ENERGINET

LONG-TERM DEVELOPMENT NEEDS IN THE POWER GRID

Energinet's long-term development plan 2022 – Needs analysis

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LONG-TERM DEVELOPMENT NEEDS IN THE POWER GRID

This report presents a likely scenario for the initiatives that will be needed in the power grid up to the year 2040.

The aim is to obtain a clear picture of the planning activities, as a starting point for dialogue about the solutions that will be studied and ultimately selected, paving the way for an effective green transition.

NEEDS ANALYSIS: GREEN TRANSITIONS REQUIRE NEW INITIATIVES AND DIALOGUES

This report presents a likely outcome for the **initiatives that will be needed in the Danish power grid up to the year 2040** in order to maintain a high security of supply throughout the green transition. Along with the report on possible solutions, the needs analysis must contribute to making the green transition as cost-effective as possible.

Big changes are taking place in our energy landscape, which will look very different in the coming decades – driven by the green transition and the Danish climate target to reduce CO_2 emissions by 70 per cent by 2030 and to achieve climate neutrality by 2050.

Much more energy will have to be transported in the electricity system because of a big increase in renewable energy production far away from the consumers, who in turn will be using more energy for heat pumps, electric vehicles, etc.

The needs analysis aims to form a basis for dialogue and effective solutions

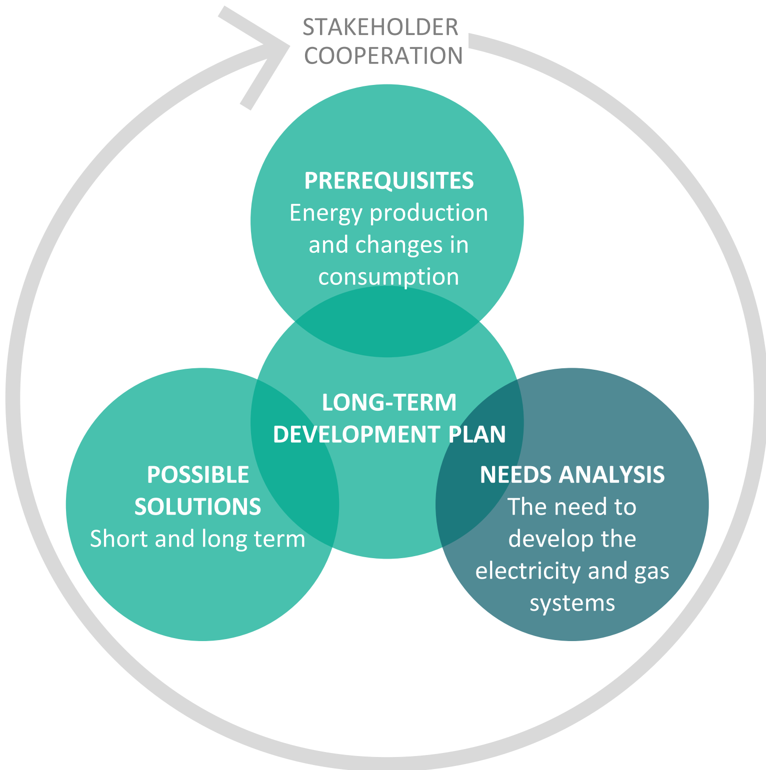
Close dialogue across society and with stakeholders is vital if we are to succeed in combining security of supply with an effective green transition of our energy system. This needs analysis therefore seeks to establish an qualified basis for the dialogue that will help us, to find effective and future-proof solutions.

How did we do our calculations?

Our models for calculation and analysis are based on the Danish Energy Agency's Analysis Assumptions for Energinet from 2020 (AF20). The Analysis Assumptions provide a likely scenario for developments in the consumption and production of gas and electricity, which are aligned with the political objectives.

Where can you find out more?

- See the background material for the needs analysis: www.energinet.dk/el-baggrund2021 (in Danish)
- The needs analysis forms the basis for possible future solutions which are set out here: www.en.energinet.dk/power-solutions2021



An important part of the bigger picture: Energinet's long-term development plan

Based on the assumptions used, the needs analysis forms a basis for investment decisions and thus for the solutions which are intended to guarantee a high degree of security of supply now and in the future. There are many unknowns and therefore the process is iterative, meaning that we revise and update our plans if the assumptions change and new needs arise.

THE NEEDS OF SOCIETY AT THE HEART OF THE GREEN TRANSITION

In Energinet, we are working to transform the electricity and gas systems so they supply green energy, while maintaining a high degree of security of supply and ensuring that this is all affordable for consumers and society. This is called the energy trilemma and is what concerns us overall.

The needs analysis will help us keep up with developments and continue to put the needs of society front and centre as we plan and make investment decisions. Our work is affected by three things in particular: rapid pace, green energy and existing systems.

Rapid pace

With ambitious political climate goals and a development which is increasingly driven by market forces, it is clear that the green transition is set to speed up in the coming years.

The market-based development is characterised by greater unpredictability. Where will technologies such as biogas and solar power do particularly well, and where will the systems need to be developed? This unpredictability influences Energinet's planning.

Effective solutions require timely planning because the processes involved are complex – and it will be necessary to take calculated risks so that Energinet is not left behind in terms of development needs. We are dependant on dialogue with the outside world in order to succeed.

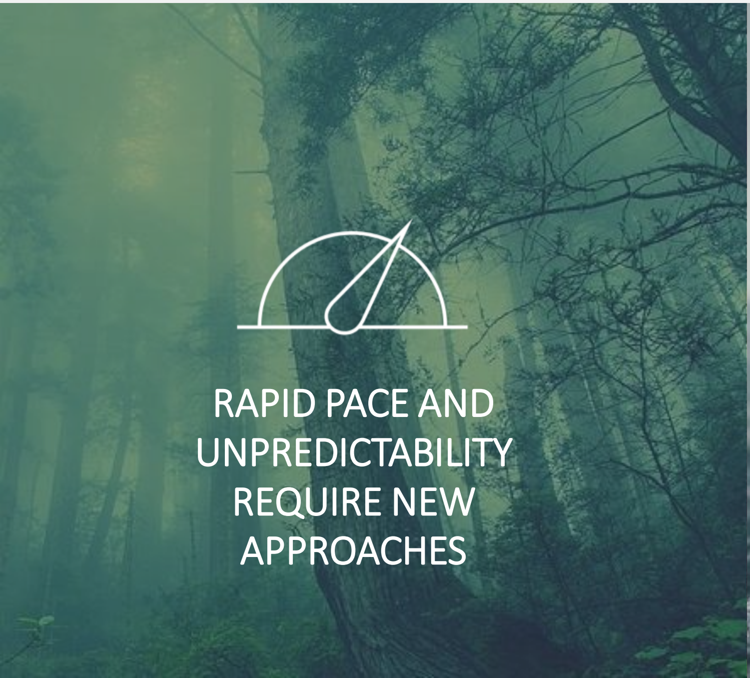
Green energy

The production and consumption of renewable energy will grow significantly as we move towards a climate-neutral society. This presents new challenges for the electricity and gas systems. The new green consumption will need to be linked to green production, as the two are often separated by great distances. Meanwhile we must maintain the existing high degree of security of supply.

Developments in Power-to-X technologies opens more possibilities for the electricity and gas systems to support each other in the green transition.

Existing systems

Alongside the development of the electricity and gas grids necessitated by the green transition, the existing systems will also be adapted and maintained so they continue to meet the needs of society and our customers. This could include reducing the visual impact of an installation, or replacing components at the end of their service life. Or modifying the gas infrastructure to allow for other developments benefiting society, for example when a new railway is built.



THERE IS A NEED TO DEVELOP THE POWER GRID

New initiatives are required if the power grid is to support development all the way to a climate-neutral society by 2050. It is not only important but vital to modify, strengthen and expand the power grid. We also need to guarantee reliable operation and a high degree of security of supply in the existing power grid. Three factors will particularly influence on our work.

RAPID PACE

There is a lot of interest across Denmark in installing large PV power plants in particular. They can be set up without subsidies and very quickly, and this presents Energinet's planning process with new challenges bearing in mind the considerable uncertainties around the size and location of the individual facilities.

Furthermore large projects such as energy islands and Power-to-X plants will have a major influence on the power grid of the future. The location of the large new facilities – and how they will be integrated with the energy system as a whole – remains uncertain. As a result, strategic choices will increasingly have to be made on an uncertain basis.

GREEN ENERGY

More (green) electricity in our power grid means that more of it will have to be transported from generation to consumption. In fact we expect solar and wind generation capacity to increase threefold by 2040. Meanwhile there will be a big increase in electricity consumption as heating and transport are increasingly electrified.

Expansions in solar and wind often take place in sparsely populated areas where there is land available for the installations. Around the towns and cities, on the other hand, consumption usually increases. One of the main drivers behind development in the power grid is to link new consumption with production.

EXISTING SYSTEMS

Reinvestments will be necessary in much of the Danish power grid in the years to come. These projects will have to be prioritised and coordinated with other essential projects in order to arrive at the best solutions. Meanwhile it is important to keep the system running reliably at all times, with a high degree of security of supply. Remedial projects may be needed to clear the way for the most system-critical reinvestments.

Energinet works constantly to reduce the visual impact of our installations, for example in visual enhancement projects and the undergrounding of overhead lines when they become due for reinvestment.

