line in figure 23).

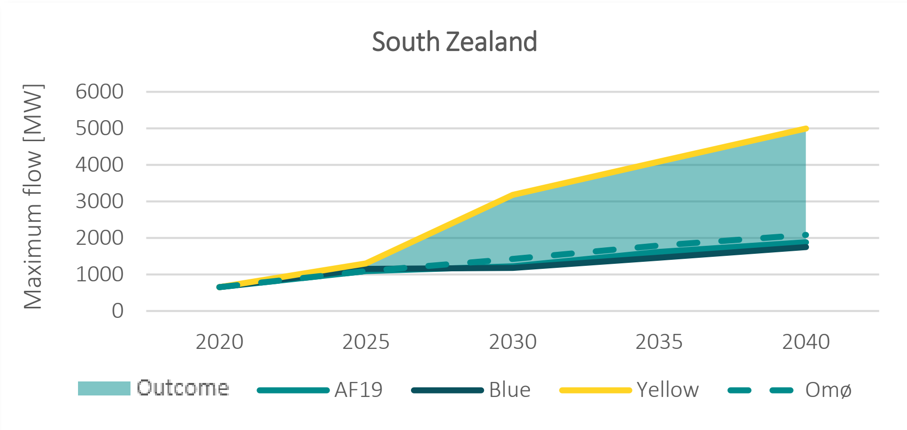


Figure 23. Maximum flow of electricity across the cross section from south Zealand to the north. The flow roughly doubles between 2020 and 2040, from just under 1 GW to almost 2 GW under AF19, but slightly less with power-to-X (blue scenario). In the yellow scenario, with strong growth in solar power plants, in particular, the load will be many times greater. The yellow scenario is considered to be a relatively extreme solar cell scenario. Read more about analysis assumptions and the scenarios on page 35.

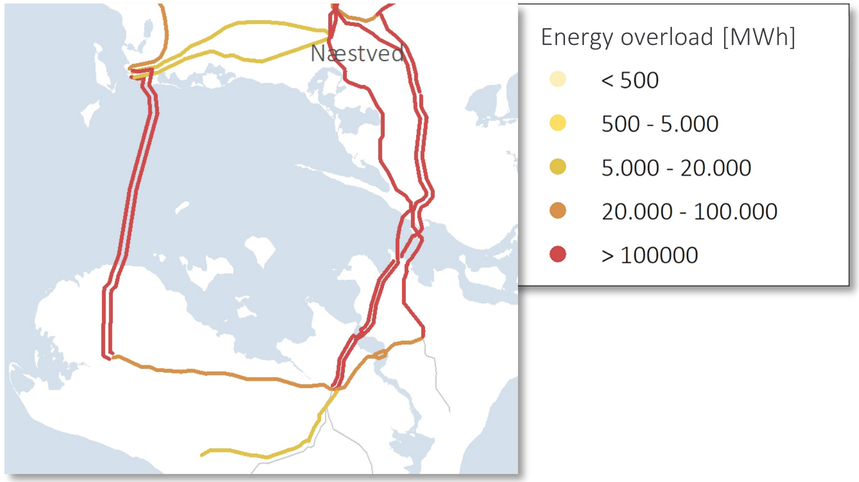


Figure 24: The energy overload in 2040 based on AF19, taking into account N-1. Read more about the different terms on page 35.

SOUTH ZEALAND AND LOLLAND-FALSTER: ELEVEN NEW 132 KV-CABLE CONNECTIONS AND NEW HIGH-VOLTAGE SUBSTATIONS AND TRANSFORMERS

The needs analysis (page 29) shows that a significant increase in the production of renewable energy, especially from large solar power plants, will lead to a need to transmit renewable energy to consumption areas on Zealand and for export, at volumes that the current power grid cannot handle.

This page presents solutions based on physical changes to the grid which could address the challenges if grid solutions are the path taken.

Gradual expansion best given major uncertainties

It is to a large extent the market-driven trend, with the establishment of an increasing number of solar power plants, that defines the need for grid reinforcements in Lolland-Falster and south Zealand.

As the needs analysis reflects, there is a high degree of unpredictability linked to the proliferation of RE production plants in the current growing market. Energinet, municipalities and grid companies can see that there is a significantly larger portfolio of potential projects than is assumed in the AF19 analyses. How many end up being realised is inherently uncertain.

