
ENERGINET
SYSTEM PLAN 2018
– ELECTRICITY AND GAS IN DENMARK

CONTENTS

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A HOLISTIC APPROACH TO ELECTRICITY AND GAS PLANNING

Energinet is the Danish state energy infrastructure company. It is an independent public enterprise that owns, operates anddevelops the Danish transmission systems for electricity and gas and parts of the gas distribution grid

1.1 Energinet's objectives and the political framework

Energinet's objectives are to safeguard the efficient operation and expansion of the grids, and to guarantee open, equal access for all users. New grids may be created and major changes may be made to existing grids if there is sufficient need for expansion, for example relating to security of supply, emergency planning, market competition or the integration of renewable energy.

The following chapters set out how factors such as security of supply, operation, and the market interact to influence the expansion and modification of the electricity and gas transmission grids. The long-term expansion of the grids is based on technical and financial considerations, but must also be seen in the context of the long-term Danish and European political objectives concerning energy and climate.

The general Danish context

The long-term political goal is for Denmark's energy supply to become fossil fuel free by 2050. Another objective is to make the Danish utility sector as cost-effective as possible in the interests of consumers and to improve Danish competitiveness. Alongside security of supply, these goals constitute the general Danish context in which Energinet will expand the grids and develop market models, security concepts and operating strategies in the short, medium and long term.

Initiatives to achieve the Danish political objectives are specified in energy policy agreements, the most recent of which is from June 2018. Such agreements can contain specific details of specific projects, for example expansion with renewable energy, and indeed this is encouraged. The political initiatives establish the framework in which Energinet works, in terms of construction activities, market development, security of supply and operating strategies.

Within this framework, Energinet has a duty to take the initiative to examine the socio-economic benefits of new initiatives, including expansion of interconnections with neighbouring countries, in order to integrate renewable energy, develop market competition, maintain security of supply and optimise operation over the long term.

The general EU context

Danish energy and climate policy is driven in large part by compliance with Denmark's international obligations on climate change, including in particular the EU's goals and initiatives. The EU has two energy initiatives with particular relevance to long-term development – ambitious climate targets and building an Energy Union.

By 2030 the EU plans to reduce total CO_2 emissions by at least 40 per cent compared to 1990. This should be seen in light of the long-term EU climate target to reduce CO_2 emissions by 80-95 per cent by 2050, which is now being reconsidered following conclusion of the Paris Agreement. The targets indirectly affect Energinet's analysis, planning and development

activities – for example converting the Danish transport sector and the electricity and heating sector to renewable energy will also affect the overall development of electricity and gas transmission grids.

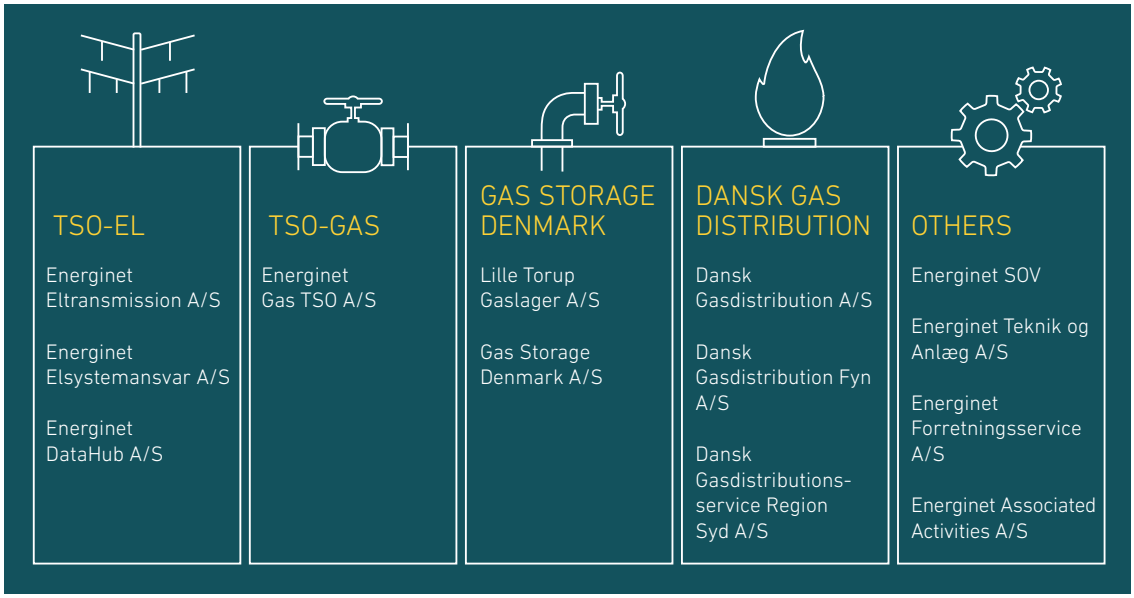
The other significant EU initiative is the Energy Union. The Energy Union focuses on security of supply, implementation of the internal market, energy efficiency, reduced climate impact and the promotion of research and innovation. These initiatives will have a direct impact on Energinet's analysis work, planning and development activities – for example security of supply is now also about regional cooperation between EU countries and better competition in Europe to push consumer prices down.

1.2 New organisation

On 1 May 2018, Energinet became a group with central corporate departments and independent legal service and business units, each with its own supervisory board and executive board. The purpose of the reorganisation was to improve transparency around decision-making and allow the Energinet group to perform its many and varied functions in a more focused and efficient way. It was a response to Energinet's growth in recent years as it takes on more and more duties and projects relating to the development and operation of the Danish electricity and gas grids and the electricity and gas markets.

These developments have increased the complexity of Energinet's overall portfolio of activities and the roles it has to perform, and they will continue to do so. This background of greater complexity partly explains why the group was more clearly subdivided into independent companies and legal units with their own supervisory board and executive board, each with its own particular business logic, mandates and problems to solve as they strive to achieve Energinet's vision of balance in a sustainable energy system.

FIGURE 1: ENERGINET'S SUBSIDIARY STRUCTURE AS OF 1 MAY 2018.



1.3 Analysis and planning

Energinet regularly analyses scenarios predicting how the transition to renewable energy in the Danish energy supply might develop. These long-term, holistic analyses across energy systems are key to ensuring reliable and efficient design and operation of the electricity and gas transmission grids in Denmark. Investments in energy systems, production plants and infrastructure are often long-term, large-scale investments. It is therefore important to carry out long-term analyses that can help to identify needs and solutions across energy sectors in order to minimise the risk of making bad investments in long-term energy infrastructure.

Long-term analyses

In the spring of 2018, Energinet published System Perspective 2035, a long-term scenario analysis which focuses on the opportunities and challenges related to the transition of Danish energy supply. System Perspective 2035 is based on extensive scenarios and modelling of the entire European energy system, because the energy supply system in Denmark is highly cross-border and international in nature. In 2019, too, this scenario and modelling complex is expected to form the basis for a number of detailed analyses that further explore issues from System Perspective 2035, and for new long-term analyses that examine the options for further market coupling of different energy sectors and its derived effects on the future energy infrastructure.

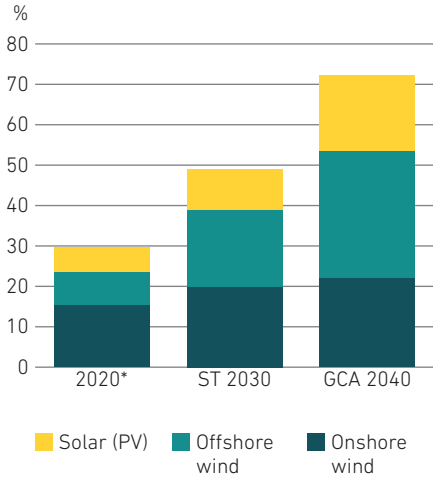
System Perspective 2035 is centred on three pan-European scenarios which present likely outcomes of the overall development in the European energy supply system – two green scenarios and one that is less green. Common to all three scenarios is that there will be much more wind power and solar energy in Europe, not least in North-Western Europe with large wind resources in the North Sea region. In Denmark, the proportion of electricity generated from wind and solar in 2020 is likely to reach 55 per cent of electricity consumption. As the entire region around Denmark approaches these levels, a wide range of measures will be necessary to integrate and utilise the large and fluctuating volumes of renewable electricity generated.

Integration in the electricity system is not enough on its own

Strong, international electricity transmission lines are still an important part of the solution, but with the share of wind power across the North Sea region set to increase significantly in future, this will not be enough on its own. And it is no simple matter to get permission to build new, high-power electricity transmission lines down through Europe.

FIGURE 2: EXPECTED RE GROWTH BASED ON ENTSO-E SCENARIOS.

*2020 is derived from Energinet's Analysis Assumptions 2017. Sustainable Transition (ST) 2030 is the ENTSO-E/ENTSOG scenario for 2030 with the least renewable energy, and Global Climate Action (GCA) 2040 is the scenario for 2040 with the most renewable energy. For more, please see the System Perspective 2035 report.



Electricity storage in batteries will be able to smooth out electricity production over several hours, making better use of the infrastructure. But even with the price of batteries falling sharply, it is not likely to be financially viable to store generated electricity for days rather than hours.

Electricity generated from wind and solar to be utilised in other energy sectors too

A central part of the solution is to utilise the green, cheap and abundant electricity in other energy sectors. Power-to-heat and power-to-transport are important elements in this electrification process, and combined with electric vehicles and heat pumps, they are expected to deliver significant energy efficiency improvements and

replace significant quantities of fossil fuels in the years to come.

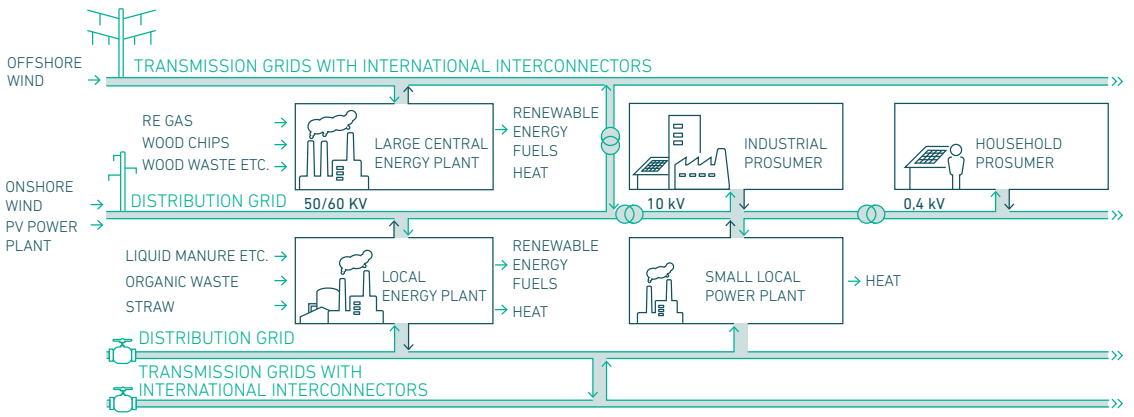
Power-to-high-value products are not quite as mature, but there is major potential. With power-to-gas (PtG), electrical power is converted to hydrogen by means of electrolysis, and the hydrogen can then be used directly, transported in a hydrogen grid, injected or methanised for the (methane) gas system, converted into high-value energy products such as liquid fuels, fertilisers, plastics, etc. Sources of carbon for high-value hydrocarbon products include CO_2 from biogas upgrading and, looking slightly further ahead, carbon from thermal gasification, CO_2 capture from industry (e.g. cement plants) or possibly direct air capture.

The analyses in System Perspective 2035 suggest that electrolysis/PtG/PtX can not only give the electricity system great flexibility in terms of consumption but can also transform large volumes of renewable electricity generated from wind and solar into essential high-value products traditionally based on fossil gas and oil. The analysis also indicates that Denmark occupies a position of competitive strength in the transformation of green power into high-value energy products that can be sold in the international market: plenty of wind in the North Sea region, competitive electricity prices, a district heating system that can use surplus heat, lots of experience handling biomass in the energy sector, etc.

Large and small prosumers will support each other
A steadily increasing proportion of our energy is expected to come via the electricity system as a cheap and plentiful supply of renewable electricity generated from wind and solar in particular. The transition to an efficient energy system based on renewable energy is therefore expected to be achieved by means of comprehensive electrification and sector coupling. To efficiently integrate such large volumes of fluctuating wind and solar power, the electricity system needs much greater demand-side flexibility than today.

System Perspective 2035 suggests that much of this flexibility can come from so-called energy plants, which can consume electricity, e.g. for electrolysis or heat pumps, when renewable electricity generation is cheap and plentiful, but can also generate electricity in periods of high demand. This means that energy plants are flexible large-scale prosumers. Households and businesses are increasingly expected to have their own solar cells and perhaps local battery storage. They will therefore become small prosumers generating much of their own electricity, especially during the summer months. Small prosumers are not expected to go completely off-grid, however, as this would be very expensive. The analysis

FIGURE 3: THE POTENTIAL ROLE OF ENERGY FACILITIES IN THE 2035 ENERGY SYSTEM.



suggests that large scale solutions and distributed supply solutions will support each other. In the summer, surplus electricity from distributed solar cells can be used in energy plants, and in the winter, wind power from large onshore and offshore wind turbines can be used to supply small prosumers.

Analysis assumptions for electricity and gas

Energinet's task of developing the infrastructure of the Danish electricity and gas system according to long-term and holistic planning is based on analysis assumptions about the future development of the energy system.

The analysis assumptions describe developments in detail until 2040 in terms of prices, consumption, and production and transmission capacity in the electricity and gas system chiefly for Denmark, but also to some extent for Denmark's neighbouring countries. The analysis assumptions are intended for use by Energinet, but are published to give stakeholders an insight into Energinet's assumptions about the future energy system. Energinet used to be responsible for preparing the analysis assumptions, but in the 2017 Danish Finance Act (finansloven), the government decided to transfer responsibility to the Danish Energy Agency. The aim was to involve the authorities in the decision-making process at an earlier stage and to improve the legitimacy of Energinet's investment decisions.

"If Denmark is to achieve the political goal of a fossil fuel free energy system by 2050, it will be necessary to discover new knowledge and create new solutions'"

The Danish Energy Agency expects to release the 2018 analysis assumptions to Energinet in late 2018, and the particular expectations arising from the energy agreement of 29 June 2018 will be included as changes compared to previous analysis assumptions.

Strategic investment plan

Energinet is facing the introduction of a new regime of financial regulation. Part of the new regime is rooted in the Danish government's supply strategy from 2016, in which Energinet was asked to create a 'multi-year economic investment plan on the basis of long-term development plans. The plan constitutes the financial framework for Energinet.dk's investments.' The investment plan was later renamed the strategic investment plan (SIP).