THE ENERGY SYSTEM'S NEW PLAYERS AND SECTOR COUPLING

The goal is a climate-neutral society

The Danish Parliament adopted the Danish Climate Act (*Klimaloven*) in 2019, with the target of a 70 percent reduction in Danish climate gas emissions by 2030. Together with the goal of net zero emissions by 2050, these objectives set the general direction for development of the energy system. The objectives were revisited on multiple occasions in 2020 and 2021. The climate agreement for the energy sector from June 2020, for example, has moved towards specifying how the objectives can be met.

Difficult to forecast development

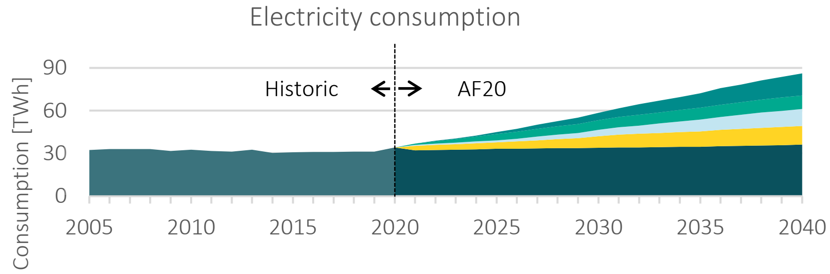
It is clear that the energy system is facing a major transformation in order to meet the political objectives. But how will the development unfold? Every year, the Danish Energy Agency prepares key data projections for the Danish energy system in the Analysis Assumptions (AF). They were published most recently in August 2020 and describe a likely development of the energy system over the next 20 years, in line with the current political objectives.

AF20 is the main basis for the work done by Energinet. The rapid pace and unpredictable nature of the development, however, means that we must take a number of uncertainties into account. For example, it is difficult to predict the pace of expansion and the location of Power-to-X plants. The government is currently working on a Power-to-X strategy in Denmark. Depending on how the strategy turns out, the development could take a different direction. Power-to-X plants may become so large that even just one plant on its own could be a game changer for the needs we are looking into.

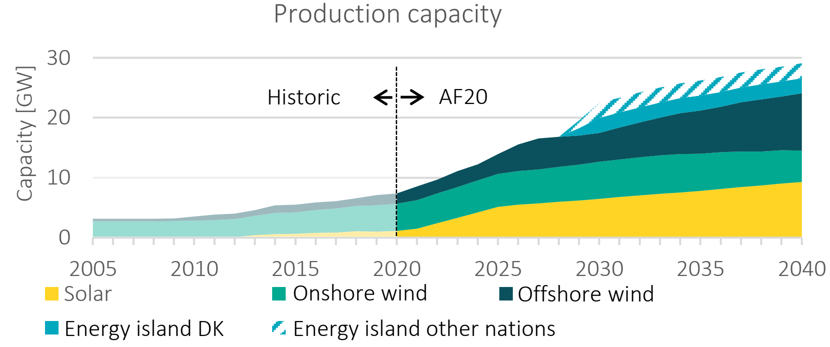
Energy islands, Power-to-X and sector coupling will play an important part

AF20 addresses new players in the energy system – energy islands and Power-to-X – for the first time. It is generally agreed that these new technologies have great potential and will play a part in the energy system of the future even though they are associated with many unknowns. For Power-to-X, important details are uncertain, such as the geographical location of the plants and the end product. Energinet is able to influence many of these factors, but the final decisions – of significant importance to Energinet's work – are made elsewhere.

As new players emerge, sector coupling is now on the agenda. Here, too, it is generally agreed that the interaction between the electricity, gas and heating sectors is crucial to the effective transition of the energy system. As the transmission system operator for both electricity and gas in Denmark, Energinet is working to integrate the two system more closely.



Direct as well as indirect electrification is expected to play a decisive role in achieving the reduction targets. Electricity consumption will increase as a result – and is expected to more than double by 2040.



The geographical separation between electricity consumption and electricity generation is expected to increase as more of the existing thermal generation capacity is shut down and replaced with renewable energy capacity. In particular, a big increase is expected in solar and offshore wind generation capacity. By 2040, these two technologies are expected to grow at least eightfold.

UNCERTAINTIES

The Danish Energy Agency's Analysis Assumptions (AF) are the main basis for Energinet's work and for this needs analysis. AF represents one of many possible ways to achieve the political objectives.

AF offers a likely development, but there is considerable uncertainty regarding the precise direction the development will take. The uncertainties concern the rapid pace, the amount of renewable energy to be transported, and the geographical distribution.

Selected examples of these uncertainties are shown on the right, and they could have a big impact on the needs analysed by Energinet.

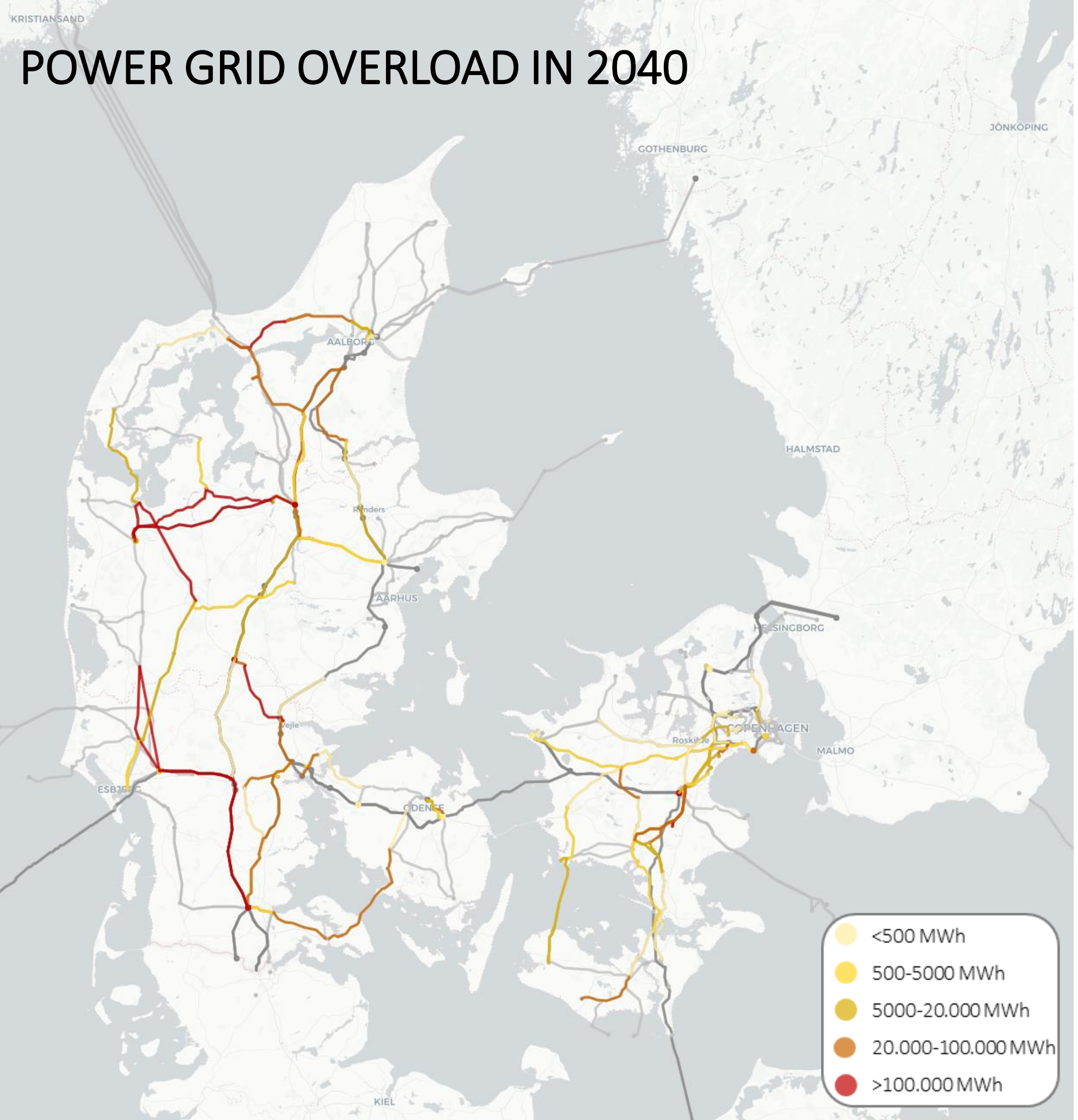
NEW GREEN ENERGY SOURCES

Energy islands and large PtX-plants are examples of large individual units, any of which could be a game changer for the power grid. Where and how they will be integrated with the power grid will therefore be crucial.

CO-LOCATING CONSUMPTION AND GENERATION

The need to transport electricity will depend on whether new renewable energy production capacity is located close to existing and new electricity consumption - or the other way around.

POWER GRID OVERLOAD IN 2040



ENERGY OVERLOAD

The map shows the volume of energy that must be relieved on a connection if no other measures are taken. It is determined by simulating the electricity spot market over a year. The energy volume will be larger if the overload occurs frequently, or if the component transfers a lot of energy.

POWER GRID OVERLOADING MAKES NEW INITIATIVES NECESSARY

With the anticipated development of for example, consumption and generation, we can present the most likely scenario for the need for initiatives in the power grid as a result of the green transition. In this context, ‘need’ means that there is 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. There are big geographical differences in how pressing the needs are and what developments are driving them.