The relatively high degree of unpredictability means that gradual expansion using 132 kV-connections is most prudent. The map to the right (figure 25) shows all the reinforcements capable of addressing the long-term transmission requirements.

Eleven new 132 kV-cable connections

In various phases, a total of eleven new 132 kV-connections of various lengths in the area would be able to meet the need (the dotted lines on the map in figure 25). The eleven new cable connections can be jointly described as an collection network for the distributed production of renewable energy. Part of this will be fed into the distribution network at lower voltage levels, then into the regional transmission grid at the 132 kV-level, which transmits the electricity over large distances. In this case, towards the consumption centres on Zealand and for export.

New transformers and high-voltage substations

When power from the area has to be changed to transmission at higher voltage levels, it will be necessary to establish new transformers at existing high-voltage substations, as well as establishing new substations.

In some places, transformers and substations must be used to step up 50 kV to 132 kV, while in other places they must be used to step up the power from 132 kV to 400 kV.

The map (figure 25) on the right only shows the places where new high-voltage substations may be needed in order to meet the needs in 2040.

Possible new 400 kV-connection

The dramatic increase in the volume of RE production in the area may also lead to the need for a new 400 kV connection in the central Zealand area. This is described together with other initiatives in this area on page 27.

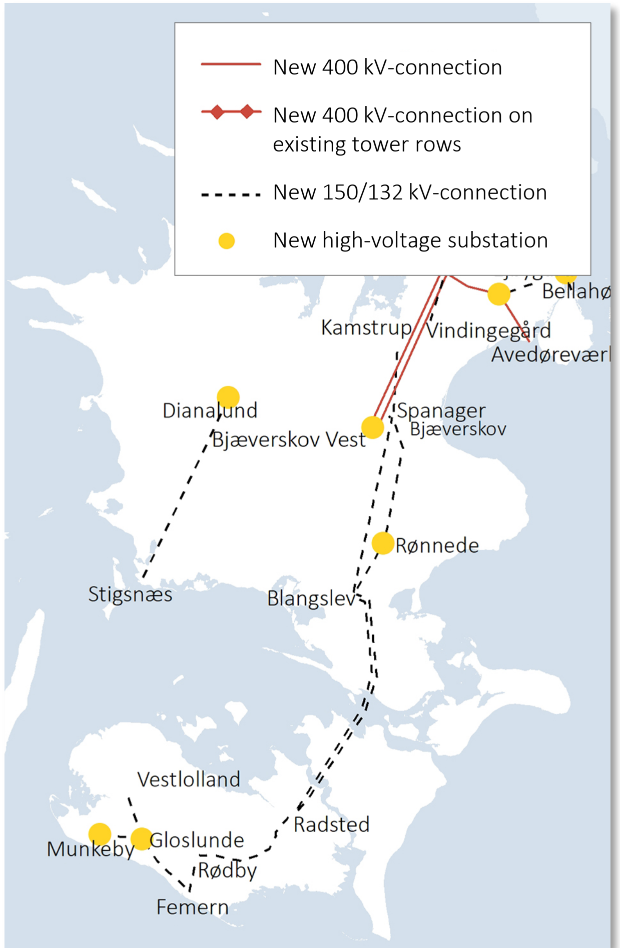


Figure 25: Possible grid solutions on south Zealand and Lolland-Falster towards 2040.

COPENHAGEN – NEEDS AND POSSIBLE GRID SOLUTIONS

COPENHAGEN: INCREASED ELECTRICITY CONSUMPTION DUE TO URBAN DEVELOPMENT AND ELECTRIFICATION ENTAILS THE NEED FOR NEW INITIATIVES

In the Central Copenhagen area, the power grid will need significant and almost identical development, irrespective of which of the analysed paths towards a more climate-neutral society is realised.

This is because it is predominantly an increase in electricity consumption resulting from urban development and electrification (electric vehicles etc.) that will make it necessary to increase the capacity of the power grid. Electricity generation capacity from power stations in this area will be reduced at the same time. The various scenarios provide a relatively consistent picture of the flow of production from renewable energy, primarily from areas outside Copenhagen, which must meet the increasing electricity consumption in Copenhagen.

The estimated overloading of existing grid capacity has been calculated based on AF19. Given that the climate agreement's goals for faster electrification are not included in this scenario, the estimated load shown will be conservative. It will probably be larger than shown in the figures on this page.