Against this background, Energinet is working closely with the Danish Energy Agency and the Danish Ministry of Energy, Utilities and Climate to develop

a concept for the SIP. A key goal of the SIP will be to increase the transparency of Energinet's decisions to invest in new electricity and gas infrastructure. The investments must be designed to safeguard security of supply, incorporate more renewable energy and develop the energy markets. Moreover, the SIP is expected to become a central element in the future financial regulation of Energinet.

The strategic investment plan will be based on the analysis assumptions announced by the Danish Energy Agency, and the first SIP is expected to be created in 2019.

1.4 Research and development

If Denmark is to achieve the political goal of a fossil fuel free energy system by 2050, it will be necessary to discover new knowledge and create new solutions.

Energinet owns and operates Denmark's main electricity and natural gas grids, and safeguards security of supply in Denmark. In the period up to 2050, Denmark has the political goal of a fossil fuel free energy supply. More renewable energy can only be integrated with continuous improvement of the existing system and with completely new solutions. Knowledge-sharing is crucial in driving development and finding new solutions. This is true of day-to-day challenges as well as the longer-term challenges which come from being part of the Danish and European energy sector.

Integrating the remaining share of renewable energy will be complicated. In the years to come, there is no doubt that the energy sector will need to create and share new knowledge and find new solutions to an even greater extent than today. The existing solutions are no longer up to the task. Not just Denmark, but Europe is facing the same challenge. In the years to come, in Energinet and throughout the energy sector in Europe, we will need to work on our development activities in a more focused way. We need to find entirely new solutions, compelling us to use experimental and theoretical approaches to gain new knowledge and understanding. We need to learn from our practical experience in a systematic way, and collaborate with others to achieve continuous improvements. And we need to keep trying, failing and pushing the boundaries to find the required solutions. Energinet must work alongside the other energy stakeholders to cover the entire development spectrum, including research, development, demonstration and innovation (R&I).

Energinet is now a group with genuine subsidiaries which carry out their own F&I activities to guarantee relevance to the particular challenges facing each subsidiary. As part of R&I, Energinet addresses trends, analyses, challenges and opportunities which are all important for electricity and gas systems in the long term. The activities are coordinated across subsidiaries, too, which is essential for consistency, knowledge sharing and efficiency.

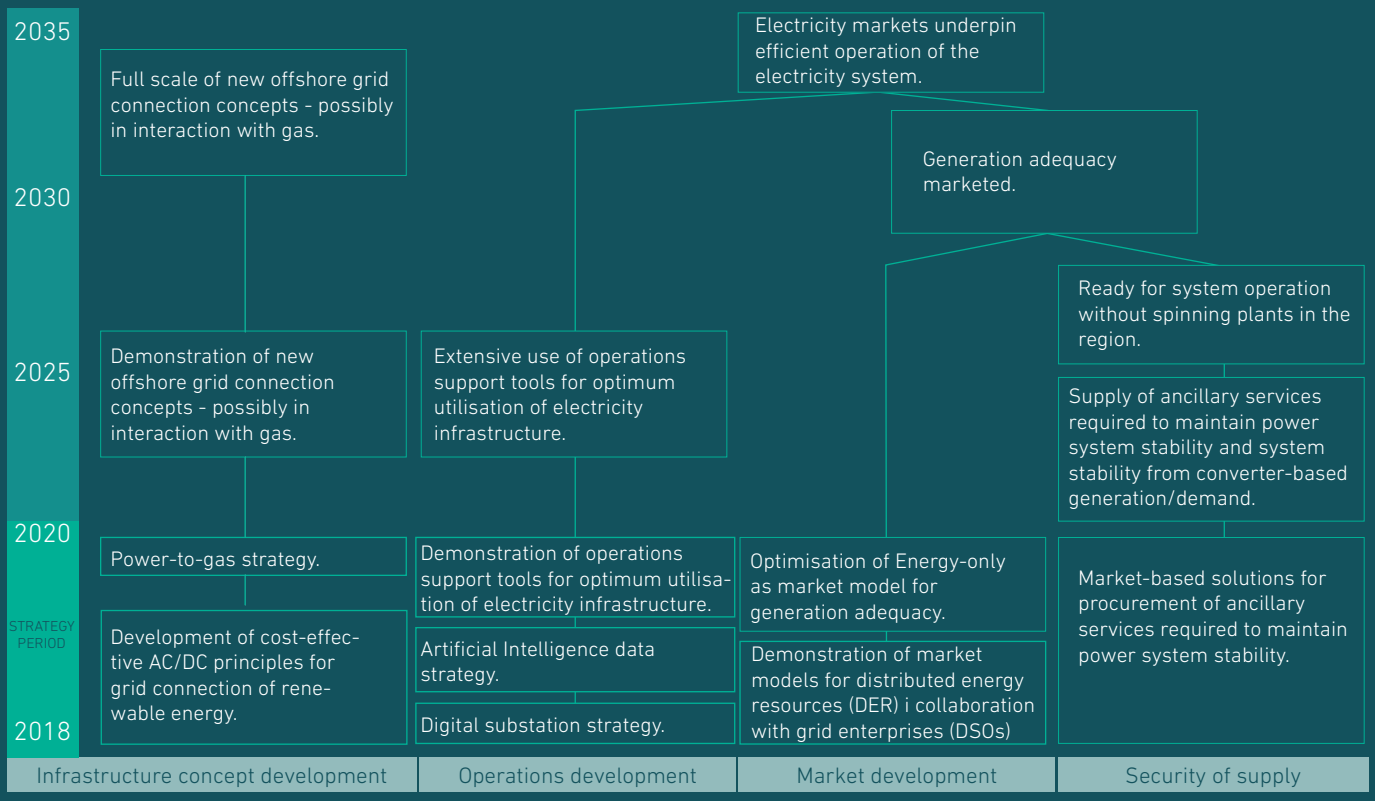
"Energinet must work alongside the other energy stakeholders to cover the entire development spectrum, including research, development, demonstration and innovation'"

More small-scale collaborative projects

Energinet's R&I activities are focused on the short term as well as the long term. The rapid pace of technological development means we have increased the number of small-scale and demonstration projects in Energinet. This approach can produce results more quickly and minimise risks, and allows closer collaboration on specific solutions. This links the short term and long term together. The approach also helps to prove or disprove new ideas quickly.

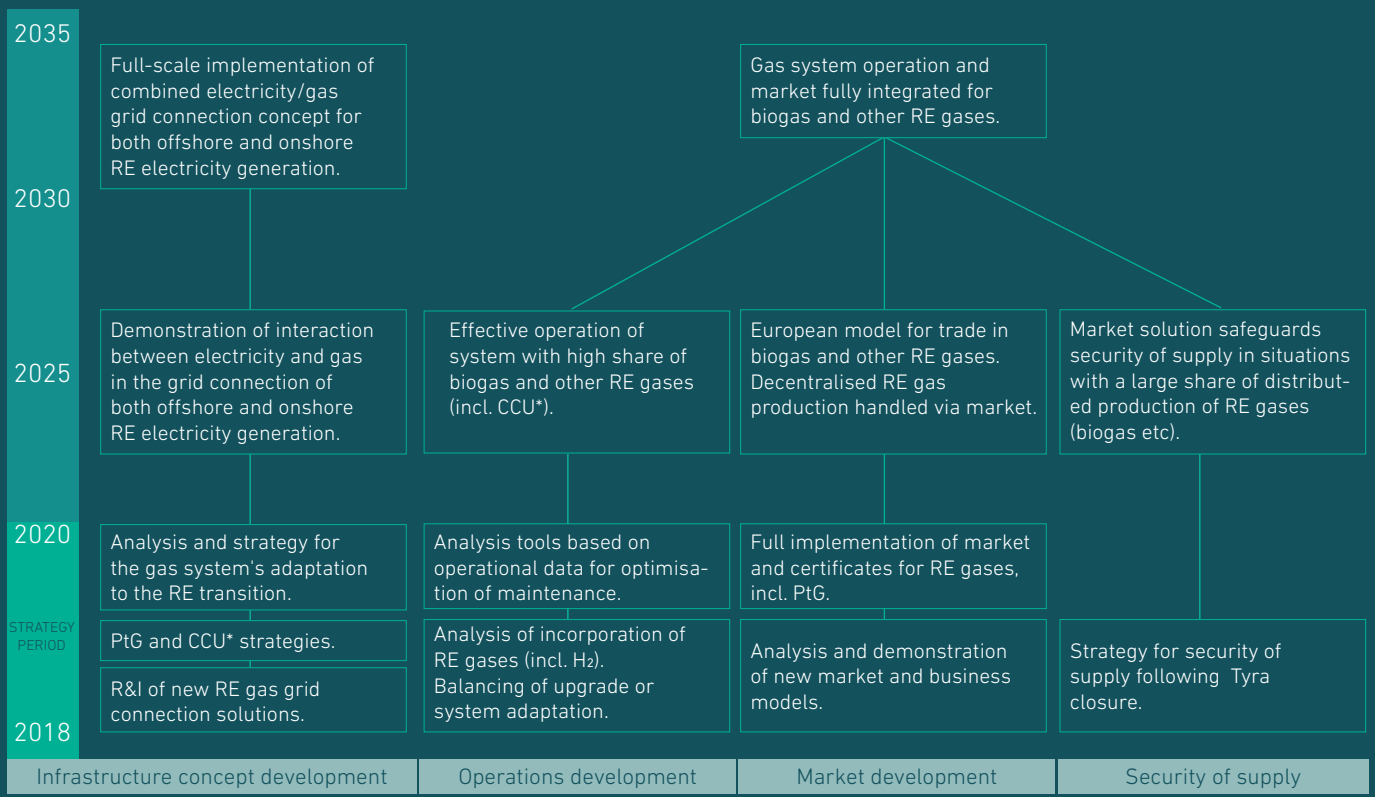
The R&I activities are generally aimed at increasing value creation in Energinet's core activities by finding new ways to perform the activities in a smarter and more efficient way. The main focus is on development of the electricity and gas infrastructure, development of data and digitisation, development of operation, flexibility and storage, the green gas transition, standardisation and optimisation, and integration across energy systems (sector coupling). The long-term points of reference for the R&I activities are summarised in figures 4 and 5.

FIGURE 4: R&I PERSPECTIVES FOR ELECTRICITY.



*DER - Distributed Energy Resources

FIGURE 5: R&I PERSPECTIVES FOR GAS.



*In this context, PtG and CCU are Power-to-Gas and Carbon Capture & Utilisation (CO_2), respectively.

FIGURE 6: CHANGE IN ELECTRIC CAPACITY FROM 2016 TO 2017

Electricity output according to main fuel	2016	2017	Change
Wind	5,250	5,497	247
Solar	845	908	63
Hydroelectric	7	7	0
Biogas	118	118	0
Biomass	1,507	1,582	75
Waste	351	351	0
Natural gas	2,151	2,150	-1
Oil	722	723	1
Coal	1,604	1,567	-37
Other	26	26	0
Total	12,581	12,929	348

The plans should not be regarded as hard and fast, but as moving points of reference. They should be interpreted in light of a society and a sector in constant flux, where network codes, operational collaborations, common balancing rules, market coupling and regional adequacy calculations are crucial in determining how we will achieve a fossil fuel free energy system by 2050. The dynamic between the here and now and the bigger picture in research and innovation allows the direction of Energinet's current activities to be adjusted in a transparent way to reflect the long-term transition activities and general developments in the energy system.

1.5 Environmental reporting

Every year on 1 May, Energinet publishes an environmental report setting out developments in Danish electricity and CHP generation and the principal environmental impacts in the form of fuel consumption, production of residues and atmospheric emissions. The environmental report consists of a situation report covering the previous year and a forecast for the next 10 years. The following atmospheric emissions are included in Energinet's environmental reporting:

- Greenhouse gases: carbon dioxide, methane and dinitrogen oxide.
- Acidifying gases: sulphur dioxide and oxides of nitrogen.
- Other emissions: particulates, unburned hydrocarbons other than methane and carbon monoxide.

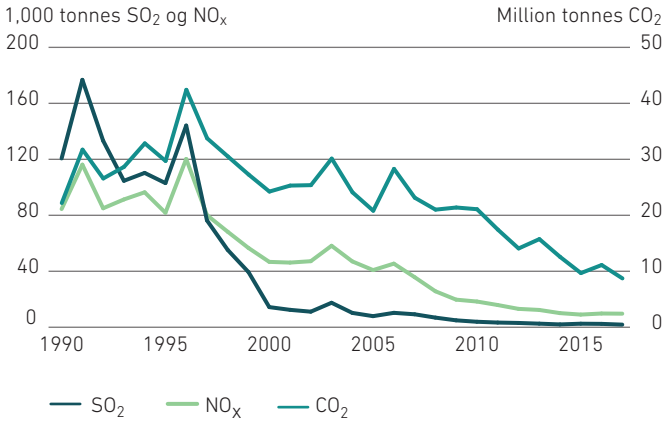
Every year, Energinet collects environmental data from the largest Danish electricity producers for inclusion in the environmental report. As a result, Energinet receives environmental data for facilities that collectively represent about 91 per cent of total Danish thermal electricity generation. Energinet estimates the data for the remaining plants based on generation conditions from previous years.

Energinet's environmental report has helped to document the expansion of renewable energy in the electricity supply industry, and, importantly, the reduction of acidifying gases produced by the electricity supply industry. Development in recent years has also seen a downward trend in thermal electricity generation based on fossil fuels in Denmark, and consequently also in CO_2 emissions from the electricity supply industry. This is expected to continue in the forecast period of the environmental report.

In 2017, thermal electricity generation based on fossil fuels was at its lowest-ever level in the historical period for which data is available (1990 onwards). The shift from fossil fuels to renewable energy generation is reflected in the changes in electricity generation capacity in figure 6.

In 2017, biofuels (biomass and biogas) were the most commonly used fuels in Danish power stations, overtaking coal for the first time. The biomass conversion of several primary power stations is a major factor in the reduction of CO_2 emissions from Danish electricity and CHP generation by around 22 per cent from 2016 to 2017.

FIGURE 7: CHANGE IN CO_2, SO_2 AND NO_X EMISSIONS FROM DANISH ELECTRICITY AND CHP GENERATION.



"The decrease in SO_2 emissions since 1990 can be attributed to the use of fuels with a lower sulphur content and the installation of desulphurisation units at the large power stations and waste incineration plants"

Energinet also uses the data basis underpinning the environmental report to calculate the annual environmental impact statement for electricity and the annual electricity labels. The environmental impact statement sets out the average environmental impact of consuming one kWh of electricity, and is commonly used by companies in their environmental reports. Electricity labels are prepared on the basis of the Danish Executive Order on Electricity Labelling (elmærkningsbekendtgørelsen), which obliges electricity suppliers to provide information about the environmental benefits of the electricity they sell to their customers.