Renewable energy must be transported to where it will be used

Even today, certain parts of the country generate more electricity than they consume. As a result, the excess power has to be transported out of the region and either delivered to consumers or exported. This trend is expected to grow over time because renewable energy facilities tend to be installed in areas with low consumption. Examples of such regions include Lolland-Falster, South Zealand, West Jutland and North Jutland. In many parts of the country there is particular interest in installing PV power plants, and this could make the needs more pressing than indicated by the analyses here.

Maintaining security of supply for consumers

Increasing consumption means more power will have to be delivered to the consumers. Electricity must be available from the wall sockets, to charge the electric vehicle, or to heat the house. Electricity consumption is also expected to grow significantly from technologies with the potential to improve flexibility in the system. Examples include electric boilers and heat pumps in the district heating sector, and PtX plants.

It is mainly in the densely populated areas that increasing consumption will determine power grid development needs. These include the areas around the major cities of Copenhagen, Aarhus and Odense, the east coast of Jutland and the Triangle Region. In many parts of the country, there is potential for bigger increases in consumption than predicted in the analyses here. If more of these potential increases is realised, the needs may exceed the forecasts in the analyses.

AN AGING POWER GRID REQUIRES SIGNIFICANT REINVESTMENTS

The bulk of the Danish power grid was set up in the second half of the 20th century. The basic service life of most of the high voltage components is about 40 years. Clearly, then, large parts of the electricity transmission grid are in serious need of reinvestment. The map below shows the components requiring reinvestment within the next approximately 10 years. The need is determined by assessing the condition of the individual facilities.

UNDERGROUNDING OF OVERHEAD LINES

A pool of money has been set aside for undergrounding 132- and 150 kV-overhead lines. The pool is used for undergrounding when the power lines are due for reinvestment anyway. That way, society gets the best value for money.

COORDINATION OF MULTIPLE NEEDS

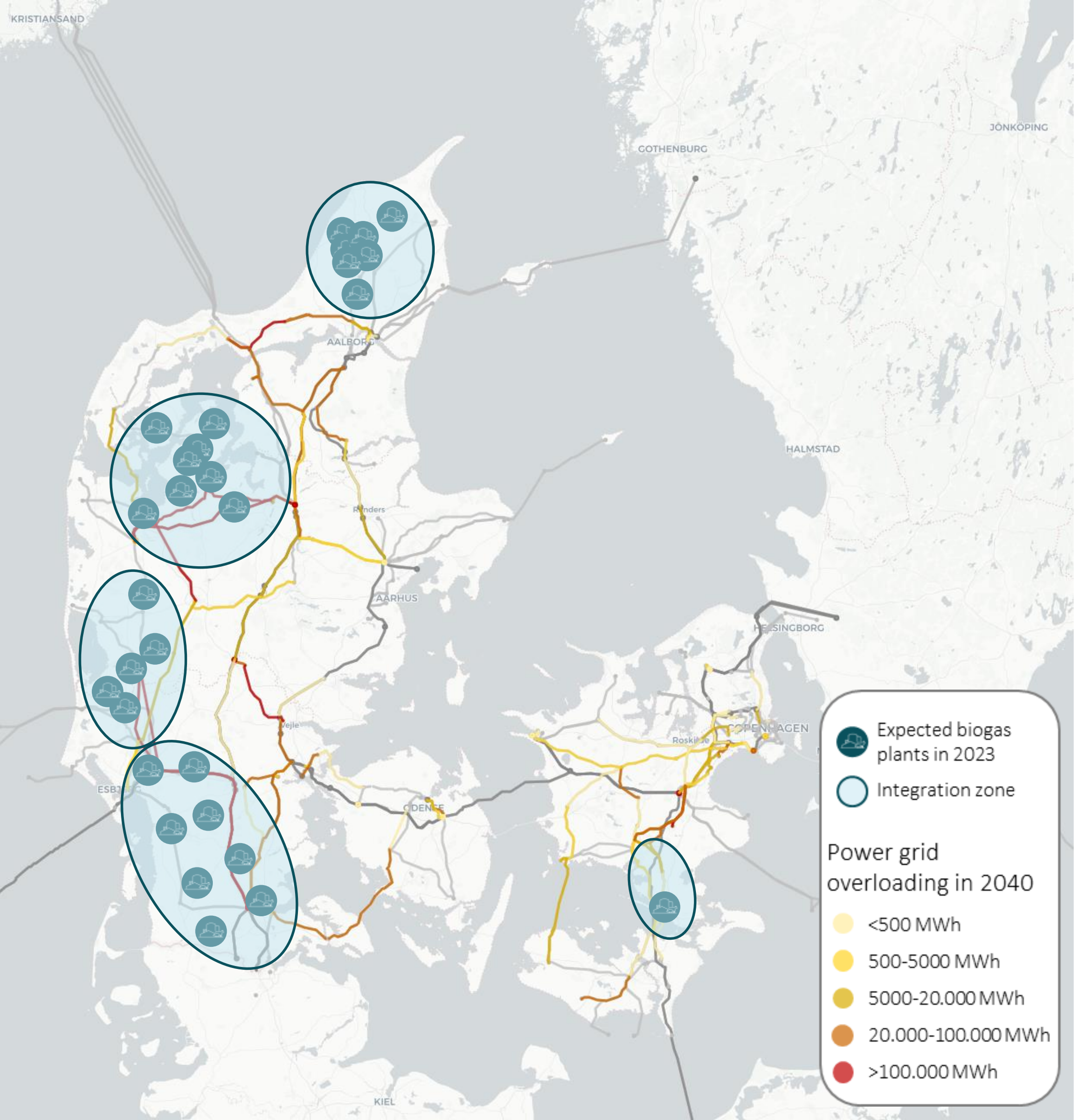
The large reinvestment portfolio must be coordinated with other needs in the system. For example the capacity of a component could be increased when a reinvestment takes place if the amount of electricity it carries is expected to increase in the future.

SYSTEM-CRITICAL REINVESTMENTS

Many of the imminent reinvestments in the 400 kV-grid are system-critical reinvestments. This means that when the connection or the transformer is taken out of operation in order to renew it, there will be a big impact on the security of supply.

To reduce this risk, remedial actions may be necessary before the system-critical reinvestments can be carried out.

Examples of remedial action include investments in grid expansion and/or downward regulation of the market.



BIOGAS METHANISATION

A process in which CO_2 separated from biogas is combined with hydrogen to produce a synthetic biomethane. 70 percent more green gas can potentially be produced because biogas contains about 35 percent CO_2. CO_2 from biogas is a by-product of the process to upgrade biogas to natural gas quality. That is why CO_2 from biogas is seen as an easily accessible source of carbon.

TOPIC: SECTOR COUPLING OF ELECTRICITY AND GAS IMPROVES INTEGRATION OF GREEN ENERGY

Sector coupling will play an important part in achieving the objectives of the green transition. Energinet continuously investigate and support opportunities for sector coupling. This page presents an example showing how the electricity and gas systems can support each other in the context of methanisation.

Methanisation can ease parts of the electricity system with an excess of green electricity

By 2040, parts of the electricity transmission system are expected to become overloaded as more green electricity is produced which cannot all be utilized where it is generated. In many of these areas there is also significant biomethane production. In these areas, methanisation can help integrate green electricity by increasing electricity consumption.

According to expectations in AF20 about the quantity of green gas in 2030, methanisation could consume up to 2.8 TWh of electricity at the national level. However, the potential is much greater, especially in the regions generating large amounts of green electricity, where methanisation could create a demand for 7 TWh of electricity by 2030. This is 20-30 percent of the total generation of green electricity in those areas. The extent to which the potential for offtake of green electricity can be realised will depend on how widespread methanisation becomes. The potential is expected to increase towards 2040.

The potential for green gas can utilize both the electricity and gas system

Methanisation of CO_2 has considerable potential to increase the quantity of green gas without the need to build more biogas plants or use biomass. Increasing the quantity of green gas, through methanisation, may however, necessitate changes to existing gas infrastructure. The potential for methanised biogas is as high as 4.2 TWh in parts of the country with the highest anticipated generation of green electricity. Thus the gas system would receive 40-45 percent more green gas in 2030 than assumed in AF20 so far.

Methanisation could change the pattern of gas supply

With methanisation, the gas system must be prepared for a more fluctuating green gas supply, with periods of abundance as a result of a hydrogen supply that depends on low electricity prices. The low electricity prices usually occur when RE electricity generation is high, where the electricity system, in the areas, needs to be relieved.

Analyses show that supplies will be abundant mainly outside the summer months when gas consumption is low. This helps to avoid imbalance in the local gas distribution grid in summer, and allows green electricity to be integrated in the gas system in winter when gas consumption is high.

THE NEEDS ANALYSIS IS THE BASIS FOR FURTHER WORK WITH SOLUTIONS

This needs analysis contributes with an overview of the challenges and needs we foresee. Energinet continuously work with several types of solutions that support the development needs of the power grid in a future with fluctuating energy sources such as solar power and wind. Below on the right you will find the four main categories of solutions we work with. The solutions are further described in Energinet's solution catalogue, which you can read more about here: www.en.energinet.dk/power-solutions2021. The needs analysis and the solution catalogue forms the basis for a dialogue on how both known and new solutions can be brought into play when solving the identified needs.

DEVELOPMENT NEEDS

- Renewable energy must be transported to where it will be used
- Maintaining security of supply for consumers
- An aging power grid requires significant reinvestments

SOLUTION CATEGORIES

- Construction solutions
- Operational solutions
- Market solutions
- Dialogue-based initiatives and third-party solutions

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THE NEED FOR NEW INITIATIVES IN AREAS

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

WHAT OUTCOMES CAN WE EXPECT AND WHAT MIGHT INFLUENCE THEM?