There are also a number of plants in the pipeline which will have an impact on the exact future needs of the power grid in the Greater Copenhagen area. This particularly applies to two potential near-shore wind farms, connection of the an energy island near Bornholm and plans by a number of Danish companies to establish large-scale electrolysis in Copenhagen.

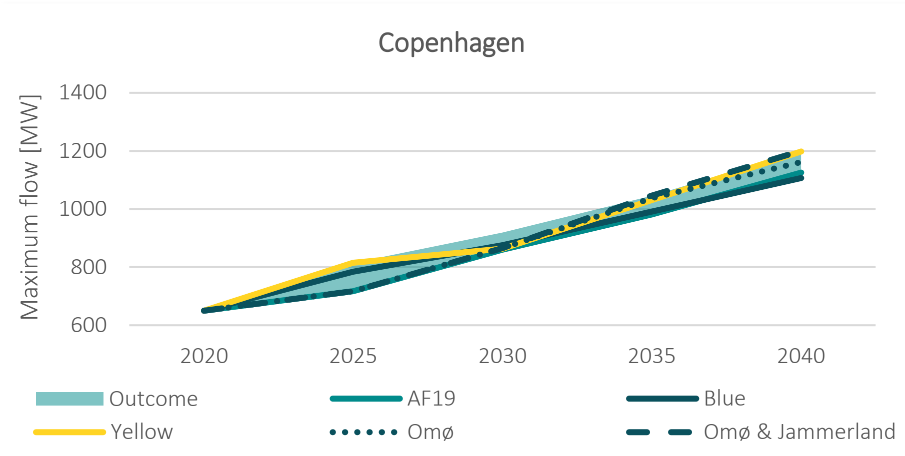


Figure 26: Maximum flow of electricity towards central Copenhagen, through the cross segtion (shown with a dotted line in Figure 27). The analysed scenarios result in very similar trends in the flow. If power-to-X is connected in central Copenhagen, it could result in a greater flow through the cross section. Read more about analysis assumptions and the scenarios on page 35.

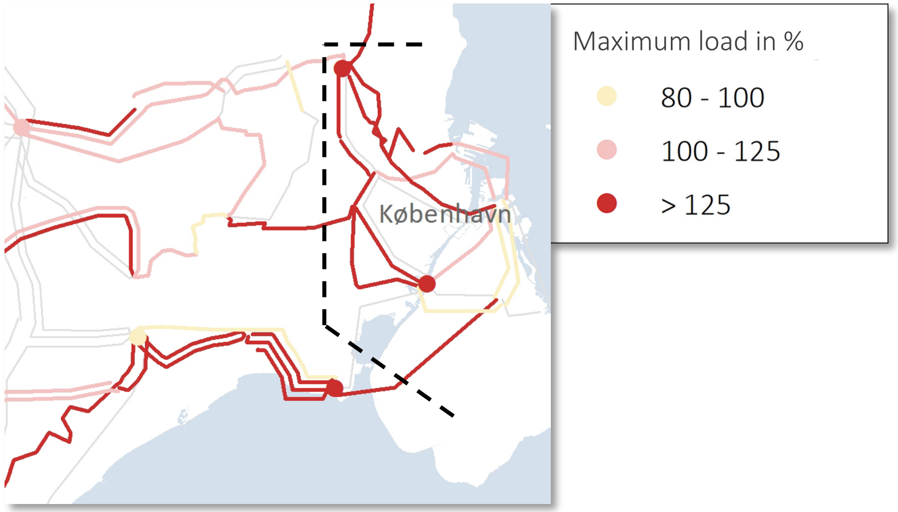


Figure 27: Overloading in 2040 based on AF19 and supplying consumption in the N-2 case. Read more about the different terms on page 35.

COPENHAGEN: POSSIBLE NEW 400 KV-CONNECTION, REINFORCEMENT OF THE 132 KV-GRID AND GREATER TRANSFORMER CAPACITY

As the needs analysis shows (see page 32), all scenarios forecast that the power grid in Copenhagen will be overloaded when electricity consumption increases in the coming years as a result of urban development and electrification.

This page presents solutions based on physical changes to the grid which could address the challenges if grid solutions are the path taken.

Possible new 400 kV-connection

In situations where connections trips it is expected that the current supply grid to Copenhagen will be insufficient. A new 400 kV-connection between Hovegård and Ejbygård (figure 28) towards Copenhagen would address this challenge.