According to the most recent national statement for all sectors from the Danish Centre for Environment and Energy (DCE) from 2016, out of total Danish emissions of CO_2, SO_2 and NOx, the Danish electricity supply industry contributes 31 per cent, 24 per cent and 9 per cent respectively. The development in emissions of these three substances from Danish electricity and CHP generation in the period 1990-2017 is shown in figure 7. Since 1990, emissions of CO_2, SO_2 and NOx have fallen by 61 per cent, 98 per cent and 89 per cent respectively.

The decrease in SO_2 emissions since 1990 can be attributed to the use of fuels with a lower sulphur content and the installation of desulphurisation units at the large power stations and waste incineration plants. SO_2 emissions are so low that fluctuations in generation from individual power stations are clearly discernible. Despite the general improvements in the sector as a whole, increases in emissions are therefore possible in some years. NOx emissions have primarily been reduced through the installation of deNOx units and low-NOx burners at the large power stations. Through to 2027, SO_2 and NO_X emissions are expected to remain at a consistently low level. CO_2 emissions reflect changes in the use of fossil fuels at the Danish power stations, and substantial variations are therefore seen in the historical values, depending on Denmark's electricity trading with neighbouring countries.

1.6 Energy efficiency

The EU's Energy Efficiency Directive 2012/27/EU mandates the Member States, among other things, (a) to undertake an assessment of the energy efficiency potentials of their gas and electricity infrastructure, and (b) to identify concrete measures and investments for the introduction of cost-effective energy efficiency improvements, see Article 15(2).

Electricity transmission

Energy efficiency in the power grid is about issues including reducing the

FIGURE 8: TRANSMISSION LOSS IN THE ELECTRICITY TRANSMISSION GRID INCLUDING INTERCONNECTORS (HVDC).

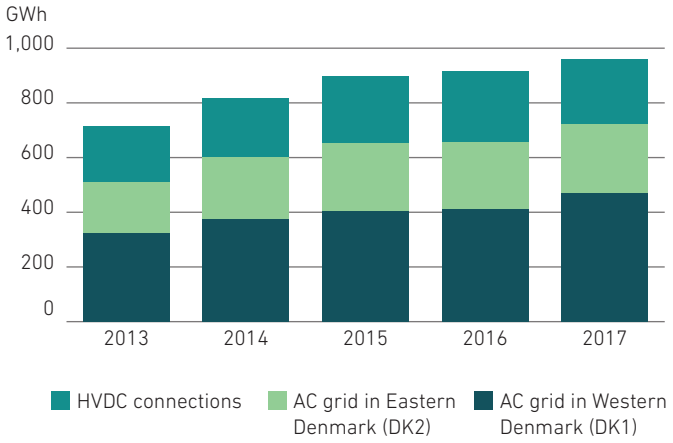
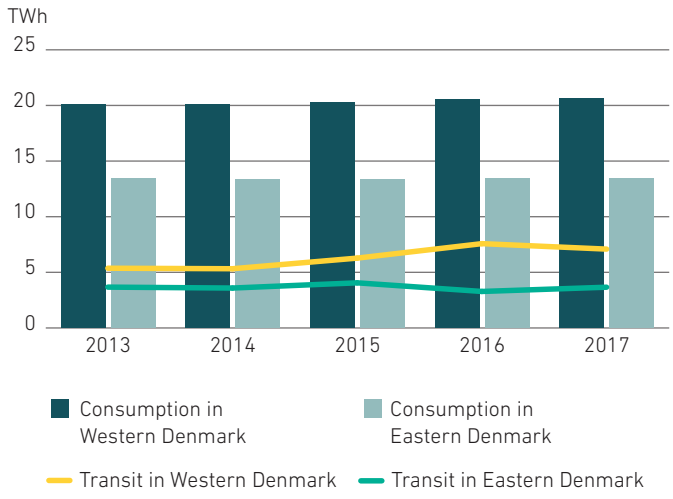


FIGURE 9: CHANGE IN GROSS ELECTRICITY CONSUMPTION AND TRANSIT IN DENMARK.



energy lost during transfer from the production facility to the consumption site. The loss is caused by the development of heat in the components, and this loss of energy in the electricity grid is known as transmission loss.

Transmission loss in the electricity transmission grid is heavily influenced by transit through the Danish electricity system, caused by trade between the Nordic and Central European electricity markets. In terms of the physics, transmission loss increases in proportion to the square of the load. The greater the transit load, the higher the transmission loss. Previous studies have shown that in practice, the transmission loss increases by up to a factor of four from no-transit situations to full-transit situations.

Transmission loss in the electricity transmission grid is the result of power transmission through the grid components plus the no-load loss. The average transmission loss in the electricity transmission grid over the past five years has been estimated at 2.5 per cent of gross electricity consumption in Denmark.

Assessment of energy saving potential in electricity transmission

Energinet pays for the transmission loss in the 132 kV, 150 kV and 400 kV grids, half the transmission loss in the HVDC connections to Norway and Sweden, and a third of the transmission loss in the HVDC connection to Germany. In the period 2013 to 2017, the transmission loss was between 700 and 1,000 GWh as shown in figure 8. Transmission loss has been increasing due to the commissioning of the 400 MW offshore wind farm at Anholt in 2013 and the commissioning of the 700 MW Skagerrak 4 connection at the end of 2014.

The increase in the transmission loss in Western Denmark is also explained

by the increase in transit, which grew from about 5.4 TWh in 2013 to about 7.1 TWh in 2017. This corresponds to 27 per cent and 34 per cent of gross electricity consumption in these years respectively. In addition, the current trend is that electricity is not consumed where it is produced, but instead has to be moved through the electricity transmission grid, inevitably increasing transmission loss.

Energinet is the Danish transmission company, and as such it is under an obligation to incorporate energy-efficient solutions in its transmission planning. In this connection, the planning process uses a method which assesses the economic value of individual projects. Losses in the transmission grid are included as a factor in the economic assessment of transmission projects alongside capital costs and operating expenses. The eventual solution is assessed in its entirety. This guarantees consumers the lowest possible transmission tariffs by implementing cost-effective and energy-efficient improvements in the grid infrastructure. The cost-effective and energy-efficient improvements are therefore implemented continuously in all transmission projects in Denmark.

Analysis of energy consumption and transmission loss in the electricity transmission grid
Transmission loss is very difficult to measure in practice, so it is calculated as the difference between the energy added (production, infeed from the distribution grid and imports from other countries) and energy removed (consumption, offtakes for the distribution grid and exports to other countries) in the electricity transmission grid.

Losses result from power transmission through the grid components (load loss primarily in the transmission lines and transformers), and from no-load loss (primarily in transformers and reactors) in the grid. No-load losses are virtually independent of the electricity consumption in the system, and even though they are smaller than the load losses in terms of power, they occur in full whenever the components are energised, which they usually are throughout the year except during inspection and maintenance. The components are kept activated throughout the year to allow grid failures to be managed by diverting the flow of electricity to consumers if necessary. Load losses are proportional to the square of the power transported.

All else being equal, as Denmark's electricity system is increasingly integrated with neighbouring countries, the transmission loss is expected to rise. Transmission loss likewise increases when new production capacity is located further away from the consumers, meaning that the transmission grid must be used more if the output is not consumed locally. This is already evident today with offshore wind farms, for example.

Efficiency potentials in the operation of existing grids
The energy efficiency initiatives in the transmission grid described below are usually initiated as positive side-effects of other initiatives. In the existing grid, the cost of investment is usually greater than the savings in terms of transmission loss. On the other hand, there are some measures which could reduce transmission loss, but which Energinet chooses not to carry out as they would have a negative impact on the security of electricity supply. For example, synchronous condensers could be turned off, but this has been shown to affect the operational reliability of certain HVDC connections.

The need for voltage-regulating components in the electricity grid is constantly monitored. If there is no need for certain voltage-regulating components during a particular period, it may be useful to turn them off and thereby reduce the transmission loss.

Reactive power controllers
Among the initiatives that Energinet is working on are the so-called reactive power controllers (RPCs). RPCs facilitate proper functioning of the electrical system by connecting and disconnecting reactive components. This helps to maintain an optimal reactive balance and prevents overvoltages in the electrical grid. Higher utilisation of voltage regulation from new wind farms also helps to maintain a constant voltage level.

For now, implementation of automation is only done locally to address local challenges. But Energinet's long-term ambition is to implement automatic optimisation of flows and voltage using centralised calculations for the overall transmission grid. This would not substitute decentralised control, but merely supplement it. For the time being, though, the reduction in transmission loss solely as a result of investments in automation can not outweigh the investments. is not outweighed by the savings.

Implicit transmission loss
As things stand, the optimization algorithms used in electricity markets do not take into account that there is a cost (transmission loss) associated with transporting energy between price areas. This means that in hours during which exchanges take place between price areas, and there is little or no price differences, there is an economic loss.

If transmission loss is included in the optimization algorithms used by the exchanges (implicit loss handling), the economic losses associated with transporting energy will be taken into account when capacity is allocated. In practice, this will be done by including a loss factor expressing the percentage of the energy lost during the exchange. This means that before any exchange can take place, the marginal welfare gain (the price difference between the areas) must be greater than or equal to the marginal welfare loss from transporting the energy.

Energinet has applied to the Danish Utility Regulator to introduce implicit transmission loss, which is expected to happen for the first time in the Skagerrak connection at the end of 2019.

Efficiency potentials in grid expansion
Energinet uses a general method to assess projects in the Danish transmission grid. The projects are assessed on the basis of their economic value, and losses in the transmission grid are included as a factor in the economic assessment of a project. Apart from losses, capital costs and operating expenses are considered for all Energinet projects (for example the landing facilities for offshore wind farms).

"The Energinet group has set itself an official target to reduce methane emissions by 10 per cent in 2020 compared to the 2015-2017 average"

Losses are primarily determined in two stages in the analysis of new projects. As a project matures, several alternative ways to achieve the project goal are considered, and losses of the relevant equipment (transmission lines, transformers and reactors) are included in the assessment of the costs of the different solutions analysed. The losses are also assessed on the basis of the anticipated load curve according to the location of the component in the grid. However, the solutions are assessed as a whole, so a solution with lower losses is rejected if the total value of a solution with higher losses is found to be better.

When components for construction projects (transmission lines, transformers and reactors) are put out to tender and procured, the process also considers whether it is worth optimising the losses for the components. If the value of the loss reduction exceeds the investment costs, the procurement process seeks to find the most attractive overall economic solution.

Gas transmission
The 2015 assessment of the energy efficiency potentials of the electricity and gas infrastructure in Denmark, which was produced to meet the requirement in point (a), states that the energy loss in the Danish gas grid is very low (about 0.05 per cent of total gas consumption). The report shows that no significant potential efficiency improvements can be identified that have not already been implemented in ongoing operations, although it does indicate that energy savings are possible by reducing gas preheating at the meter and regulator stations.

This happens on a regular basis by adjusting the boiler control to minimise the margin between the minimum outlet temperature of the gas supplied from the meter and regulator stations and the setpoint temperature, thereby reducing fuel gas consumption. In addition, the replacement of the 1980s boilers in the remaining meter and regulator stations is expected to be completed in 2019.

MRNewtech is another initiative, in which densitometers are removed and replaced with calculated values (a densitometer is a measuring instrument that measures the gas density). Densitometers release a small amount of gas, so the substations that have undergone MRNewtech have managed to reduce their gas leaks.

Continued focus on energy efficiency
All in all, major projects such as biogas return, the shutdown of Tyra, and potentially Baltic Pipe will have an impact on natural gas emissions and the electricity consumption of compressors. The Danish Natural Gas Supply Act (lov om naturgasforsyning) requires Energinet to safeguard efficient gas transport and financial resources through holistic planning. This means that new construction projects must take due account of economic and environmental factors, and that gas grid operation must be optimised on an ongoing basis, with components routinely replaced with more energy-efficient models during operational maintenance.

The Energinet group has set itself an official target to reduce methane emissions by 10 per cent in 2020 compared to the 2015-2017 average. A detailed action plan is currently being prepared and is expected to be finished by the end of 2018.

ELECTRICITY

New electricity supply legislation means that from June 2018, a different legal framework applies to the work Energinet does around security of supply

As of June 2018, the Danish Minister of Energy, Utilities and Climate assumes overall responsibility for security of electricity supply and specifies the level. According to the new legislation, Energinet is responsible for maintaining the specified level of security of electricity supply and to monitor changes.

Cooperation within the EU and within the Nordic region is becoming increasingly important for the Danish energy system. European grid development planning must be closely coordinated with Danish planning. Very significant investments will be needed in future in the European and the Danish power grids, and close cooperation between countries is a high priority so that all stakeholders can share in the rewards.

The same is true of market issues at the present time. In both the Danish and European context, the market has been identified as the central factor that will drive development of the energy system towards independence from fossil fuels. Market formation, data and digitisation will propel the future development of the energy system.

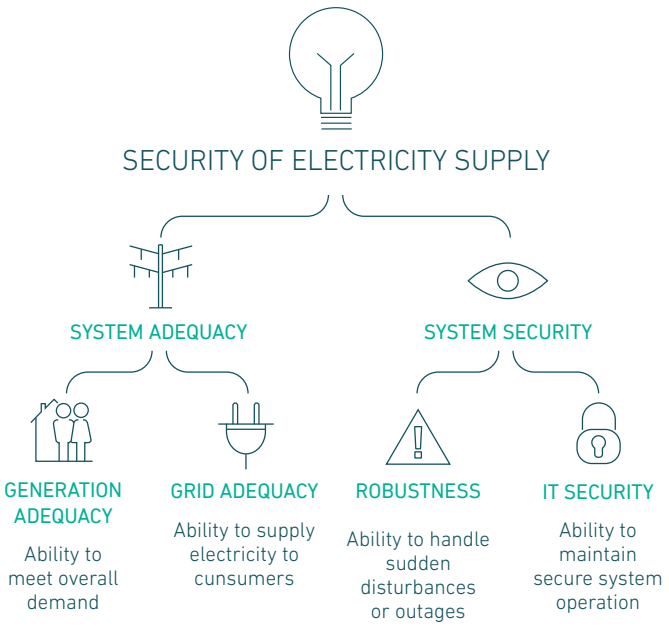
The pan-European network codes, which establish the scope and framework for markets, operation and grid connection, are currently being implemented. This is a crucial step in the process of developing the energy system – not only must the initial implementation succeed, but continuous development will also be necessary as technologies change.

In the cooperation with other grid operators, the relationship between the distribution grid and the transmission grid will be extremely important in the years to come. Technological development, alongside a greater emphasis on distributed electricity generation, will make cooperation between the two grid levels even more important in order to maintain security of supply for maximum economic benefit and to effectively integrate renewable energy.

Also in the years ahead, it will become necessary to expand the transmission grid. In most of Jutland and in South Zealand and Lolland-Falster, this will mainly involve integration of electricity generation from renewable energy facilities. On the islands, Copenhagen is in particular need of reinvestments and expansions due to higher electricity consumption combined with the declining importance of thermal power stations. At present, reinvestment projects account for approximately a quarter of the total planned investments in the transmission grid, and in future, reinvestment projects are expected to make up a steadily increasing proportion of overall investments.