In the following pages we explore in more detail the development needs of the power grid in various geographical areas in Denmark. We focus mainly on the needs arising from the development predicted in the Analysis Assumptions 2020 described on page 6.

Sensitivities which might particularly affect developments

However, as described above on page 7, there are a number of uncertainties around how the political climate objectives will be met. That is why we study factors which are currently thought to be particularly relevant and important in terms of the coherence of the system as a whole. We call these studies sensitivities – you can find out more about the factors we studied in the fact box below.

The sensitivities are used to project outcome spaces for the needs in different places. The presented outcome spaces are based on the analysed sensitivities and probably do not correspond to the full potential outcome space.

Potential for further increases in consumption and production

Beyond the analysed sensitivities there is potential for further increases in consumption and production virtually all over the country. Not all the potentials are covered by the analyses, but Energinet continuously handles enquiries about connecting new consumption and production, and assesses whether this gives rise to any new needs.

SENSITIVITIES

- PtX high: A high outcome space for the PtX development from AF20, with a total of 6 GW of PtX installed by 2040 – twice as much as in AF20.
- +500 MW offshore wind power: 500 MW extra offshore wind power on Lolland from 2030 – initial assessment of the impact of restoring the Rødsand and Nysted offshore wind farms.
- +1500 MW offshore wind power: 500 MW extra offshore wind power on Lolland and 1000 MW extra offshore wind power on South Zealand from 2030 – initial assessment of the impact of restoring the Rødsand and Nysted offshore wind farms and additional near-shore wind farms in the area.
- Energy island points of connection: Different variations of possible points of connection for the two energy islands. In this initial phase, the analyses are based on connections to existing substations. In practice, new substations are expected to be built because the existing ones have limited space. In these analysis a series of possible connection points are investigated, but there are many factors to be weighed, and no decisions has been made on connection points yet.

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

West Jutland is one region where the need for new initiatives will become particularly acute. This area will be highly impacted by a number of new facilities generating renewable energy. These include offshore wind power (the Thor offshore wind farm, the Vesterhav Nord and Syd near-shore wind farms and several large offshore wind farms in the longer term) and expected growth in large PV power plants.

Local surplus of green electricity

West Jutland will therefore be an area in which the production of renewable energy increases markedly, while energy consumption does not increase in step. So the need to use the renewable energy to supply consumers elsewhere will 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 1.6 GW today to somewhere between 6 and 7.5 GW in 2040 depending on whether the energy island is assumed to be connected outside (AF20) or inside (Idomlund energy island) the West Jutland region.

Solar, wind and Power-to-X

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.

Connecting substantial PtX capacity or other major consumers within the area could reduce the need to transport the electricity outside the area, depending on the interaction between consumption and production. This would also take the load off the power grid.

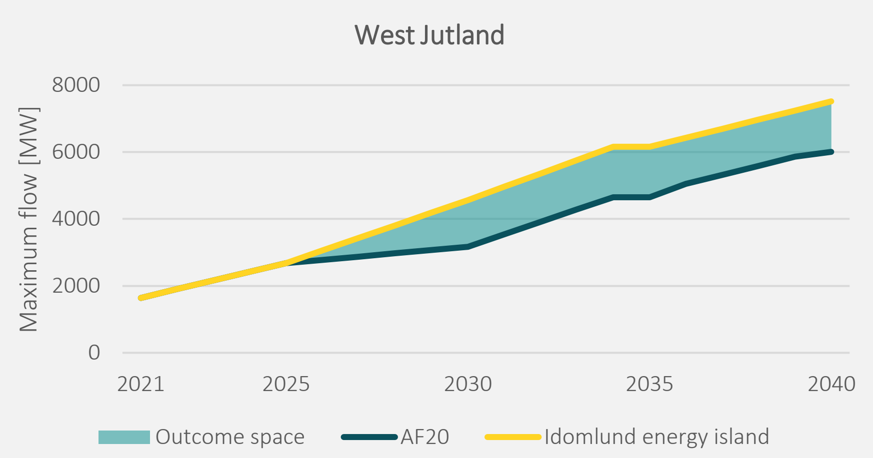

Figure 1: Maximum flow of electricity across the segment in West Jutland shown in Figure 2. High growth in RE generation will create a need for development. If the energy island is connected in the West Jutland region (Idomlund energy island) there will be a greater need to transport energy out of the region. See page 26 for a definition of AF and other terms.

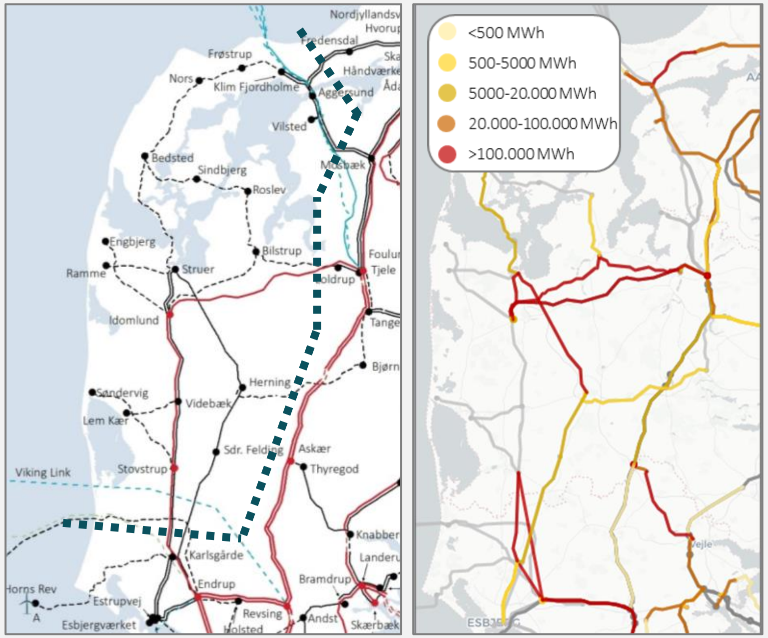

Figure 2: The grid reference in West Jutland which is used as the basis for the analyses (left) and the energy overload in 2040 based on AF20, in an N-1 situation (right). See page 26 for term definitions.

NORTH JUTLAND: INCREASING CONSUMPTION AND PRODUCTION

In the North Jutland region, generation is generally forecast to exceed consumption. Solar power generation is expected to increase steadily up to 2040, with a general increase in classic consumption.

The development assumed in the AF20 analyses can mostly be accommodated within the existing grid. As shown in the diagram below, no major overloads are predicted apart from isolated issues in the grid near Aalborg.

More projects might lead to more initiatives

In addition to the development assumed in the AF20 analyses, there is potential for more solar plants and more consumption. In particular, we know of some major potential consumption projects in the region. They include data centres, charging facilities for electric ferries and other projects which could require initiatives that are not covered by this analysis. These initiatives will be covered if and when the particular projects are launched.

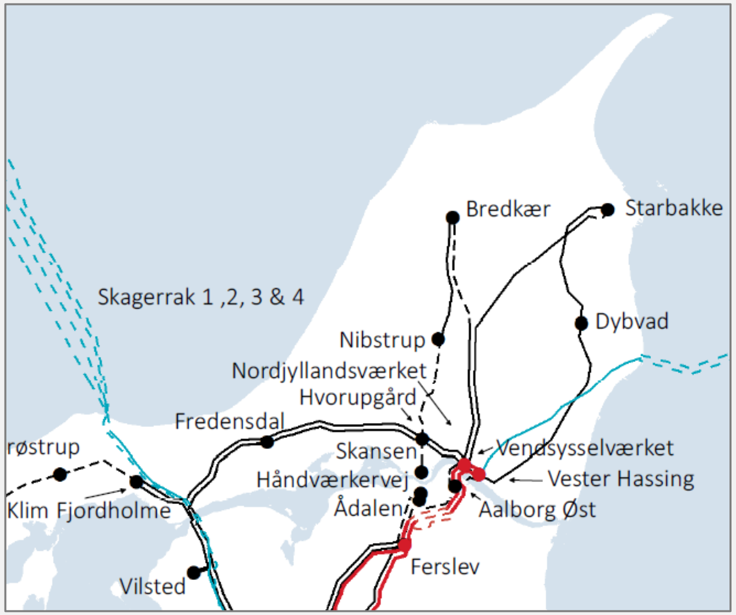

Figure 3: The grid reference in North Jutland on which the analyses are based.

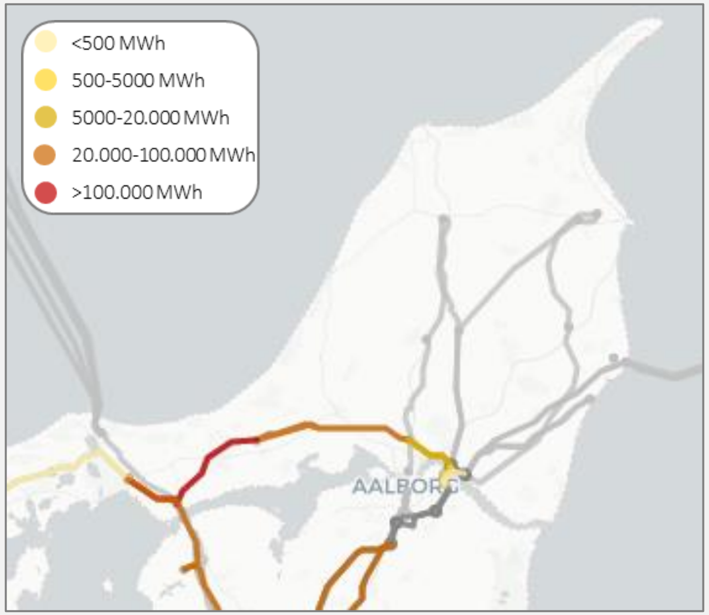

Figure 4: The energy overload in 2040 based on AF20, in an N-1 situation. See page 26 for term definitions.