Connection of RE production at Avedøreværket

In the long term, Avedøreværket could be used as a connection point for large volumes of RE production, including from an energy island near Bornholm.

The grid around Avedøreværket does not have sufficient capacity to receive large volumes of RE production, but this can be addressed by extending the above 400 kV-connection from Ejbygård to Avedøreværket (figure 28).

If the increased RE production is not connected around Avedøreværket, or is combined with electrolysis and power-to-X, it may not be necessary to construct this extension to the 400 kV-connection between Ejbygård and Avedøreværket. However, this will depend on whether the specific connection conditions for electrolysis encourage flexibility in the production of hydrogen.

Reinforcement and modernisation of the 132 kV-grid

In addition to an upgrade to the 132 kV-cable between Ejbygård and Lindevang that is currently underway, strain on the 132 kV-grid resulting from increased electricity consumption could initially be addressed by increasing the transmission capacity of the existing cable connection between the Bellahøj and Lindevang. This will meet the need during the first years, while a new 132 kV-cable connection between the Bellahøj and Ejbygård will be needed later (figure 28).

Extensive parts of the cables in the Copenhagen grid will need reinvestment in the coming years. By using new cables with a higher transmission capacity and optimising the cable structure, it is possible to reduce the total number of cables in the area. As part of this, a new connection can be established between Amagerværket and Glentegård, with a new substation, Nordhavn, along the way. This new substation will be able to support increasing consumption in the area as a result of urban development.

New 400 kV-substation and transformers

The possible new 400 kV-connection (figure 28) will require the establishment of a 400 kV-high-voltage substation in Ejbygård. Two transformers at the substation, together with an upgrade to the existing transformer in Hovegård, will provide sufficient transformer capacity while also helping to relieve the 132 kV-grid in Copenhagen.

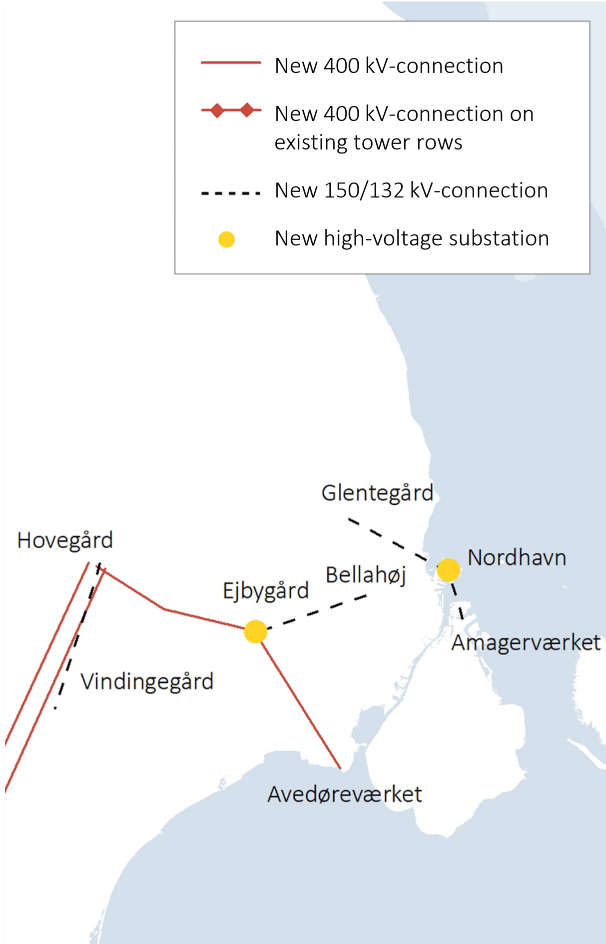


Figure 28: Possible grid solutions in the Copenhagen area up until 2040.

APPENDICES

GLOSSARY

Power grid
In this report, the power grid refers to the part of the power grid which is above 100 kV – the 'motorways' in the Danish power grid. It therefore does not include the part of the power grid under 100 kV, which, among other things, is responsible for transmitting electricity to and from ordinary electricity consumers.

N-1
Denotes the transmission capacity of the grid, while allowing for one connection or operation-critical component to drop out of operation due to breakdown, without overloading the grid. The grid capacity must be sufficient to secure the electricity supply in the N-1 case, when it is electricity generation that is at risk of being disconnected.

N-2
Denotes the transmission capacity of the grid in situations where two connections or operation-critical components are out of operation due to breakdowns. The grid capacity must be sufficient to secure the electricity supply in the N-2 case, when it is electricity consumption that is at risk of being disconnected.