In terms of installations and maintenance, the focus is on Viking Link, the West Coast Connection, the connection between Endrup and Idomlund, and the replacement of end-of-life grid components that were installed in the 1960s and 1970s. Installations and reinforcements will also be necessary as new data centres are added, which by Danish standards are very large electricity consumers.

FIGURE 10: ILLUSTRATION OF SECURITY OF ELECTRICITY SUPPLY, WHICH CONSISTS OF SYSTEM ADEQUACY AND SYSTEM SECURITY.



2.1 Security of electricity supply

According to the Danish Electricity Supply Act (lov om elforsyning), Energinet is responsible for maintaining the specified level of security of electricity supply and to monitor changes. Security of electricity supply is defined as the probability that electricity will be available to consumers when they need it.

In its efforts to maintain the level of security of electricity supply and to monitor changes, Energinet uses a model that splits the security of electricity supply into two main elements. These two elements address the adequacy of the electricity system and the security of the electricity system, referred to as system adequacy and system security respectively.

In assessing system adequacy, Energinet examines whether the electricity system has enough electricity-generating units to meet demand for electricity in Denmark, and whether the power grid is capable of carrying the electricity. These elements are referred to respectively as power adequacy and grid adequacy.

System security, on the other hand, addresses whether the electricity grid can be operated reliably. This element examines changes in system resilience to component failures and breakdowns – components in the grid as well as critical IT systems – and the capacity to maintain reliable operation of the system.

Security of electricity supply is therefore an interaction that changes with differing demands on the electricity system. For example, the green transition alters the relationship between types of electricity-generating units, with more fluctuating electricity generation (e.g. wind turbines) and less dispatchable electricity generation (e.g. large power stations). Energinet is therefore constantly working to develop and specify methods to monitor and assess changes in the security of electricity supply.

Control center, Erritsø, Southern Denmark

Security of Electricity Supply Report
Energinet presents historical and forecast assessments every year in the Security of Electricity Supply Report, which has been published since 2015. The report has its roots in the recommendations of the Committee for the Regulation of Electricity (Elreguleringsudvalg) and the 2015 report entitled 'Security of electricity supply in Denmark' (Elforsyningssikkerhed i Danmark), which covers methods, concepts and calculations around security of electricity supply in Denmark. This report was prepared by the Danish Energy Agency with input from key players in the electricity sector. It contains recommendations about the reporting of security of electricity supply, including the way generation adequacy forecasts will be calculated in future.

In the summer of 2018, the Danish Electricity Supply Act was amended to state that Energinet must prepare an annual Security of Electricity Supply Report. The report is not, however, expected to differ significantly from previous editions of the Security of Electricity Supply Report. This is because previous editions were based on the recommendations in 'Security of electricity supply in Denmark', most of which have now been incorporated into the Danish Electricity Supply Act. Even so, the report is expected to be more comprehensive in selected important areas. For example, Energinet's method of assessing generation adequacy is expected to be developed as described in the 2018 Security of Electricity Supply Report. In addition, the light shed on generation adequacy will probably reveal several sensitivities and alternatives to improve the way recommendations are given.

Method development in connection with security of electricity supply
Among the new initiatives, Energinet must from now on provide recommendations on the future level of security of electricity supply. The Minister for Energy, Utilities and Climate sets the level on the basis of the recommendations. This is expected to improve transparency and increase the acceptance of the chosen level of security of electricity supply. The report also goes out to four weeks of public consultation.

Energinet must also prepare relevant alternatives to the generation adequacy forecast so it includes factors such as the anticipated changes to the security of electricity supply and an assessment of the economic costs and benefits of specific initiatives. Value of Lost Load[1] indicators must be incorporated to describe the costs associated with the forecast.

[1] Value of Lost Load, abbreviated VoLL, is a financial indicator that expresses the cost of interrupted supply, and is normally stated as DKK/kWh.

Generation adequacy assessments
Until now, Energinet has used the FSI (Forsyningssikkerhedsindeks) model but expects to move to the Better Investment Decisions (BID) model going forward.

The BID model is an electricity market model which, among other things, can be used to assess generation adequacy. The model carries out simulations of the electricity market across Europe, thus reflecting Denmark's links to its neighbours.

Outages of power stations and interconnectors are stochastic elements. The model calculates generation adequacy in all modelled price areas, thus incorporating the impact of foreign generation adequacy on Danish generation adequacy. The model can also handle flexible electricity consumption directly, which is one of the recommendations in 'Security of electricity supply in Denmark'.

BID is used by the other Nordic TSOs, as well as in ENTSO-E's Midterm Adequacy Forecast[2], which gives Energinet greater opportunity to use the results both nationally and internationally.

One of the main differences between FSI and BID is that BID incorporates both modelling of the power situation throughout Europe and compulsory heat production for power stations. FSI only models selected neighbouring areas, with the other areas modelled with a probability of availability. In addition, the increased regional cooperation in Europe, for example in Nordic RSC[3], makes BID's assumptions about perfect coordination between neighbouring countries more reasonable than before, when things like inspection and maintenance plans were prepared according to different processes and time frames in each country. Although coordination in Europe is expected to improve, it is not likely to be perfect. BID's assumptions about perfect coordination will therefore be a focus point in the interpretation of BID results.

More detailed modelling of other countries and thus a larger geographical area could mean more or less available power compared to FSI, but is expected to result in more available power through more coordinated use of capacity in Europe in future. BID is therefore expected to estimate a lower probability of power shortage than FSI.

Precision in the assessment of generation adequacy in the future therefore depends on the assumptions and on developments in the electricity system nationally and internationally. For example, in the assessment of generation adequacy, Energinet has included an increased risk of deficient system security due to power shortages, and as the model covers a larger geographical area, the assessment of generation adequacy in Denmark will increasingly vary according to the available power in Europe.

Grid adequacy
With regard to grid adequacy, Energinet is starting to look at new methods to assess the possibility of constraints in the electricity transmission grid within Denmark, including several probabilistic assessments. This should be seen as complementing Energinet's grid dimensioning criteria, which seek to ensure that situations of deficient grid adequacy and system security cannot occur. To a large extent they define the scope and framework for the expansions and reinvestments necessary to maintain security of supply and the quality of the supplied electricity. The criteria specify, for example, that supply must be maintained in the presence of any grid defect without affecting neighbouring TSOs and without disconnecting consumers. In addition, the transmission grid must be resilient to a possible subsequent fault without causing further outages.

In the interface between the electricity transmission grid and the electricity distribution grids, new methods must also be developed as a result of the Demand Connection Code (DCC). One example is the exchange of reactive power between the electricity

[2] Within the ENTSO-E framework, a comprehensive European level risk assessment of generation adequacy is carried out. Results are reported annually in the Mid-term Adequacy Forecast (MAF) report.

[3] Nordic RSC stands for 'Nordic Regional Security Coordinator' and is a joint office located in Copenhagen, where employees across the TSOs in Finland, Norway, Sweden and Denmark collaborate to resolve a number of operational issues.

transmission and distribution grids, for which methods must be developed for the planned expansion of reactive components in the grids and requirements must be specified for the physical flow of reactive power during operation.

Coordination of the expansion of reactive components in both grids is intended to ensure that there are no areas with overexpansion and no areas with a shortage of reactive components. In grid operation, too little or too much reactive power can have a major impact on the voltage in the electricity grid and therefore on security of supply.

Resilience

As part of the new concept for the Security of Electricity Supply Report, Energinet must specify a total estimated level of annual outage minutes[4] for the entire Danish electricity system. This includes the output minutes from the BID calculations and the expected number of outage minutes from other outages.

Energinet has not specified expected outage minutes before, so it needs to develop new methods to predict or assess the development of future outage minutes. The forecast for future outage minutes must include an assessment of the number and duration of future disconnections of electricity consumers and the annual electricity consumption.

Disconnections due to deficient system security are difficult to predict because the risk of failure is very low, but the consequences can be very serious. Some years are therefore expected to have only a few outage minutes, and others are expected to have many.

IT security

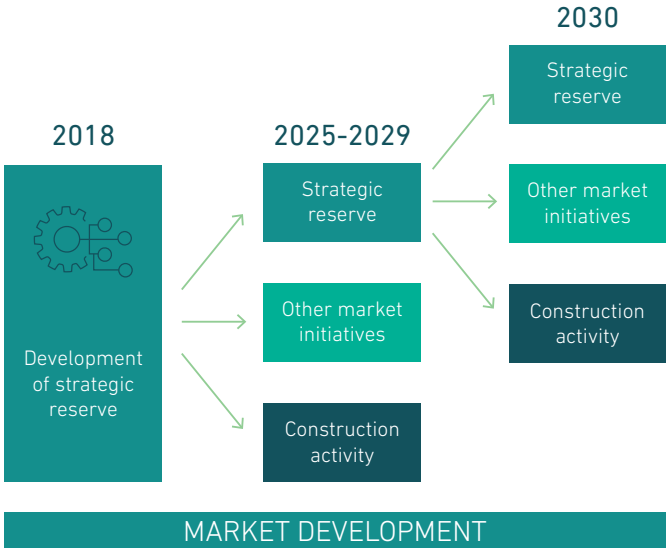
IT systems are increasingly being used to monitor and control components in the electricity supply industry. This greater dependence on IT makes the electricity system more vulnerable if IT systems are unavailable or faulty. This applies not only to Energinet systems but also to systems in the distribution and generation companies and balance responsible parties, which handle many generation facilities.

In 2016, the Danish Energy Agency revealed a number of issues that might make it more complicated and difficult to address cyber security in the sector. Some of the issues arise because the exchange of data between players creates a dependency that can be difficult to evaluate in terms of risk. In addition, local circumstances and internal processes within companies indirectly create challenges for overall communication in the sector. The threat situation for IT systems has changed in recent years, and with increased digitisation of the energy systems, Denmark will be increasingly vulnerable to breakdowns and attacks.

Energinet must therefore regularly reassess the methods it uses to guarantee a high level of IT security. With cyber attacks becoming more organized and aimed at different IT systems, it is necessary to keep assessing which tools are the right ones to prevent and combat destructive cyber attacks.

[4] Outage minutes correspond to the average duration of electricity supply outages in minutes per electricity consumer per year in Denmark.

FIGURE 11: ENERGINET HAS OPTED FOR A STRATEGIC RESERVE FOR THE PERIOD 2025-2029, AND WILL REVISIT A WIDE RANGE OF POSSIBLE SOLUTIONS FOR 2030 AND BEYOND, IF NECESSARY.



Because the attacks can be both targeted and non-targeted, a strong IT defence is essential.

In addition, other players in the electricity system may be exposed to attacks affecting their operations. Depending on the player's area of responsibility, there may be an impact on the operation of the electricity system. To reduce the risk of destructive cyber attacks, Energinet cooperates widely with players in Denmark and abroad. The aim is to work together to find the vulnerabilities in IT systems before they are exploited. In this way, the prevention methods are updated on an ongoing basis with the players in the electricity system.

Energinet is examining the need for a temporary strategic reserve in Eastern Denmark

Energinet's analyses and projections show that the risk that electricity will not be available when needed in Eastern Denmark is set to increase from 2025 onwards, irrespective of the progress of Kriegers Flak. This is due to deficient generation adequacy, which is measured in output minutes[5]. Energinet's previous target was no more than five output minutes. Without new initiatives, the expected outage level will be 11 output minutes in 2025, increasing to 42 output minutes in 2030.

In the next few years, Energinet will implement new market reforms that will incentivise the market players to take their own steps to balance production and consumption of electricity. The reforms are therefore also expected to help maintain generation adequacy. However, there is uncertainty about the precise timing and impact of these market initiatives. This is because a number of regulatory and technological changes are expected in and around the electricity market in the next few years, significantly influencing the effect of the market measures. Examples include new digital management solutions for households and industrial facilities, changes to electricity taxes, increased use of battery solutions, etc.

In terms of the specific power challenge facing Eastern Denmark by 2030, the uncertainty means that there will continue be an increasing risk of insufficient power in Eastern Denmark unless one or more initiatives are implemented. That is why Energinet has studied a number of infrastructure expansions and market initiatives designed to improve generation adequacy in Eastern Denmark. The economic assessment indicates that a strategic reserve is the lowest-cost initiative capable of safeguarding generation adequacy in Eastern Denmark.

A strategic reserve is a time-limited and flexible initiative that can maintain generation adequacy – provisionally until 2030 and possibly beyond. This allows Energinet to assess whether

[5] Output minutes are consumer-weighted outage minutes, calculated by dividing unserved electricity by the average hourly consumption in the year.

FIGURE 12: RESERVE TYPES.

	WESTERN DENMARK	EASTERN DENMARK
Frequency reserves	Frequency Containment Reserves (FCR)	Frequency-controlled reserves - normal operation (FCR-N) Frequency-controlled reserves - disturbance (FCR-D)
Ancillary services	Automatic frequency restoration reserves (aFRR) Manual frequency restoration reserves (mFRR)	Manual frequency restoration reserves (mFRR)

the market reforms are having the necessary effect or other initiatives should be implemented. A strategic reserve is established on the basis of a call for tenders aiming to give Energinet guaranteed access to generation capacity or load shedding that can be activated with minimal market impact if power shortages occur during the period.

In addition to a strategic reserve, infrastructure expansions from Eastern Denmark to Western Denmark, Sweden, Germany and Poland have been studied as a way of safeguarding generation adequacy.

In February 2018, the European Commission approved temporary strategic reserves in Germany and Belgium, and on this basis, Energinet will start talks with the Danish energy authorities about the possibility of applying to the European Commission for a temporary strategic reserve to maintain generation adequacy in Eastern Denmark. Energinet will use these talks to ask for an approval for the period 2025-2029 with an option to extend this period by five years.

2.2 Resources to safeguard balance and technical quality

Energinet is responsible for security of supply and in order to fulfil this duty must maintain technical quality and balance in the interconnected electricity supply system, cf. section 27a(1)(1) of the Danish Electricity Supply Act. In the new Danish Electricity Supply Act this has changed – Energinet is now responsible for maintaining the specified level of security of electricity supply and to monitor changes.

Balancing the electricity system is achieved by the market players trading in balance up to the delivery hour. In the hour before the delivery hour, and during the delivery hour, Energinet is responsible for balancing the electricity system. To do so, Energinet uses a number of plans and forecasts to assess the imbalance in the next delivery hour.

To maintain balance in the electricity system, Energinet purchases ancillary services, which can be activated automatically or manually. The vast majority of ancillary services consist of reserve capacity. There is a lesser need for properties required to maintain power system stability and other ancillary services such as black start capability.