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

East Jutland is an area where the integration of more renewable energy from onshore solar and wind power north of Aarhus will decide the future needs of the grid.

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.

Renewable energy north of Aarhus

In the area between Aarhus and Aalborg, there is expected to be a significant increase in renewable energy. This will create overloading in the power grid, when the production has to be transported either north towards Aalborg or south to Aarhus. In addition to the assumed development in the area, there are plans for potential solar cell projects, in Djursland in particular, which may accelerate the increase and stimulate a greater need for development.

Increasing consumption in the Aarhus area

Generally speaking, the region is also characterised by increasing consumption – especially in the Aarhus area. This will create a need to develop the power grid there, as illustrated by the load on the Tange-Tjele connection, for example, in figure 5. It is immediately obvious that the connection is already overloaded today in terms of satisfying demand. These analyses are based on operating scenarios which place slightly more strain on the grid than now. There may also be some initiatives at the moment of delivery which are not included in these analyses. A more detailed analysis will therefore be necessary to determine whether the challenges will become critical enough to require measures to address them.

Installing PtX capacity in the area may cause major overloads – but this depends on how flexible the facilities are in relation to the power grid.

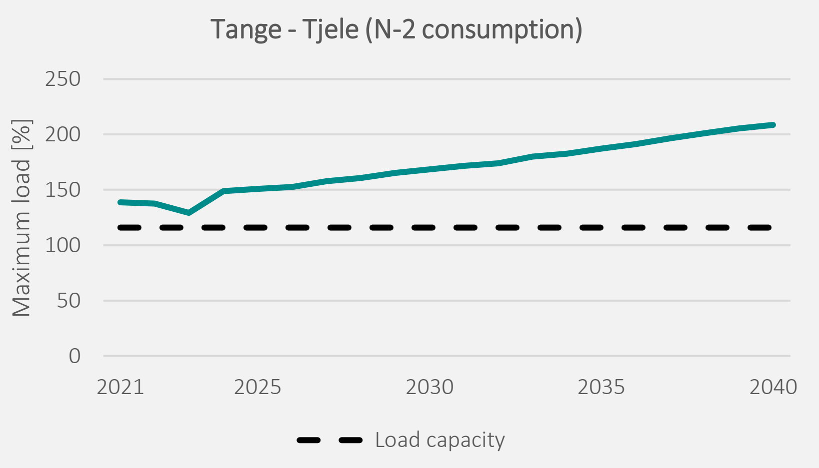

Figure 5: Maximum load for the 150 kV Tange-Tjele connection when satisfying demand in an N-2 situation. The load is compared to the load capacity of the connection. The load will increase as a result of increased electrification. See page 26 for a definition of AF and other terms.

Figure 6: The grid reference in East Jutland on which the analyses are based.

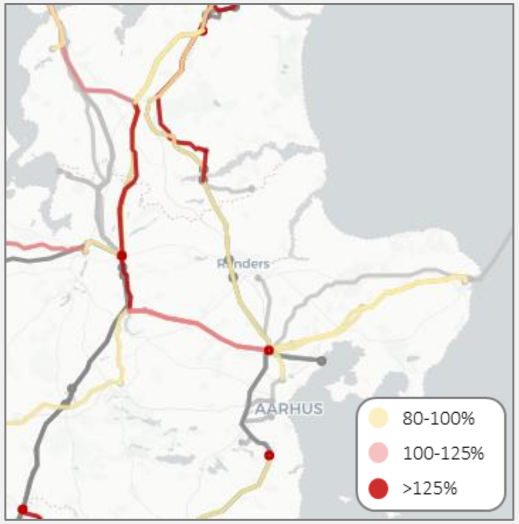

Figure 7: Overloading in 2040 based on AF20 when satisfying demand in an N-2 situation. See page 26 for term definitions.

HORSENS AND THE TRIANGLE REGION: INCREASED CONSUMPTION FROM ELECTRIFICATION AND DATA CENTRES

The area around Horsens and the Triangle Region is a centre of electricity consumption, and consumption is expected to increase in the future. The rise in consumption is due to a general increase in electrification and the connection of large consumers (data centres and PtX plants) to the transmission grid. There are plans to build a PtX plant in Fredericia with potential capacity exceeding the assumption in the analyses. If it goes ahead, the development needs may be greater than indicated in the analyses here.

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 supply the area with more electricity from other areas – a need that the current power grid is not fully geared to handle.

Power-to-X in the Triangle Region

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 facilities can be connected with lower security of supply requirements, since electrolysis plants can operate with interruptible consumption.

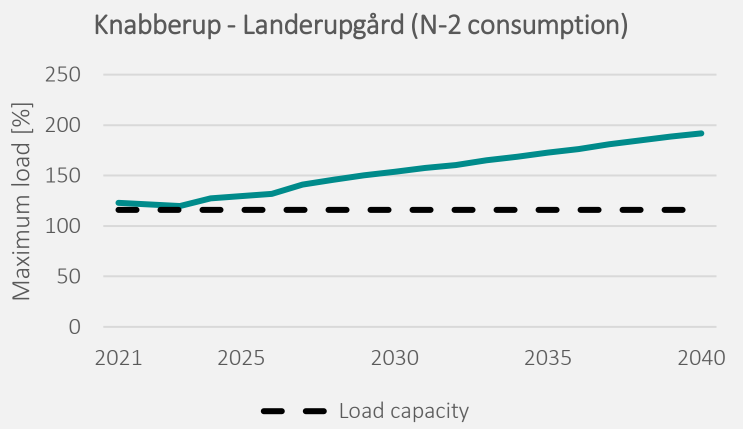

Figure 8: Maximum load for the 150 kV Knabberup-Landerupgård connection when satisfying demand in an N-2 situation. The load is compared to the load capacity of the connection. The load will increase as a result of increased electrification. See page 26 for a definition of AF and other terms.

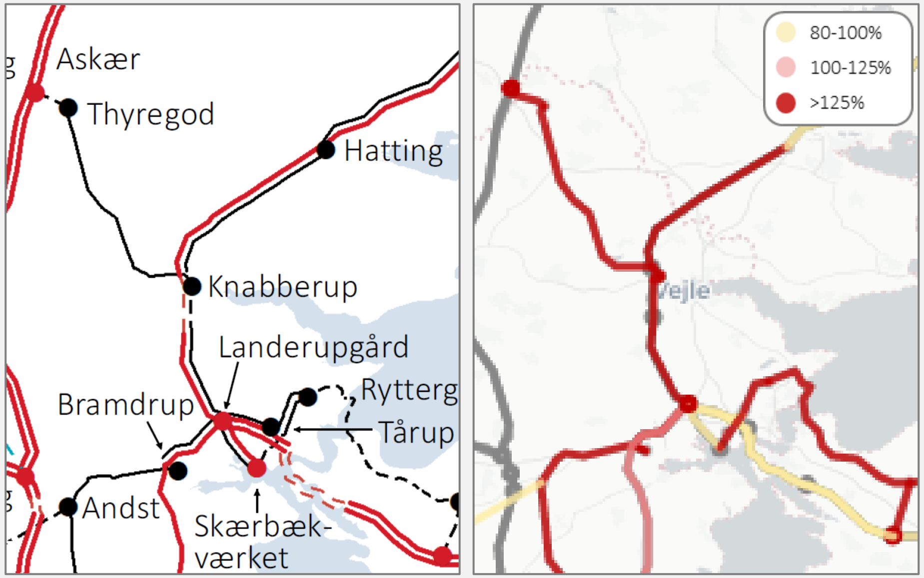

Figure 9: The grid reference in Horsens and the Triangle Region on which the analyses are based (left) and overloading in 2040 according to AF20 when satisfying demand in an N-2 situation (right). See page 26 for term definitions.

FUNEN: INCREASED ELECTRICITY CONSUMPTION FOR ELECTRIFICATION

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 from the many horticultural nurseries in the area, from the new super hospital New OUH, and from the expansion of the University of Southern Denmark. Despite a significant capacity reduction at Fyn Power Station, production capacity is expected to increase overall on Funen as solar cells are rolled out. There are numerous potential solar cell projects in the area which are not included in the analyses, so the increase in solar cells could be bigger than predicted in the analyses. This could increase the need for development.

Overloading of existing transformers

One of the consequences of the increased consumption is overloading of the existing inadequate transformers, see figure 10. It is immediately obvious that the transformers are already overloaded today in terms of satisfying demand. These analyses are based on operating scenarios which place slightly more strain on the grid than now. There may also be some initiatives at the moment of delivery which are not included in these analyses. A more detailed analysis will therefore be necessary to determine when the challenges will become critical enough to require measures to address them.

Installing PtX capacity in the area may cause larger overloads – but this depends on how flexible the facilities are in relation to the power grid. Similarly, more PV power plants could exacerbate overloading and require further measures.