Grid reference
New requirements for development of the power grid are shown in this report in relation to the 'grid reference'. The grid reference is the existing power grid, plus approved maintenance or expansion projects – see page 36.

AF19
The Danish Energy Agency's analysis assumptions for Energinet, 2019. Energinet has to plan the power and gas grids in line with the Danish Energy Agency's annual projections for the production and consumption of electricity, gas, district heating etc. The analysis assumptions are based on policy decisions and projections of the market and technological developments. AF19 was published before the Climate Act and the 70% target. The assessment of future RE development in AF19 is therefore at a lower level than current assessments.

AF20
The Danish Energy Agency's analysis assumptions for Energinet, 2020. Unlike AF19, AF20 has been updated with the latest policy decisions, such as those concerning energy islands and power-to-X, and the growth in potential onshore solar power plants is more up-to-date. AF20 was published in late August 2020, while the detailed market simulations and calculations of power grid load in this report were prepared during 2020, based on AF19, supplemented with scenarios that include the 70% target and new technology.

The blue scenario
In the blue scenario, power-to-X covers Danish consumption of RE fuels. There is also a general increase in electrification, which is supplied by a considerable expansion in offshore wind power. The blue scenario is one of two scenarios Energinet developed during 2019 and 2020, after consulting with stakeholders, with the aim of supplementing AF19 and projecting a probable outcome for the trajectory of the green transition.

The yellow scenario
In the yellow scenario, power-to-X covers Danish consumption of RE fuels. There is also a general increase in electrification, which is particularly supplied by a significant expansion in solar power. The yellow scenario is one of two scenarios Energinet developed during 2019 and 2020, after consulting with stakeholders, with the aim of supplementing AF19 and projecting a probable outcome for the trajectory of the green transition.

Power-to-X
Denotes the process in which power is used to extract hydrogen from water via electrolysis. Hydrogen can be used as an independent green energy source, or as a component in green fuels or other green products (hence the 'X').

Energy island
The 'energy island' concept refers to a physical island or platform that serves as a hub for electricity generation from nearby offshore wind farms, which are connected and distributed between countries. Other technical equipment such as storage facilities, electrolysis plants etc. can also be connected.

Energy overload
Denotes the volume of energy that must be relieved on a connection if no other measures are taken. It is measured by simulating the electricity spot market over a year. The size of the energy overload gives an indication of how critical a given grid development need is. The energy volume will be larger if the overload occurs frequently, or if the component transfers a lot of energy.

Maximum flow
Denotes the amount of energy moved across a given geographical segment, through a number of connections, during the hour of the year in which the most energy flows. Maximum flow is calculated in this report using simulations of the electricity spot market.

Maximum load
Denotes the maximum of the ratio between the energy flowing through a connection or transformer and the energy that can run through the component without it being overloaded. If the maximum load is above 100%, remedial measures will be required. In this report, maximum load is calculated by simulating situations with high consumption and low production.

On page 38, you can click to access the background reports if you are interested in more explanation and details than are provided here.