To guarantee availability of the necessary balancing resources, Energinet purchases a range of services on an ongoing basis, primarily from Danish electricity generators and through international markets and agreements. There are two types of reserves: frequency reserves and balancing reserves. Purchases of ancillary services differ in DK1 and DK2, since the regions each belong to a different synchronous area. DK1 and DK2 use different balancing approaches that reflect the size and composition of the electricity system. In the Nordic synchronous area containing DK2, balancing is based on the frequency, whereas in the Central European synchronous area containing DK1, balancing is based on imbalances of energy.

Frequency reserves are characterised by being automatic reserves, which constantly respond to frequency

Studstrup CHP plant

fluctuations and stabilise the frequency at around 50 Hz.

Frequency Restoration Reserves (mFRR) with manual activation are known as regulating power in the Nordic region and are activated from a common Nordic platform in which bids for upward and downward regulation are submitted by the market players on an hourly basis. Frequency Restoration Reserves (aFRR) with automatic activation used to be called secondary reserves or LFC.

Automatic and manual balancing reserves are used to maintain the energy balance between production and consumption during the delivery hour. They respond within 15 minutes in order to restore balance.

Properties required to maintain power system stability

Energinet purchases properties required to maintain power system stability from the primary power stations. The parties seek to use competitive tendering to purchase properties required to maintain power system stability. If a need for properties required to maintain power system stability can be predicted, Energinet announces a call for tenders and the players can submit bids.

If there is only one potential supplier, Energinet is unable to complete the tendering process. In this situation, the call for tenders is cancelled and the contract is then awarded directly to the player. This means that the need is instead met on the basis of an order and settled using the cost plus method (see below) approved by the Danish Utility Regulator[6] in April 2017. The new Danish Electricity Supply Act makes it possible to continue using market-based methods and to use regulated prices for payment instead.

If there is a sudden need for properties required to maintain power system stability, Energinet executes a remedial action on the basis of section 27c of the Danish Electricity Supply Act. In this case, an order is issued.

Properties required to maintain power system stability are also provided from Energinet's synchronous condensers. If the primary power stations are able to supply sufficient properties required to maintain power system stability to allow Energinet to switch off its synchronous condensers, Energinet proposes that the power stations should be compensated for this. The compensation method has been notified to the Danish Utility Regulator and is currently awaiting approval.

[6] The Danish Utility Regulator was called the Energy Supervisory Board until 30 June 2018.

Market purchases
Planned market purchases are always the preferred method for Energinet to fulfil the responsibilities described in section 27a(2) of Consolidated Act (lovbekendtgørelse) 1009 of 27 June 2018. Market purchases are directly related to section 27a.

Under the old Danish Electricity Supply Act, an order was issued when there was only one potential supplier that could meet a particular need. This need could be defined geographically for example. The order was made on the basis of section 27b of the Danish Electricity Supply Act. The relevant section has been amended in the new Danish Electricity Supply Act, which entered into force on 1 July 2018.

The new Danish Electricity Supply Act gives Energinet Elsystemansvar the option to continue with the market-based call for tenders even if there is only one supplier offering the service in question. In these situations, regulated prices are used for payment. The option to continue with the market-based call for tenders is sanctioned by section 27a(2) of the new Danish Electricity Supply Act. This means that greater use can be made of market-based methods when purchasing the services necessary to safeguard security of electricity supply.

If Energinet Elsystemansvar is unable to issue a market-based call for tenders, section 27c(2) of the new Danish Electricity Supply Act is applicable. This is in pursuance of the Commission Regulation establishing a guideline on electricity transmission system operation. The Regulation provides a legal basis for plans to be changed and remedial actions to be activated. If remedial actions are activated, payment will be based on a forthcoming cost plus method that is yet to be notified to the Danish Utility Regulator. Until this method is notified and approved, payments under sections 27a(2) and 27c(2) will be based on the currently approved settlement method for purchases of properties required to maintain power system stability.

2.3 Cooperation with other countries

The Danish electricity grid is designed to be closely interconnected with the grids of neighbouring countries. This helps to guarantee a high level of security of supply in Denmark even when there is no wind and the sun is not shining, and makes better use of renewable energy production across a larger geographical area. Close cooperation with the other European countries is a prerequisite for a well-functioning European internal energy market and is a cornerstone of Energinet's efforts to maintain high security of supply.

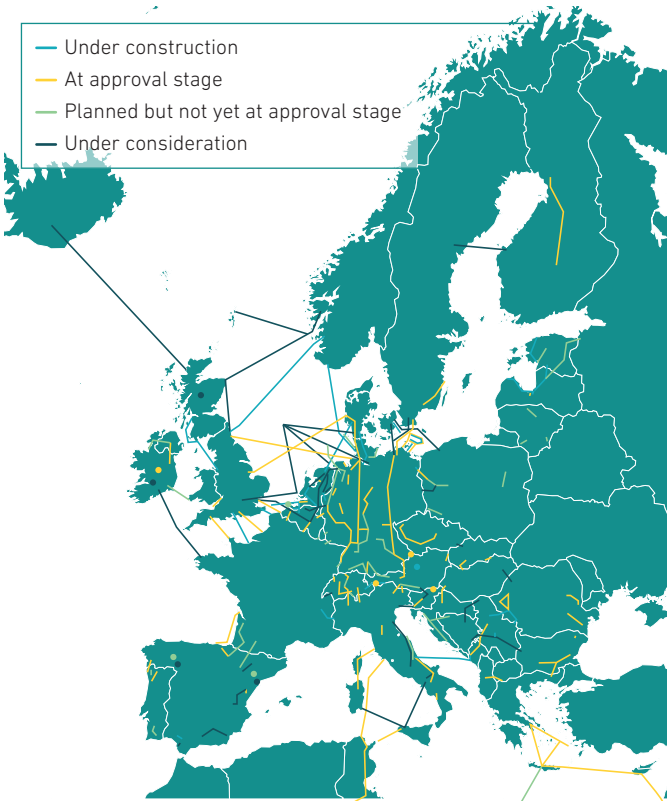
The EU's third liberalisation package created ENTSO-E in 2009 to promote cross-border electricity transmission and ultimately to create a genuine internal market in electricity. With the establishment of ENTSO-E, the European TSOs have been given important duties as well as a significant influence on the development of the European electricity market and electricity transmission system.

Energinet and the other Nordic TSOs have prioritised their cooperation in ENTSO-E, and considerable resources are still being devoted to the Nordic TSOs' contribution to the development of pan-European cooperation. Under the auspices of bodies including the Nordic RSC[7], Energinet and the other TSOs are on track to deliver a genuine internal electricity market. The Nordic RSC and the Nordic Balancing Concept are concrete examples of a regional implementation of efforts to develop the common European energy market (read more about the Nordic Balancing Concept in section 2.8 and about the RSC in section 2.3).

At this pan-European level, ENTSO-E is responsible for grid planning, while ACER (Agency for the Cooperation of Energy Regulators) is responsible for supervision. As a TSO, Energinet is responsible for national grid planning at transmission level. The Danish Energy Agency oversees national grid planning, and the Danish Utility Regulator ensures that national grid planning is compatible with European grid planning.

[7] Nordic RSC stands for 'Nordic Regional Security Coordinator' and is a joint office located in Copenhagen, where employees across the TSOs in Finland, Norway, Sweden and Denmark collaborate to resolve a number of operational issues.

FIGURE 13: TYNDP 2018 PROJECTS IN EUROPE: 166 TRANSMISSION PROJECTS AND 15 STORAGE PROJECTS (12 HYDROELECTRIC POWER AND 3 COMPRESSED AIR).



Clean Energy for all Europeans is a package of legislative initiatives that builds on the third liberalisation package, for example by strengthening regional cooperation. Greater regional cooperation is therefore seen as a step towards a fully integrated internal market in energy throughout Europe. The Nordic countries are front and centre in this development, and are boosting cooperation in the electricity market by setting up an Electricity Market Forum involving energy ministers and relevant players.

European planning cooperation

In terms of planning, Energinet is working with other European transmission system operators on the European Ten Year Network Development Plan (TYNDP), as set out in EU Regulation 714/2009 and section 28 of the Danish Electricity Supply Act. The European ten-year plan is produced on the basis of investment plans for six European regions and presents a summary of the principal electricity infrastructure projects with pan-European significance. The projects typically concern interconnections between countries or between different price areas as well as national connections with common regional or common European significance. Denmark contributes to regional investment plans in the North Sea and Baltic Sea regions and thus also to the pan-European ten-year plan. Energinet is working to ensure close coordination between national and European grid planning.

The TYNDP 2018 report contains a package of deliverables:

- Scenario report, describing the future scenarios on which the TYNDP is based. The scenario storylines were developed in collaboration with various stakeholders, including the Member States and regulators. And now, for the first time, the same scenarios are used in electricity and gas planning. In other words the electricity TYNDP and gas TYNDP are based on the same future scenarios and data for 2025, 2030 and 2040.
- Regional investment plans, which address system and grid requirements at the regional level. ENTSO-E is divided into six regions, and Energinet is in two regional groups: North Sea and the Baltic.
- The TYNDP 2018 main report, which analyses the effect of grid expansion at the pan-European level up to 2030 with a detailed economic cost-benefit analysis of all 181 projects in the plan.
- Various reports, which illustrate various regional and pan-European topics with relevance for the future development of the electricity system. This includes four regional reports tailored to the European

corridors as defined in EU Regulation 347/2013 on the trans-European networks. And a number of technical reports.

TYNDP 2018 describes a total of 166 transmission projects and 15 storage projects expected to be commissioned by 2035. They include nine Danish transmission projects, of which four electricity projects and one gas project have been designated Projects of Common Interest (PCI). For each TYNDP project, cost-benefit analyses were prepared in four European scenarios with two time frames. The overall investment requirement in the TYNDP is valued at about EUR 114 billion up to 2030. The investments will allow 48-50 per cent of electricity consumption to be covered by renewable energy, and emissions of CO2 to be reduced by 65-75 per cent compared to 1990 levels. Furthermore, it will be possible to save EUR 2-5 billion in production costs per year (2030 figures). The projects in the TYNDP will also help to improve security of supply because they will relieve existing grid congestion points. The European system is facing the same challenges as in Denmark: the production portfolio is evolving. Some countries are discontinuing nuclear power, others are replacing or phasing out old power stations, and most countries are increasing the share of renewable energy in electricity consumption. This development will trigger major changes in electricity flow patterns across Europe and therefore changes in requirements concerning system flexibility and system stability in order to maintain security of supply. The electricity grid will have to be modified in response, for example better control systems for existing lines, upgrades of existing connections, or completely new connections in order to facilitate European energy policy.

Projects of Common Interest
Every two years the European Commission updates a list of projects of particular European importance. The list is based on the latest TYNDP, and Denmark has five projects in the current list. The next list (list IV, which is based on TYNDP18) is due for publication at the end of 2019.

Denmark has two current PCIs under construction: the East Coast Connection and Kriegers Flak Combined Grid Solution. Two of the other projects – Viking Link and the West Coast Connection – have been approved by the minister, and the Baltic Pipe gas project is planned but not yet approved by the minister. PCIs are subject to special requirements with regard to transparency and public involvement, but can also receive faster processing of approvals or financial support from the EU. As a result, Energinet has obtained financial support for feasibility studies for these three Danish projects: the Viking Link project, the East Coast project and Baltic Pipe.

"Although the four Nordic TSOs already work together within ENTSO-E, there is still a need for close Nordic cooperation"

Midterm Adequacy Forecast
One important activity of ENTSO-E is the pan-European assessment of generation adequacy, called the Midterm Adequacy Forecast or MAF for short. The MAF is also a requirement from EU Regulation 714/2013, and has been updated to reflect the closure of many primary power stations in step with the massive expansion of wind and solar. This trend puts future generation adequacy under pressure in many countries including Denmark, see the Security of Electricity Supply Reports from 2016, 2017 and 2018. The MAF developed a new probabilistic methodology for the interconnected European system. The methodology uses hourly resolution and a climate database with 35 years of statistics on factors such as wind, solar radiation and temperatures. Also included are the unplanned outages of power stations and international connections. The methodology also forms the basis for calculation of generation adequacy in the Nordic system.

Nordic planning cooperation
Although the four Nordic TSOs already work together within ENTSO-E, there is still a need for close Nordic cooperation. Cooperation was intensified in 2015 with a joint Nordic TSO strategy and in 2016 with an analysis of the challenges facing the Nordic system in the years to come. The findings were published in the summer of 2016 in the so-called Challenges Report. The report highlights challenges around system

FIGURE 14: NORDIC RSC.

flexibility, generation adequacy, frequency quality and inertia. In March 2018, The Way Forward – Solutions for a Changing Nordic Power System was published, setting out some solutions to these challenges. Inputs included the Nordic Grid Development Plan 2017 (NGDP 2017) and Generation Adequacy. They describe the current plans and grid development projects in the Nordic countries, and the market initiatives potentially required to safeguard generation adequacy, including a new generation adequacy calculation method.

NGDP 2017 identified five corridors of major interest in the Nordic region (NO-DK, NO-SE, NO-FI, FI-SE and DK-SE). The reason why the corridors to Denmark are of interest is that several connections are approaching their technical end-of-life. It is also necessary to consider whether further integration is needed between the Nordic and continental synchronisation system to provide the system flexibility required to cope with the evolving production portfolio. In addition, the corridors connect two areas with plentiful hydroelectric power and solar and wind energy.

Operational cooperation in the Nordic region

The Regional Security Coordinator (RSC) is an operational unit intended to provide strong and close regional coordination of transmission system operation. For the time being, the objective is to provide five services to the TSOs:

- Capacity calculations
- Maintenance planning
- System security analyses
- Generation adequacy analyses
- Grid model calculations
- Five RSCs have been created in Europe:
- Baltic RSC
- Coreso
- Nordic RSC
- SCC
- TSCNET

Due to its special situation operating in two synchronous areas, Energinet is in two RSCs:

- One is called TSO Security Cooperation (TSCNET), and this operational cooperation involves 13 continental European TSOs. This cooperation is well established, and Energinet has been involved since 2013. At the end of 2014 Energinet became co-owner of the operating company set up by the participating TSOs. TSCNET has its offices in Munich.
- The other is called Nordic RSC, and is an operational cooperation involving

Statnett, Svenska Kraftnät, Fingrid and Energinet. The office, located in Copenhagen, was set up in 2017, and is staffed from all four Nordic TSOs.

The statutory basis for the creation of Regional Security Coordinators (RSCs) is contained in EU Regulation 2017/1485 establishing a guideline on electricity transmission system operation (System Operation Guideline Regulation). At the European level, however, TSOs have been creating RSCs on a voluntary basis since 2008, when Coreso and TSC were established. In 2015, the European TSOs and ENTSO-E entered into a multilateral agreement on the establishment of RSCs, and it is this agreement which formed the basis for the establishment of other RSCs including Nordic RSC.

Market cooperation

The interconnected European electricity transmission grid links the European countries together, and through ever-closer cooperation in terms of markets, planning and operation under the auspices of the Nordic RSC and other organisations, Energinet and the other TSOs are on track to deliver a genuine internal electricity market.