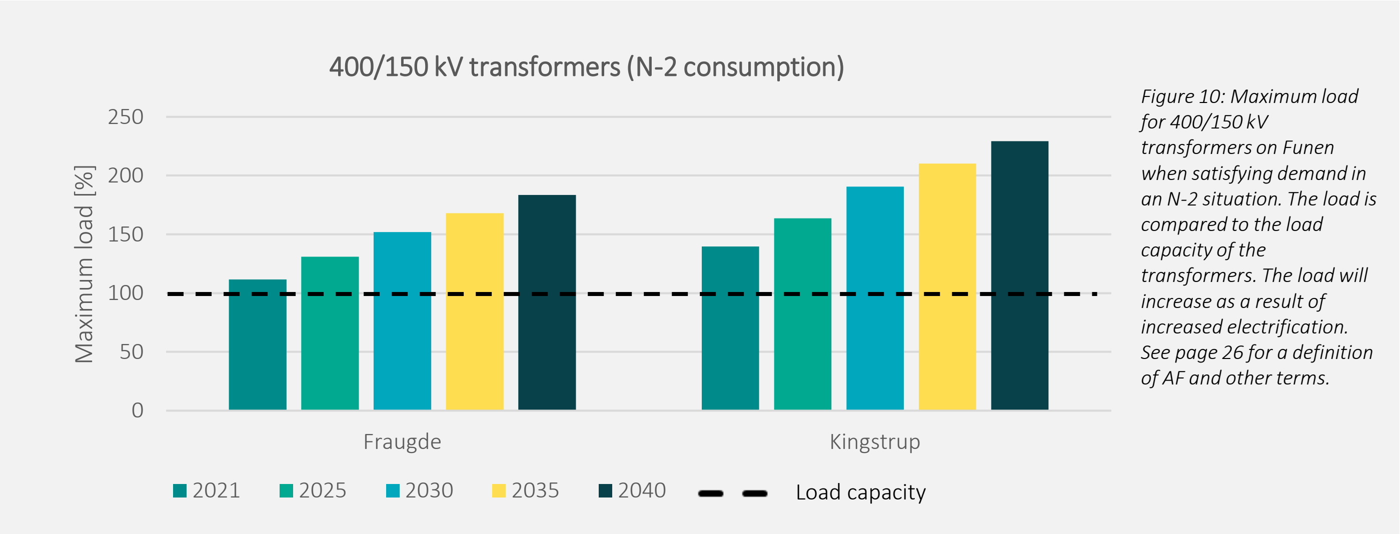

Figure 10: Maximum load for 400/150 kV transformers on Funen when satisfying demand in an N-2 situation. The load is compared to the load capacity of the transformers. The load will increase as a result of increased electrification. See page 26 for a definition of AF and other terms.

Figure 11: The grid reference on Funen on which the analyses are based.

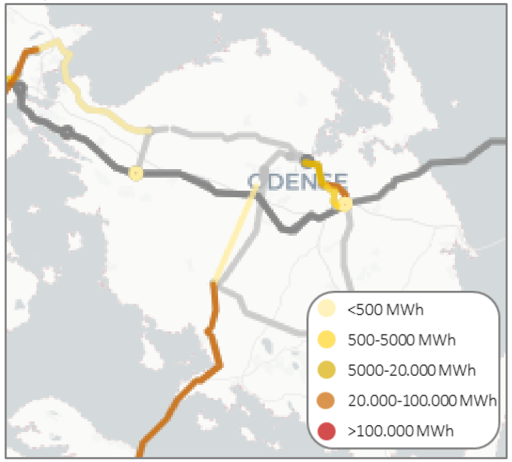

Figure 12: The energy overload in 2040 based on AF20, in an N-1 situation. See page 26 for term definitions.

SOUTH JUTLAND: MAKING USE OF RENEWABLE ENERGY FROM THE NORTH SEA

The future energy needs in South Jutland are characterised by moderate local production of renewable energy, and increased consumption from data centres. However, it is primarily the construction 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.

Possible points of connection to the planned energy island
In the AF20 analyses, the connection of the energy island is assumed to be divided between Revsing and Tjele substations. However, a number of other possible connections have been studied, for example in Endrup or Kassø, or connecting the full capacity in Revsing. In practice, new substations are expected to be built due to space limitations in the existing ones. The results obtained by connecting in Endrup and Revsing are comparable with AF20. This is because there are many hours in which energy is exported to Germany through the Kassø-Revsing connection, almost independently on where in the country the energy island is connected.

If Kassø substation is used, the energy overload on the Kassø-Revsing connection will be less because the electricity from the energy island does not need to pass through the connection on its way to Germany. On the other hand, it will cost more to connect the energy island there because a longer landing cable will be needed. In addition, new consumption patterns could change the energy distribution over the various links.

The local power grid is being expanded
The analysis of grid overloading based on the assumptions in AF20, primarily shows an increased flow in the local 400 kV overhead lines, while the power grid at lower voltage levels in the area is less affected.

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 as yet. The planned grid will result in a robust system that can also handle the subsequent development in AF20.

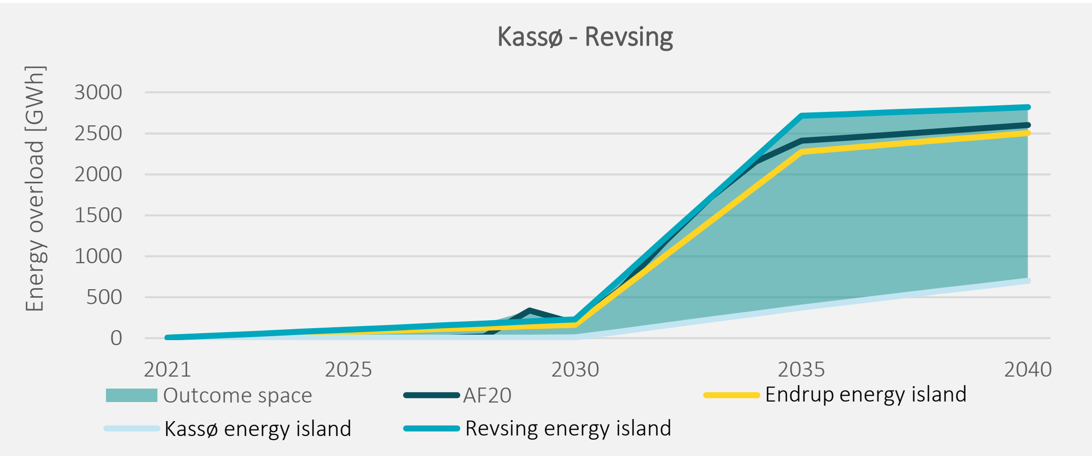

Figure 13: Energy overload in the Kassø-Revsing 400 kV system, in an N-1 situation. The connection will be overloaded after 2025 in all analysed scenarios. This is due to the expansion of renewable energy in both West and Central Jutland, which will increase the use of the connection as an export corridor to Germany. See page 26 for a definition of AF and other terms.

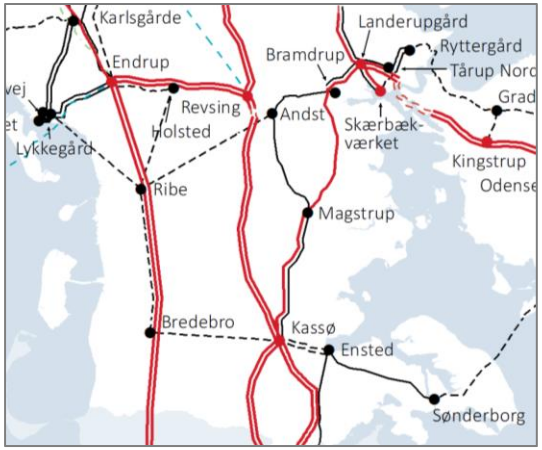

Figure 14: The grid reference in South Jutland on which the analyses are based.

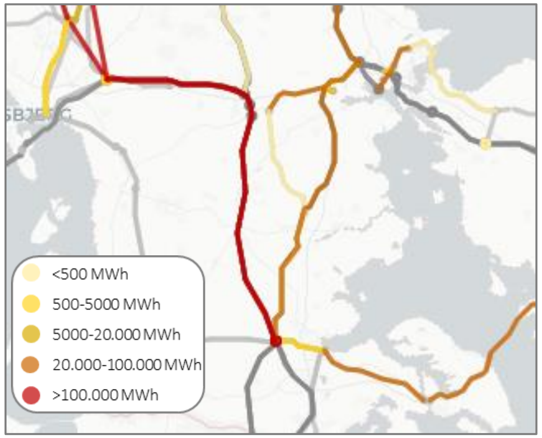

Figure 15: The energy overload in 2040 based on AF20, in an N-1 situation. See page 26 for term definitions.

SOUTH ZEALAND AND LOLLAND-FALSTER: STRONG GROWTH IN PV POWER PLANTS

Development in the South Zealand and Lolland-Falster area is likely to be characterised by strong growth in onshore renewable energy, especially from large PV power plants. The production of renewable energy in the area will thus increase markedly, while energy consumption will not increase in step. 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 increase, especially in the short term, is striking.

AF20 assumes that the two offshore wind farms south of Lolland, Nysted and Rødsand, will be decommissioned in 2029 and 2036 respectively. Meanwhile, electricity consumption is expected to increase over the long term – as a result of electrification and new data centres in the area. This means that overall, the flow will peak around 2025 and then stagnate.