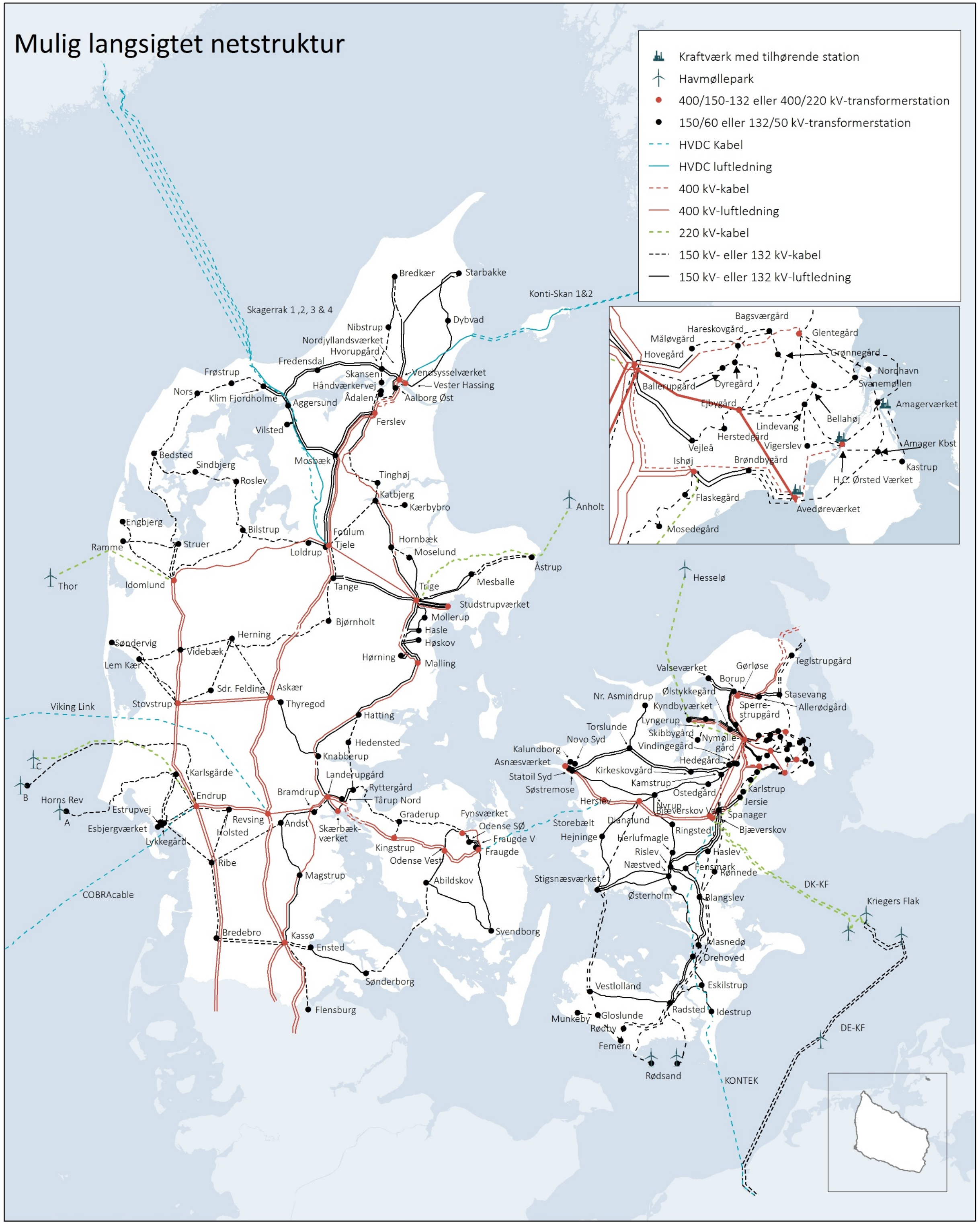
GRID REFERENCE

New requirements for development of the power grid are shown in this report in relation to the 'grid reference'. The grid reference is the existing power grid, plus approved maintenance or expansion projects. The grid reference is expected to be established before 2025. Major new projects included in the grid reference in addition to the existing grid include the following project, where the year refers to the first whole year the expansion is expected to be in operation:

- The east coast connection between Jutland and Germany – increases transmission capacity between Germany and west Denmark by 800-1,000 MW (2021)
- The Kriegers Flak connection between Zealand and Germany – 400 MW transmission capacity (2021)
- The Viking Link connection between Jutland and the UK – 1,400 MW transmission capacity (2023)
- The 400 kV Endrup-border connection – increases transmission capacity between Germany and west Denmark by 1,000 MW (2023-24)
- The 400 kV Idomlund-Endrup connection (2023-2024)
- Connection of 600 MW of offshore wind turbines at Kriegers Flak (2022)
- Connection of the Vesterhav Nord and Vesterhav Syd near-shore wind farms – a total of 350 MW (2024)
- A new 150 kV cable structure that replaces overhead lines between Kassø and Lykkegård (2023-25)

LONG-TERM GRID STRUCTURE

The long-term grid structure on the map to the right is the grid structure that will result if the potential grid changes presented on page 9 are realised.



LINKS TO BACKGROUND REPORTS

- Needs analysis for the electricity transmission grid 2020 (in Danish): www.energinet.dk/behovsanalyse2020
- Long-term electricity transmission grid structure in 2020 (in Danish): www.energinet.dk/netstruktur2020
- Analysis assumptions: https://ens.dk/service/fremskrivninger-analyser-modeller/analyseforudsaetninger-til-energinet
- Long-term perspectives – data memo (in Danish): www.energinet.dk/scenarier2020

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