According to section 28(2)(3) of the Danish Electricity Supply Act, Energinet must 'cooperate with system operators in other countries to establish mutual, equivalent principles for electricity supply and grid tariffs, grid access and transit, market issues, etc., co-ordination of transmission connections (including the handling of balance and capacity problems) and enter into any joint system operation agreements necessary in order to ensure that the benefits yielded by interconnected systems are exploited.' In continuation of this provision, section 28c of the Danish Electricity Supply Act states that 'Energinet or its wholly owned subsidiaries may, as part of the cooperation with the transmission system operators of other countries and with the approval of the for Minister for Energy, Utilities and Climate approval, become the co-owner of limited liability companies which carry out cross-border TSO functions as mentioned in section 28(2)(3) and functions relating to interconnection of electricity markets.' On the basis of these provisions, Energinet has established and participates in a number of different collaboration forums in the Nordic region and in Europe.

With the creation of ENTSO-E, the European TSOs have been given important duties, including quasi-regulatory duties, as well as a significant influence on the development of the European electricity market and electricity transmission system. This is a major commitment, Energinet is actively involved in all the main areas: market, system operation, planning and research and development. Energinet advocates market-based solutions delivering economic benefits, and

even greater transparency and stakeholder involvement in ENTSO-E.

The Nordic cooperation is rooted in direct collaboration between the four Nordic TSO CEOs who meet quarterly. In addition, the four Nordic TSOs join forces in many different areas including market development, system operation and planning, and there is a continuous and informal exchange of view on European activities. Energinet and several other European TSOs are co-owners of the Joint Allocation Office (JAO), which acts as a service company for the participating TSOs, offering auction services. The JAO is the designated Single Allocation Platform (SAP) for capacity allocation in the forward market covering the whole of Europe. Specifically, the JAO handles the auction of that portion of the capacity of the Great Belt Power Link and the Danish-German connections which is sold in long-term contracts.

See section 2.7 about the wholesale market for more details of European regulation of the markets.

Network codes

The network codes are part of the wider EU regulation of the electricity sector and define the scope and framework for markets, operation and grid connection. The network codes are therefore crucial for large parts of Energinet's business. What characterises network codes is that they are primarily implemented – at national, regional and European level – in cooperation between TSOs and must be based on stakeholder consultations, after which the TSOs' proposals must be approved by the respective national supervisory authorities. For Energinet it is essential for the network codes to be implemented in a way which generates the maximum economic value, meaning that implementation of the network codes is of considerable strategic importance for Energinet.

Most recently, Energinet has focused on:

- Rules for connection of generation and consumption.
- A common framework and operating agreements for frequency regulation products.
- Implementation of the pan-European intraday market XBID, see section 2.7.
- New capacity calculation methods in the CCR Nordic and CCR Hansa regions, see section 2.7.

Forthcoming topics include:

- Changes in maintenance planning.
- Descriptions for communication with installations – generation, consumption and substations.
- Description of Energinet's system defence plan and system recovery plan.
- Implementation of the new capacity calculation methodologies.
- Implementation of procedures and changes in market design to enable competition between power exchanges, see section 2.7.
- Scope and framework for two European platforms activating manual reserves (the MARI platform) and automatic reserves (the PICASSO platform)[8].

Activities to implement the current and future network codes will constitute an important task for Energinet in the future. This will probably be a more or less permanent task, as the network codes are expected to require updating and further development to keep pace with future technical progress, for example.

2.4 Cooperation with other grid operators

As the electricity system develops from being based on dispatchable energy production from primary and local power stations to having to deal with greater integration of renewable energy, there are more and more collaborative interfaces between the distribution and transmission level. In all the distribution and transmission grids, the objectives is the same: to maintain security of supply and optimise it from an economic point of view, and to effectively integrate renewable energy. The resources necessary for operating and balancing the electricity system – at distribution and transmission level – can only be provided on the basis of close cooperation and coordination.

[8] MARI stands for Manually Activated Reserves Initiative and PICASSO stands for Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation.

At EU level, the focus is on creating a regulatory structure that helps to define roles and responsibilities for grid companies and transmission companies, most recently the Clean Energy for All Europeans package that makes a number of proposals to support the green transition. The proposed legislation addresses technical and market issues in the collaborative interfaces between the distribution and transmission level, and is expected to be adopted by the Member States in 2019 and enter into force from 2021.

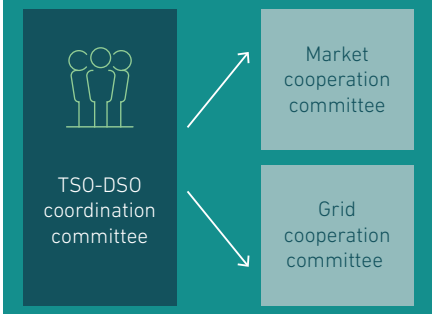
Increased cooperation across the distribution and transmission grids
Denmark has a long-standing tradition of cooperation involving grid companies, the Danish Energy Association and Energinet, both formally in various forums and informally in day-to-day operation. In 2018, the grid companies, the Danish Energy Association and Energinet decided to set up more formal collaboration forums to intensify their joint efforts to identify and overcome the challenges facing the electricity system in the coming years. By intensifying cooperation in distribution and transmission, we have made an active strategic choice, aiming to find the best solutions by cutting across boundaries.

The cooperation is organised in three committees: a TSO-DSO Coordination Committee, a Market Collaboration Committee and a Grid Collaboration Committee, of which the first two are newly established collaboration forums from 2018.

TSO-DSO Coordination Committee
The TSO DSO Coordination Committee discusses strategic issues that cut across transmission and distribution and encompass the Market Collaboration Committee and the Grid Collaboration Committee. The Coordination Committee sets the strategic direction of cooperation in the various forums, reflecting the collaborative interfaces between grid companies and Energinet concerning operation, planning, investments, market context, data exchange and data protection. The Committee also focuses on creating a common understanding of the national and European trends and developments as a basis for forward-looking, proactive coordination between the distribution and transmission level in the Danish electricity system.

Market Collaboration Committee The Market Collaboration Committee focuses on the market-related collaborative interface between the transmission grid and the distribution grid. The Committee's activities will be directed to the

FIGURE 15: THE VISION FOR DSO-TSO COOPERATION.



In their roles as neutral market facilitators, Energinet and the electricity distribution companies will ensure, that the electrical system is operated and developed in society's best interest, now and in the future. The participants will work together to ensure that consumers have a cost-effective security of supply and green transition, where balancing of the electricity system is safeguarded by market-based solutions to the extent possible, and where the framework supports innovation and technological development of benefit to the electricity consumers.

[9] The Dialogue Forum brings together Energinet and Danish electricity market players to discuss market regulations and market processes. The Technology And Implementation Group is a forum in which the market players, their IT suppliers and Energinet discuss and coordinate issues around DataHub. In the Electricity Market Players' Forum, Energinet meets with wholesale market players to update them on national and international market developments. The Electricity Market Players' Forum aims to give players the opportunity to stay up-to-date with national and international wholesale market developments. The Players' Working Group For Ancillary Services brings together the players in the energy sector and Energinet in a forum for sparring and dialogue around market-related issues relating to the development of the market in ancillary services.

areas within the natural monopolies in electricity supply, such as the communication and exchange of metered data and tariff structures. The Committee is also involved in new collaborative interfaces that have sprung up in response to developments in the electricity system, for example how to develop a market framework for efficient activation of flexible resources connected to the distribution level or implementation of aggregators in the codes.

The Market Collaboration Committee complements the broad market cooperation discussed in forums such as the Dialogue Forum, the Technology and Implementation Group, the Electricity Market Players' Forum and the Market Players' Working Group for Ancillary Services, and also includes other market players. The Market Collaboration Committee is committed to transparency and involves market players9 in projects.

The Market Collaboration Committee is currently working on the following projects:

Utilisation of flexibility from installations connected to the distribution grid
As the electricity system develops, flexible resources will increasingly be available at the distribution level that can be activated. The Market Collaboration Committee has therefore set up a working group to investigate and present proposals on how to establish the best possible conditions for the utilisation of flexibility from installations connected to the distribution grid. The aim is to establish conditions that ensure that the flexible resources from the distribution grid are utilised where they create most value for the system as a whole, therefore also including end customers and those providing the flexibility. For example, a substantial part of our automatic balancing reserves already comes from the distribution grid. The working group has members from grid companies, the Danish Energy Association, balance responsible parties, producers and Energinet.

Tariff cooperation
As a natural consequence of developments in the electricity system, it has become necessary to adapt the tariff structure so it is better able to support active customers in making informed decisions about their use of the grids. The aim is to define common general design criteria for future DSO-TSO tariffs which establish a clear and cost-based tariff structure, simplify tariffs and prevent conflicting incentives. The working group has members from the grid companies, the Danish Energy Association and Energinet. Market players will be heavily involved in the work.

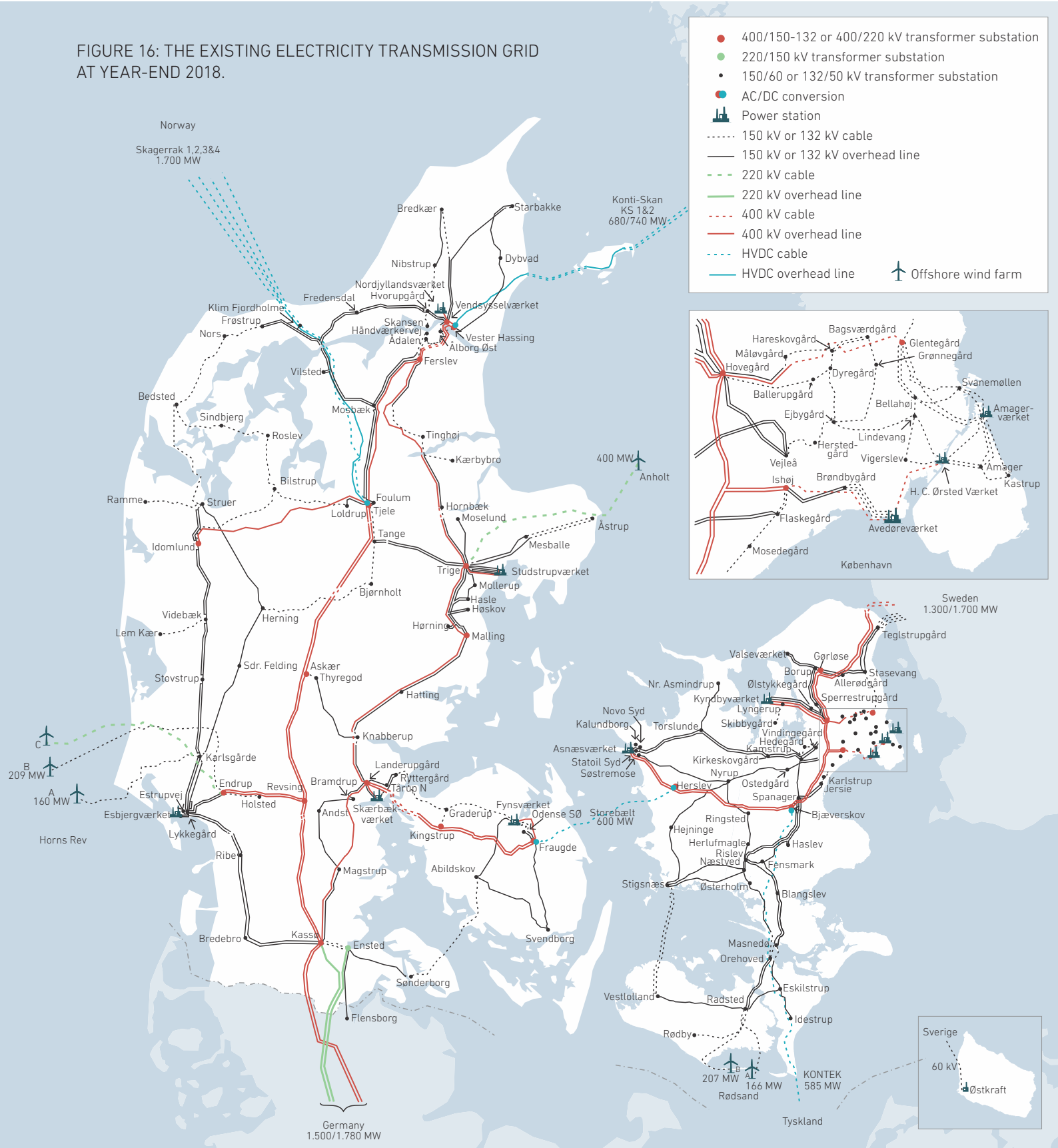
Grid Collaboration Committee
The Danish Energy Association, the grid companies and Energinet have set up the Grid Collaboration Committee to coordinate and prioritise activities of importance in the development, planning and operation of the entire electricity system at transmission and distribution level.

The Committee's goals are:
- Formulating basic guidelines concerning technical issues of relevance to the entire system.
- Safeguarding the mutual exchange of information between the Danish Energy Association, grid companies and Energinet.
- Initiating technical development activities.

Last year, the Grid Collaboration Committee worked on coordinating activities to implement EU regulations concerning network codes. It also established a working group that has developed a model for the exchange of reactive power between the transmission system and the distribution systems.

The Grid Collaboration Committee focuses on the technical and operational collaborative interface between the transmission grid and the distribution grid. The collaboration makes it possible to coordinate and prioritise activities that are relevant to the development, planning and operation of the entire electricity system. The ambition is to jointly identify, in a proactive and efficient way, a number of solutions to support the future operation and expansion of the electricity grid.
In 2018, the Grid Collaboration Committee also regularly discussed implementation of the EU regulations concerning connection to and operation of the electricity system. Implementation of these network codes affects all

FIGURE 16: THE EXISTING ELECTRICITY TRANSMISSION GRID AT YEAR-END 2018.



parts of the electricity system and requires close dialogue in the industry.

The Grid Collaboration Committee is currently working on the following projects:

Theme day focusing on the grid
The Grid Collaboration Committee arranges an annual theme day focusing on topical technical and operational issues affecting the grid. In 2018, the event covered issues including control of the electricity system and the use of batteries, and was again enthusiastically supported by the grid companies.

Exchange of reactive power
The exchange of reactive power between the transmission system and the distribution systems has evolved over the years, partly as a result of increased undergrounding in the distribution systems. These changes, combined with the need for a clear model describing how this exchange is to be regulated, prompted the Grid Collaboration Committee to set up a working group to address the issue. In 2018, it successfully completed its mission, and the model can now be incorporated into a technical regulation, ensuring that the exchange of reactive power is handled in an effective way in terms of the system.

2.5 Planning for conversion and expansion of electrical installations

Most of the 132 kV and 150 kV grid was established from the 1960s and up until the 1990s, and large parts of this asset pool are therefore facing reinvestment over the next 10-15 years. The green transition and extra consumption also mean that more expansions in the transmission grid are to be expected in the next several years.