Potential for more offshore wind

That the two offshore wind farms are not replaced with new ones at the end of their service life is a significant divergence from the previous analysis assumptions. And two potential offshore wind farms currently under development in the area, Omø Syd and Kadet Banke, are not included in the analyses. As a result, two sensitivities have been studied in which 500 and 1500 MW more offshore wind respectively will be integrated after 2030 compared to AF20.

Connecting more offshore wind to the south of the South Zealand segment, figure 17, increases the need to transport the electricity through the segment and consequently also the need to develop the power grid.

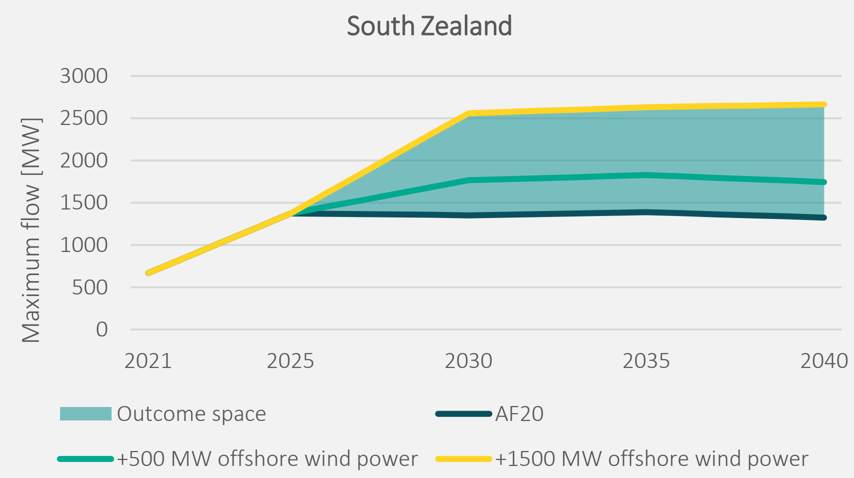

Figure 16: Maximum flow of electricity across the segment from South Zealand to the north (segment shown in figure 17). High growth in RE generation will create a need for development. With 500 and 1500 MW more offshore wind south of the segment than in AF20, there will be a greater need to transport electricity over the segment. See page 26 for a definition of AF and other terms.

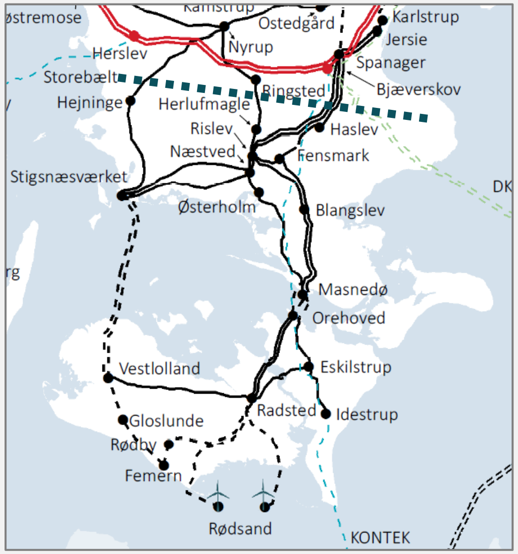

Figure 17: The grid reference on South Zealand and Lolland-Falster on which the analyses are based.

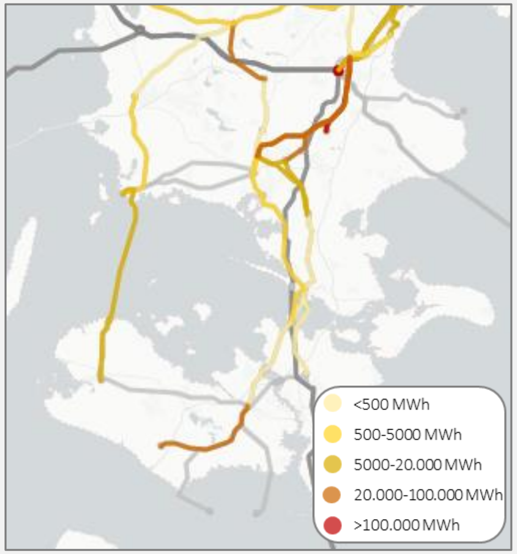

Figure 18: The energy overload in 2040 based on AF20, in an N-1 situation. See page 26 for term definitions.

CENTRAL AND WEST ZEALAND: MAKING USE 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 in terms of development. This is because the so-called Køge-Roskilde segment is located between an area with a production surplus (South Zealand and Lolland-Falster) and an area with a production deficit as well as export opportunities (Copenhagen and North Zealand).

Changes in consumption and production

In general, this segment will be under more strain if renewable energy production grows more than assumed to the south, or if consumption increases more than assumed to the north. Conversely, this segment will be under less strain 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 the planned energy island near Bornholm is connected to high-voltage substations situated north or south of the Køge-Roskilde segment in the system. In the AF20 analyses, the energy island is connected to the Bjæverskov substation south of the segment, whereas in the "Energy island northern connection" option in figure 19 it is connected north of the segment.

Potential for more offshore wind

AF20 assumes that the two offshore wind farms south of Lolland, Nysted and Rødsand, will be decommissioned in 2029 and 2036 respectively. To study the consequences if the two wind farms are extended, two sensitivities were investigated in which from 2030, 500 and 1500 MW more offshore wind is integrated south of the segment compared to AF20. In these variations, the need to transport electricity through the segment increases, as does the need to develop the grid.

The development of Power-to-X will also be important, and more PtX north of the segment ("PtX high") increases the need to transport electricity through the segment.

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.

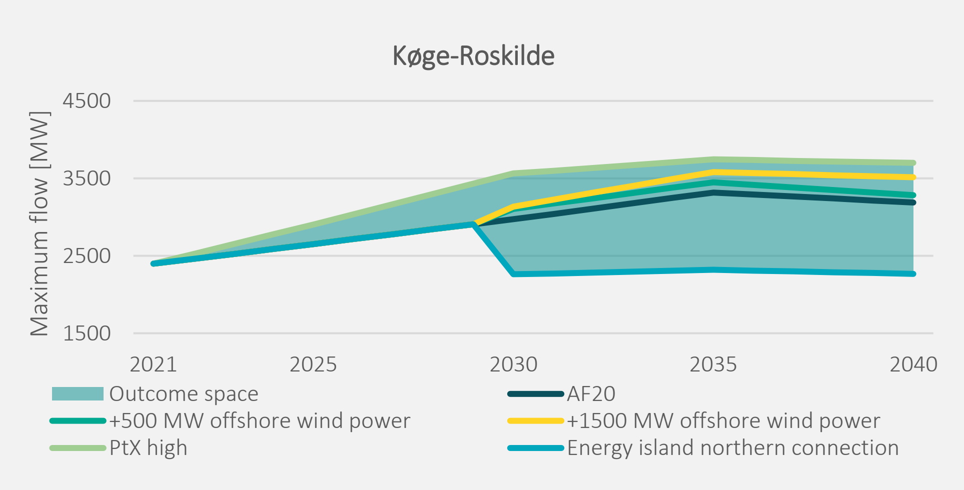

Figure 19: Maximum flow of electricity across the so-called Køge-Roskilde segment, (shown in figure 20). High growth in RE generation will create a need for development. More offshore wind south of the section ("+500/1500 MW offshore wind power") increases the need, whereas more offshore wind north of the segment ("Energy island northern connection") reduces the need. See page 26 for a definition of AF and other terms.

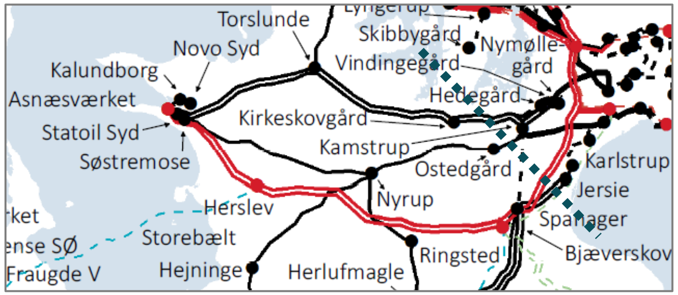

Figure 20: The grid reference on Central and West Zealand on which the analyses are based.

Figure 21: The energy overload in 2040 based on AF20, in an N-1 situation. See page 26 for term definitions.

NORTH ZEALAND: CONNECTION OF HESSELØ OFFSHORE WIND FARM

Developments in the North Zealand region are particularly influenced by the Hesselø offshore wind farm, which is expected to be connected to a new substation near Hovegård. The increase in PV power plants is also predicted to be more moderate than in other parts of the country, alongside a general increase in consumption. These developments can be accommodated without major changes to the existing transmission grid, apart from the modifications needed to connect Hesselø itself.

That is why there are no major overloads in the diagram below which presents the grid reference in the region and the energy overload based on the AF20 development in 2040.