Forward planning – grid adequacy

Currently, reinvestment projects account for around 25 per cent of the total planned investments in the transmission grid. Going forward, reinvestment projects are expected to make up an increasing share of the total investments. To ensure an appropriate level of grid adequacy, there is a need in the years ahead to expand the transmission grid. In most of Jutland and in South Zealand and Lolland-Falster, this will mainly involve integration of electricity generation from renewable energy facilities. In addition, there may be a greater need for reinforcements if large data centres continue to be built. Finally, Copenhagen needs reinvestments and expansions due to an increase in electricity consumption in Copenhagen combined with the closure or part-time operation of thermal power stations in the area.

Forward planning – system security

If the electricity system is unable to handle sudden system disturbances, in other words if system security is inadequate, the consequences may be far-reaching because in the worst case, sudden and widespread blackouts could occur in Western or Eastern Denmark, or both.

Changes in the electricity system, comprising changes in available production capacity and changes in grid structure and capacity, may affect system security and therefore create an additional need for installations with properties required to maintain power system stability. New wind turbines, grid components, power-electronic components, synchronous condensers and power stations all have properties required to maintain power system stability.

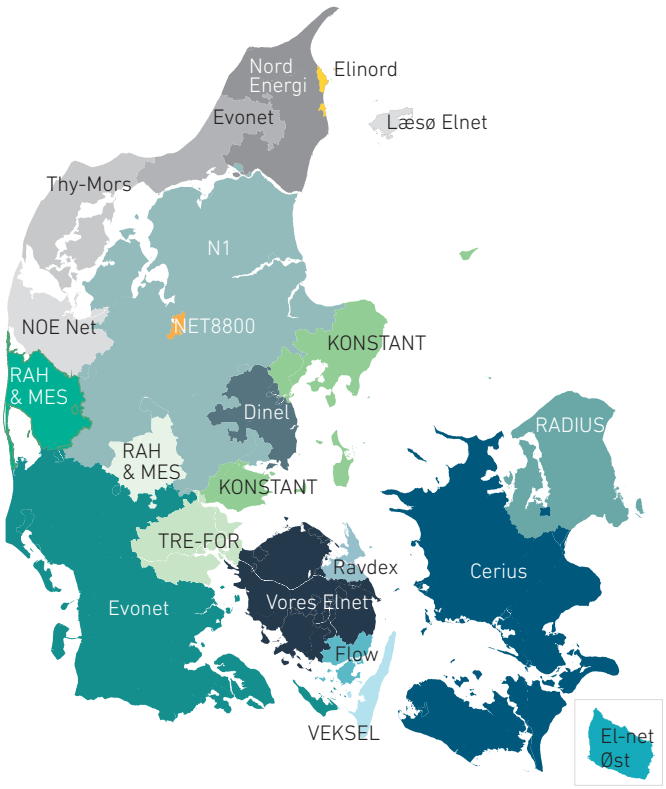
To continue to maintain secure and stable operation, there is not expected to be any need for new installations with properties required to maintain power system stability in Western Denmark. This is partly because closer electrical links are being created across borders with new international connections, which will have a stabilising effect on the Western Danish electricity system.

In Eastern Denmark, the electricity system is not as resilient to major system disturbances as in Western Denmark, and new initiatives concerning properties required to maintain power system are expected to become necessary in future in the southern part of the area. The specific needs are yet to be clarified in detail.

Cooperation with regional grid operators

Various committees, groups and forums have been set up with the grid operators and the Danish Energy Association to handle coordination and cooperation in day-to-day operation and

FIGURE 17: GRID COMPANIES IN DENMARK WITH INSTALLATIONS DIRECTLY CONNECTED TO THE TRANSMISSION GRID.



planning of the electricity grid. The cooperation takes place at several levels, making it strategic as well as operational. It is important for Energinet to foster effective cooperation at all times, through formal agreements but also informally, in order to optimise the operation and planning of the system as a whole.

Regional coordination and planning

For each grid company in Denmark with equipment that has an electrical connection to the transmission grid, there is a regional coordination group which guarantees coordinated planning and grid development of the transmission grid and the distribution grids.

The main responsibility of these groups is to maintain a project portfolio consisting of projects in the transmission grid and the distribution grids that may influence one another, and which therefore need to be coordinated in terms of planning.

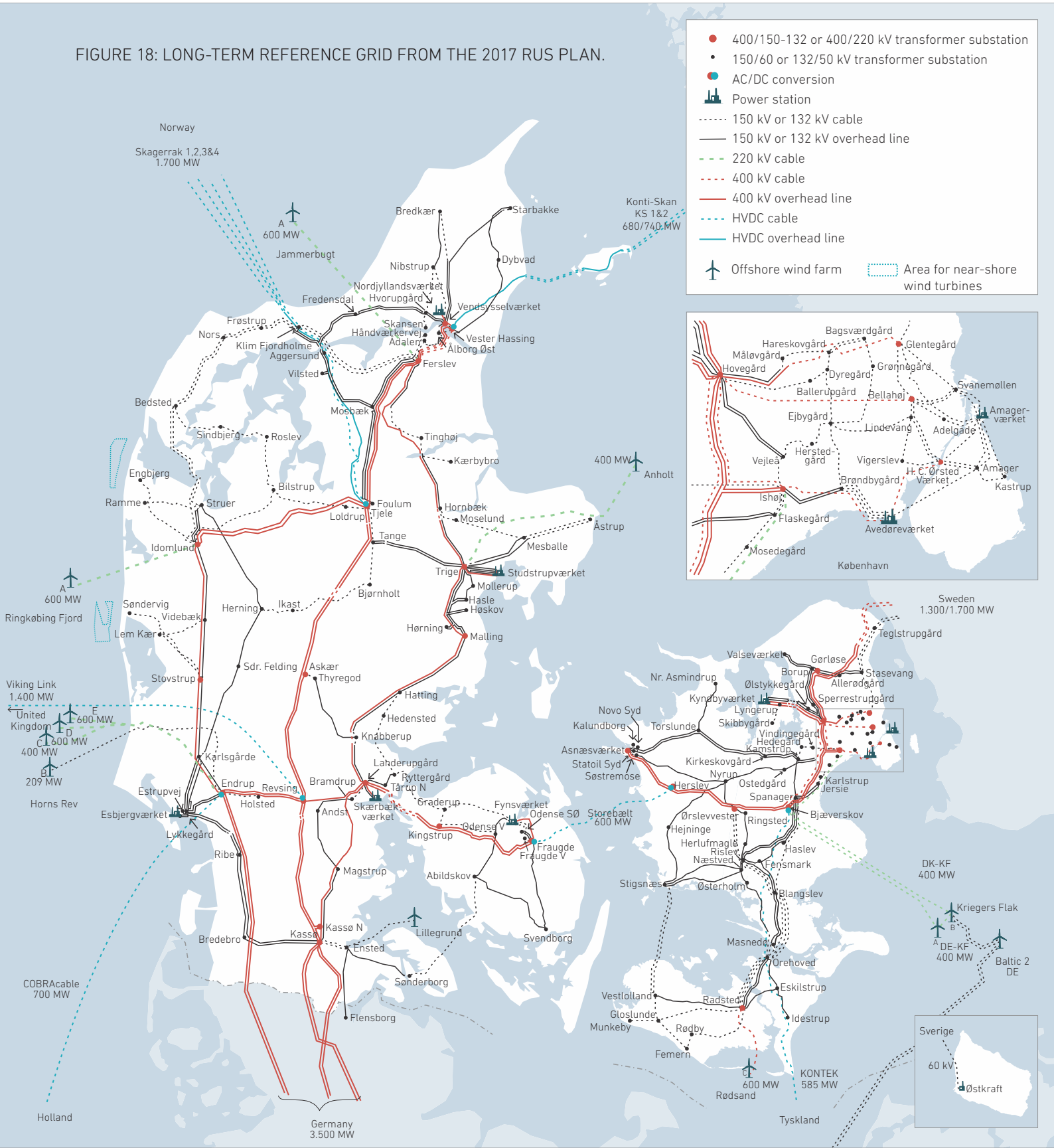
The projects in the portfolio are initiated either by the grid company or by Energinet and include:

- Connection of electricity generating facilities and major electricity consumers, where it is uncertain whether the optimal connection point is the distribution grid or the transmission grid.
- Grid expansions at one voltage level which may affect another.
- Substations connecting the transmission and distribution system.

The group makes sure the necessary analyses are performed to determine whether the specific need is best met by expanding the transmission grid and the distribution grids, and to describe the overall consequences for the grid of expansion at a particular voltage level. If the regional coordination groups identify a need to modify the transmission grid, Energinet initiates a maturation project to determine the best technical and financial solution, but if, on the other hand, they identify a need in the distribution grid, the project is passed to the grid company for maturation. Regional coordination consists of continuous, formally organised cooperation, and the resources required are entirely dependent on the current volume of upcoming projects.

Energinet is required by law to create a plan covering the future need for transmission capacity in the interconnected electricity supply system and transmission lines to other grids. The purpose is to establish a basis on which the necessary reinvestments,

FIGURE 18: LONG-TERM REFERENCE GRID FROM THE 2017 RUS PLAN.



expansions and restorations can be carried out in the transmission grid.

The RUS plan

Energinet prepares an annual national network development plan called the RUS plan (Reinvestering, Udbygning, Sanering = reinvestment, expansion, restoration). The RUS plan details the constraints that will exist in the national transmission grid under specified assumptions about long-term changes in consumption, generation and net transfer capacity, and in response proposes a far-sighted and interconnected transmission grid that removes the constraints and thereby supports long-term development. The long-term grid structure constitutes a reference point, and in detailed planning, Energinet always seeks to find solutions that meet a specific need for changes in the transmission grid. The need for expansion is coordinated with the need for reinvestment and restoration.

The RUS plan and specific development solutions support the legislation currently in force and the political objectives and agreements relating to electricity supply. Energinet, the Danish Energy Agency and the Danish Utility Regulator have a tradition of dialogue while the RUS plan is being prepared, and the two government agencies put it out for consultation before publication.

The RUS plan gives an indication of the long-term reference grid and pays detailed attention to transmission capacity and reinvestment requirements for the next 10 years. The RUS plan is based on the development specified in the defined analysis assumptions, reinvestment analyses of the existing transmission grid and other factors such as the connection of particular renewable energy facilities and consumers and new instructions from the authorities.

The RUS plan is used as input for Energinet's investment plan, contributes to Energinet's portfolio overview, and helps to ensure that forthcoming construction and reinvestment projects start their maturation phase promptly. The RUS plan also forms the basis for the project information presented on the Energinet website, where Energinet publishes and updates details of all projects for the next 10 years with the aim of keeping citizens, government agencies, grid companies and other stakeholders informed about the plans and their progress.

Basis for grid planning

The RUS plan is prepared on the basis of predefined and published design criteria (see the Danish Executive Order concerning system operator activities and the use of the electricity transmission grid (bekendtgørelse om systemansvarlig virksomhed og anvendelse af eltransmissionsnettet)) which apply to the Danish transmission grid above 100 kV and are recommended for the 50 kV and 60 kV level. The grid dimensioning criteria are updated as necessary, most recently in 2013 after Energinet took ownership of the former regional transmission companies. In 2017, Energinet issued a summary memorandum setting out the existing grid dimensioning criteria and their current use in the preparation of the annual grid plan for the electricity transmission grid (the RUS plan) and in the grid analyses for specific projects.

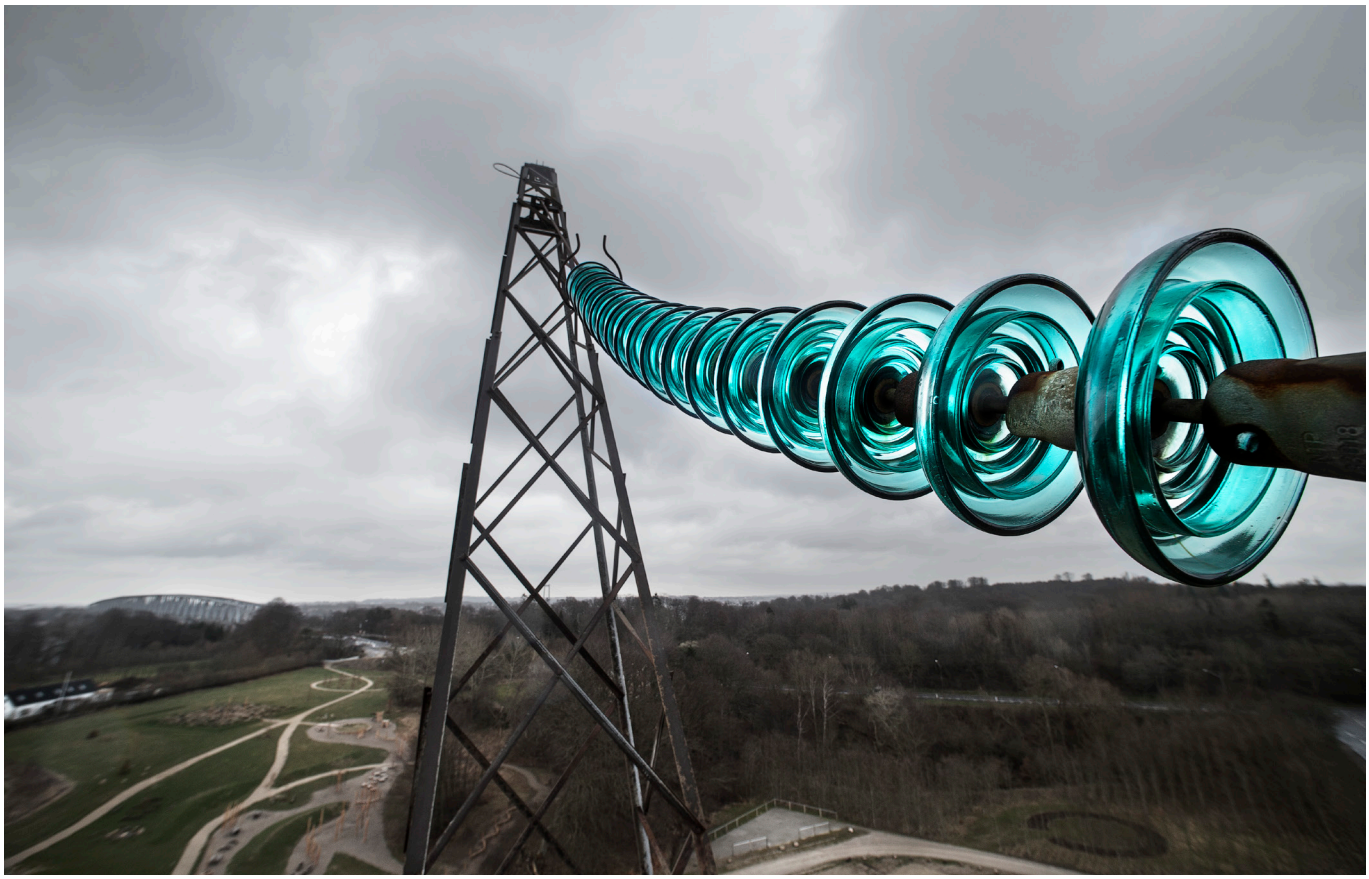
"Application of the grid dimensioning criteria identifies a need for changes in the transmission grid, and confirms that a selected solution can meet the technical requirements"

The grid dimensioning criteria establish the framework within which the need for expansion in the transmission grid is determined, with the aim of:

- Security of supply for consumers.
- Utilisation of electricity generated from renewable energy facilities.
- Market functioning in accordance with international guidelines and obligations.