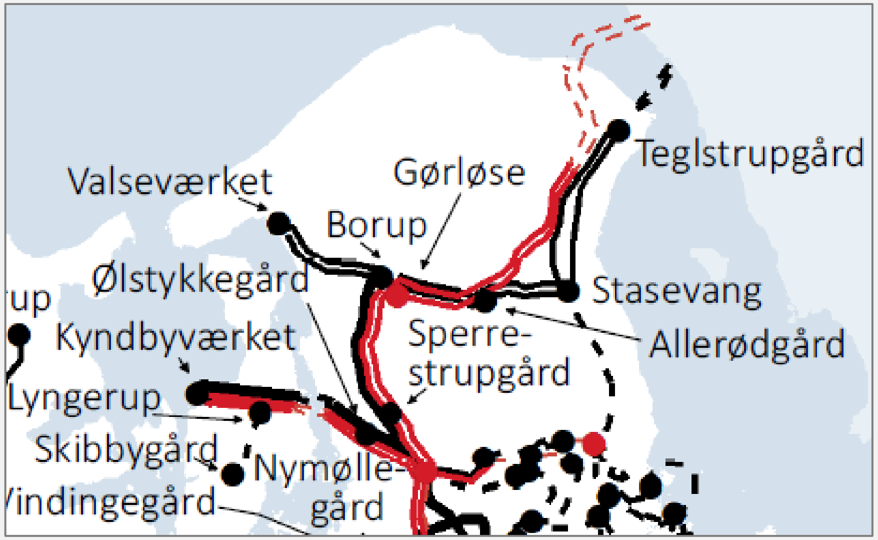

Figure 22: The grid reference on North Zealand on which the analyses are based.

Figure 23: The energy overload in 2040 based on AF20, in an N-1 situation. See page 26 for term definitions.

COPENHAGEN AREA: INCREASED ELECTRICITY CONSUMPTION DUE TO URBAN DEVELOPMENT AND ELECTRIFICATION

Central Copenhagen is an area where it will be necessary to develop the power grid. The main reason why capacity in the existing power grid will be inadequate (connections as well as transformers) is increased electricity consumption resulting from urban development and electrification (electric vehicles, etc.). Electricity generation capacity from power stations in this area will be reduced at the same time.

Energy island and PtX

There are also a number of facilities on the drawing board which can have an impact on the precise future needs of the power grid in the Greater Copenhagen area. In particular, the plans include two potential near-shore wind farms, connection of the forthcoming energy island near Bornholm, and plans by a number of Danish companies to establish large-scale electrolysis in Copenhagen. A PtX plant in the region could increase the overloads, depending on how flexible the plants are in relation to the transmission grid and how they interact with any new production capacity.

Connecting the energy island within the region could contribute production capacity in an area dominated by consumption. The extent to which this will reduce development needs, however, depends entirely on how consumption and production interact with each other. Furthermore, the connection to the energy island will have to work as an interconnector, and this may entail needs of other kinds.

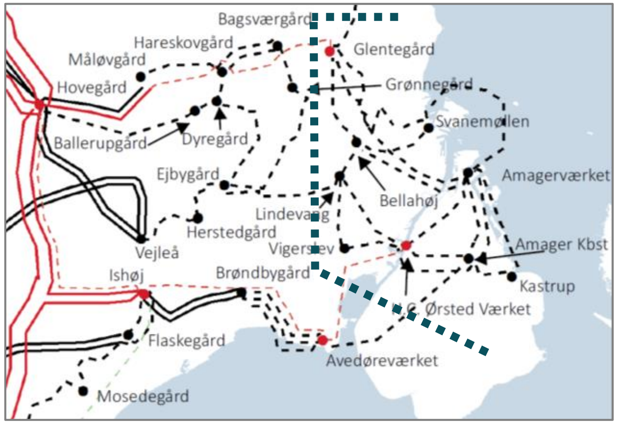

Figure 25: The grid reference in the Copenhagen region on which the analyses are based.

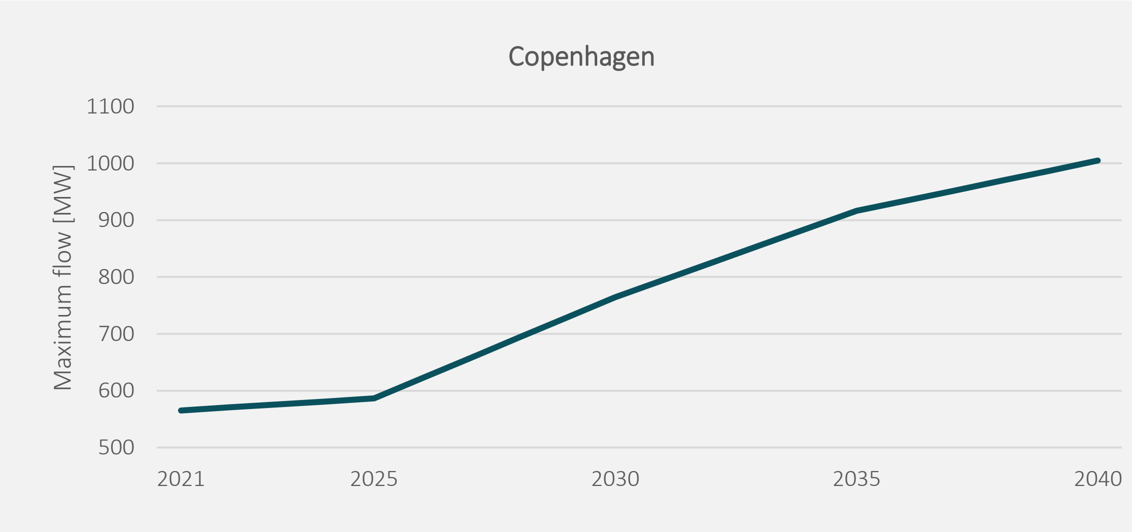

Figure 24: Maximum flow of electricity across the segment towards Copenhagen shown in Figure 25. There is a clear trend towards an increasing flow to Copenhagen as a result of urban development and electrification. See page 26 for a definition of AF and other terms.

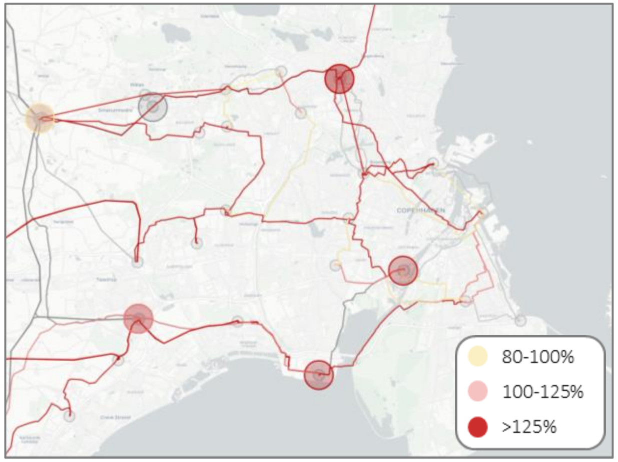

Figure 26: Overloading in 2040 based on AF20 when satisfying demand in an N-2 situation. See page 26 for term definitions.

APPENDIX

WHAT ARE WE WORKING ON RIGHT NOW?

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 2026.

The grid reference includes the following major new projects (as well as the existing grid), and the year in brackets is the first entire year the project is expected to be in operation:

- Undergrounding of Kamstrup-Spanager and transformer capacity upgrade in Bjæverskov (2024)
- The Viking Link connection between Jutland and the UK – 1,400 MW transmission capacity (2024)
- The 400 kV Endrup-border connection – increases transmission capacity between Germany and Western Denmark by about 1,000 MW (2024)
- The 400 kV Idomlund-Endrup connection with a new 400 kV substation in Stovstrup (2024)
- A new 150 kV cable structure that replaces overhead lines between Kassø and Lykkegård (2023-25)
- Connection of Femern and the new Gloslunde substation on Lolland (2025-2026)

GLOSSARY

AF20
The Danish Energy Agency's Analysis Assumptions for Energinet, 2020. Energinet has to plan the power and gas grids according to the Danish Energy Agency's annual projections concerning the generation and consumption of electricity, gas, district heating, etc. These Analysis Assumptions are based on political decisions and on projections concerning the market and technological development.

Power grid
In this report, the power grid refers to the part of the power grid which is above 100 kV – the 'superhighways' of 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.

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.

Component
A component means a part of the power grid – such as a transformer or an overhead line between two substations.

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 action will be required.

In this report, maximum load is calculated by simulating situations with high consumption and low production.

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 provide a reliable electricity supply in an N-1 situation, 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 provide a reliable electricity supply in an N-2 situation, 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 25.

Power-to-X (abbreviated to PtX)
Denotes the process in which power is used to produce hydrogen by water electrolysis. Hydrogen can be used on its own as a green energy source, or as a component in green fuels or other green products (hence the 'X').

PtX high
A sensitivity analysis in which PtX rollout is increased to the high end of the outcome space for PtX development in AF20, corresponding to a total of 6 GW of PtX by 2040 – twice as much as in AF20.

+500 MW offshore wind power
A sensitivity analysis in which 500 MW extra offshore wind power is added on Lolland from 2030. Used to provide an initial assessment of the impact of restoring the Nysted and Rødsand offshore wind farms, which are due to close down in 2029 and 2036 according to AF20.

+1500 MW offshore wind power
A sensitivity analysis which adds 500 MW extra offshore wind power on Lolland and 1000 MW extra offshore wind power on South Zealand from 2030 – initial assessment of the impact of restoring the Rødsand and Nysted offshore wind farms and additional near-shore wind farms in the area.

Where can you find out more?

- See the background material for the needs analysis (in Danish): www.energinet.dk/el-baggrund2021
- The needs analysis is the starting point for possible future solutions which are set out here: www.en.energinet.dk/power-solutions2021

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