The detailed planning of specific projects also incorporates environmental considerations, for example by minimising landscape impacts, as well as incorporating contingency preparedness.

The grid dimensioning criteria describe common faults and defects in the



transmission grid, and the permissible consequences for supply, utilisation of generation facilities and market functioning. These criteria relating to transmission system outages and consequences and used for grid planning (grids, transformers, generation facilities) correspond to the outages for which the day-to-day operation of the transmission system is planned and are based on international rules.

Application of the grid dimensioning criteria identifies a need for changes in the transmission grid, and confirms that a selected solution can meet the technical requirements. Energinet expands international connections based on economic criteria, and reinvests, expands and converts the national grid based on the cost-effectiveness principle, i.e. the implemented solution will be the one with the lowest economic cost which also meets the specified technical requirements.

The grid dimensioning criteria are tested using dimensioning situations that are formulated on the basis of defined analysis assumptions. The dimensioning situations are formulated to represent supply situations, renewable energy situations and market situations.

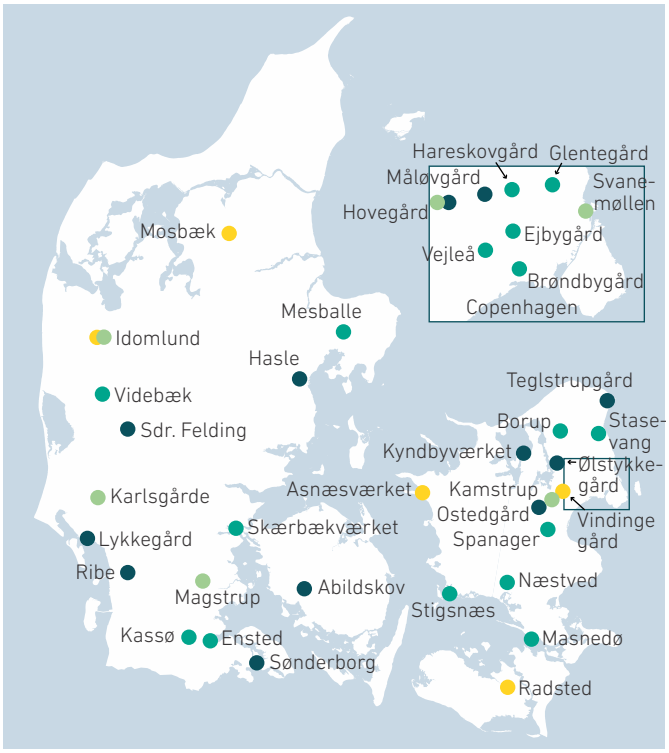
Political guidelines
Undergrounding and expansion of the transmission grid follow the currently applicable political guidelines. These were last amended as part of the political agreement on the abolition of the PSO tariffs from 17 November 2016. The agreement states the following:

- Overhead lines will initially be retained for the existing 132 kV and 150 kV transmission grid. Selected sections through areas of scenic beauty and urban areas will be undergrounded.
- The six specific projects described in the report entitled 'Improvement of the visual impact of the 400 kV grid' (Forskønnelse af 400 kV-nettet) will remain the same. Three of these projects have already been implemented.
- 400 kV connections will be established with overhead lines with the possibility of compensatory undergrounding in selected sections and undergrounding of the 132-150 kV grid in the vicinity of 400 kV overhead lines.
- New 132-150 kV connections will be undergrounded.

These principles form the basis for the choice of solutions in specific construction projects and for Energinet's RUS plans.

Maintenance and reinvestment
Energinet achieved PAS 55 certification in 2014 and ISO 55000 certification in 2015. Both schemes require the implementation of asset management activities and methodologies relating to the execution of activities, documentation and processes. As part of the

FIGURE 19: VISUAL REPRESENTATION OF ESTIMATED REINVESTMENT VOLUME.



implementation of asset management, Energinet is working towards a risk and condition based approach to maintenance and reinvestments by assessing all assets based on condition, criticality and functionality in the overall grid.

The aim of a risk and condition based approach to asset management is to maintain a high ongoing level of security of supply in a cost-effective way. Specifically, the method means that asset maintenance and reinvestment are more accurately differentiated than before and are prioritised according to need (condition) and risk (criticality) rather than just performing maintenance or replacement based on fixed intervals. The condition based approach results in significantly lower spending compared to the interval based approach, and Energinet has used the approach in a structured way since 2016.

The prerequisite for a condition and risk based approach to maintenance and reinvestment is that a large amount of data and information about the transmission grid is updated on an ongoing basis, is systematised and is evaluated in information systems that can be shared between the various players involved in the maintenance work.

To allow it to handle a significant volume of reinvestments, Energinet has:

- Developed a reinvestment strategy and associated strategic initiatives to help meet commitments around high security of supply and an efficient transition.
- Started work on developing component strategies to guarantee cost-effective and differentiated handling of our components.
- Defined a number of reinvestment principles for a common framework and business case for managing and configuring reinvestment projects.
- Introduced 'reinvestment analyses' covering the reinvestment need for a whole substation or an whole section.
- Prepared a reinvestment report including a reinvestment plan.

The reinvestment report is an important input to the annual RUS plan, in which the initial coordination between reinvestments, expansions and restorations takes place.

2.6 Conversion, expansion and maintenance of the power grid

The next few years will see a significant need for reinvestment in end-of-life components in Energinet's substations. Many of these substations were commissioned in the 1960s and 1970s, so many substation components are either approaching or have exceeded their expected design life.

Substation reinvestment programme

In view of the anticipated need for

reinvestment, Energinet decided in 2016 to launch the substation reinvestment programme with the aim of ensuring that the task is approached methodically. The programme helps to simplify and streamline the existing process of executing standalone projects, so the aim of initiating and executing more uniform construction projects can be achieved.

The first group of about 40 substations is scheduled for reinvestment in the next 5-6 years. The selected substations are shown in figure 19. On the basis of the status reports created for the first group, Energinet has developed a standardised method to survey the necessary scope of reinvestment in each substation.

Each substation is surveyed in a site visits carried out by experts in Asset, who assess the status of each individual plant component. The individual plant components, with their corresponding status report, are compiled in a substation template, which is then used to determine the overall scope of reinvestment in this substation. The scope of reinvestment is defined as all fixed components whose expected residual lifetime is less than 10 years from the scheduled reinvestment date for the particular substation. The new method of implementing extended status reports follows the existing practice based on condition scores. Certain of the relevant reinvestment principles were developed and implemented alongside the introduction of asset management.

The new method is resource-intensive in Asset, but it is an essential foundation on which the ever-increasing portfolio of substations can be assessed and prioritised. The method takes a balanced approach, aiming to operate the plant components closer and closer to their optimum service life while taking proper account of risk.

The necessary reinvestments encompass high-voltage components and equipment for monitoring and protection.

Data centres

Energinet handles the connection of large data centres to the Danish transmission grid, entering into contracts with investors stipulating the financial and electrical conditions that apply to the physical connection to the transmission grid. The first connections were commissioned in 2018, and what all the connections have in common is that Energinet establishes, owns and operates them, while the total connection costs are paid by the particular data centre. This means that the other electricity consumers are not responsible for data centre connection costs.

"In view of the anticipated need for reinvestment, Energinet decided in 2016 to launch the substation reinvestment programme with the aim of ensuring that the task is approached methodically"

The electricity consumption of data centres is expected to be high in order to run and cool IT equipment, for example. Energinet's analyses suggest that despite the uncertainty around the electricity consumption, the expected increase in consumption does not pose a challenge to security of supply or to the transmission grid (taking account of the existing network expansion plans). The addition of data centres in future is expected to require network expansion in the transmission grid.

Energinet is closely monitoring the situation and expects to adjust its assumptions about electricity consumption in the data centres as it continues to collect data on patterns of operation in the data centres over next few years. Furthermore, Energinet is engaged in ongoing dialogue with the individual consumers and the Danish Energy Agency in order to estimate the collective future electricity consumption of data centres.

Viking Link, the West Coast Connection and the 400 kV connection between Endrup and Idomlund

In November 2015 Energinet's Supervisory Board approved a combined investment in an electrical connection between Denmark and the UK (Viking Link), an additional connection between Western Denmark and Germany (the West Coast Connection), and an internal reinforcement of the 400 kV grid

between Endrup near Esbjerg and Idomlund near Holstebro. The three connections are mutually dependent and together, they are designed to enhance market integration and encourage the adoption of electricity generation based on renewable energy in Europe. Viking Link and the West Coast Connection are both included in the PCI list because analyses indicate that the connections are of major regional benefit.

The connection to the UK is a joint project with National Grid Interconnector Holdings Ltd. and will have a capacity of 1,400 MW. Capacity to Germany will be increased by construction of the Danish section of a new 400 kV connection along the west coast of Jutland between Endrup and Klixbüll. This will raise the total maximum capacity to Germany to 3,500 MW in both directions. A cooperation agreement has been signed with TenneT in Germany, which is building the German section of the West Coast Connection from the border down towards the river Elbe. The Danish and German sections of the West Coast connection, the internal reinforcement of the grid between Endrup and Idomlund, and the connection to the UK were originally planned to be ready for commissioning at the end of 2022, but due to delays in approving the plans for Viking Link in the UK, the date of commissioning has been pushed back to the end of 2023.

Viking Link, the West Coast Connection and Endrup-Idomlund received section-4 approval from the Minister for Energy, Utilities and Climate on 30 October 2017. For Viking Link, a call for tenders is underway relating to cables and substation facilities for the project. The Board of National Grid decided to invest in Viking Link on 26 September 2018, and the ownership and operating agreement for the connection is expected to be signed by National Grid and Energinet in a project steering committee meeting at the end of December 2018. Contracts to supply cables and converters for Viking Link are scheduled to be signed by June 2019 at the latest.

The EIA process for the Danish section of the West Coast Connection and for Endrup-Idomlund was launched on 9 March 2018. The first public hearing phase took place from 9 April to 9 May 2018. On the basis of feedback from local citizens and politicians, the Minister for Energy, Utilities and Climate decided to instruct Energinet to prepare a technical report examining the options that might be feasible as an alternative to overhead lines in these two sections. The Minister for Energy, Utilities and Climate published the technical report on 1 October 2018, after which the report underwent independent assessment by international experts.

The schedule has been adjusted, with the Endrup-Idomlund connection planned to be commissioned in early 2023 and the West Coast Connection at the end of 2023.

Reinvestment in 132 kV cables in Copenhagen

Large parts of the Copenhagen 132 kV cable grid have exceeded their technical service life, and the capacity of electricity generating facilities in Copenhagen is falling as a result of the closure of power station units. Combined with increasing electricity consumption in the area, this means that security of supply in the area will be challenged in the next few years. In the opinion of Energinet, reinvestment is needed in the local 132 kV cable grid in order to maintain security of supply and thereby avoid the need for preventive disconnection of large amounts of electricity consumption in the area.

Even after completion of the planned and ongoing reinvestment projects in the Copenhagen area, the age of the remaining part of the 132 kV connections in the Copenhagen area means that further reinvestments in the 132 kV cable network will become necessary again within a few years. In the past five years, several of the cables have suffered an increasing number of faults that have resulted in long outage times for the sections concerned. The old cables are expensive to operate and expertise in the cable types is being lost, and combined with the fact that many of the cables have a relatively low transmission capacity in relation to expected future needs, this means that the Copenhagen grid must be reinforced to keep step with changing consumption patterns.

Analyses indicate that there is a need for expansion and reinvestment in the Copenhagen electricity grid if security of supply is to be maintained. The need for expansion and reinvestment is set out in Energinet's RUS plan for 2017, which describes the need for

reinvestment in the existing 132 kV cable grid in the Copenhagen area.

Energinet has launched a project to analyse in detail the need to replace components in light of changing consumption patterns in the Copenhagen grid. The project is designed to ensure that the final restoration plan for the 132 kV cable grid in the Copenhagen area will be optimised as far as possible in terms of changing consumption patterns, residual lifetime of the existing cables, correct environmental treatment of the old cables, and minimal disruption to citizens as the replacement work takes place.

The ultimate goal is to ensure that the Copenhagen area has a resilient and future-proof transmission grid that guarantees an adequate supply to meet the growth in electricity consumption and maintains security of supply at a high level.

2.7 The wholesale market

Denmark constitutes a link between the Nordic and continental electricity markets, so one of Energinet Elsystemansvar's key responsibilities is to provide a resilient and well-functioning market coupling that creates value for Danish and Nordic market players.

As fluctuating renewable energy from wind and solar occupies a growing share of our electricity system, a European intraday market is an important element in balancing production and consumption just before the delivery hour. Energinet Elsystemansvar expects the intraday market to become increasingly important for the Danish players, resulting in higher trading volumes in this new European market.

European regulation of markets

The Guideline on Capacity Allocation and Congestion Management (CACM) is a European network code that lays down common rules for capacity calculation and the day-ahead and intraday markets. Energinet Elsystemansvar is actively involved in transforming these markets from regional markets to markets which are more pan-European in scope – for example the market coupling project called Multi-Regional Coupling (MRC) for the day-ahead market has been running since February 2014 and new areas are being added all the time. Virtually all of Europe is linked through market coupling, and the aim is to create a common day-ahead market covering the whole of Europe.

More power exchanges in the market

The Guideline on Network Capacity Allocation and Congestion Management has established a new role for power exchanges: Nominated Electricity Market Operator (NEMO). The designation of market operators is intended to ensure that the common day-ahead and intraday markets are established in the relevant Member State. A Member State must designate at least one NEMO. Nord Pool has been designated as a NEMO in Denmark. EPEX Spot, designated as a

NEMO in Germany and other countries, been also been given permission to offer day-ahead and intraday trading services in Denmark and the other Nordic countries. This means there will be more active power exchanges in Denmark in future, as is the case in most of North-Western Europe.

Working with the other Nordic TSOs, Energinet Elsystemansvar has launched a joint project implementing the More-NEMO Arrangement (MNA). In the project, the TSOs have joined forces with Nord Pool, EPEX, the Nordic RSC (which is responsible for the Nordic capacity calculation) and eSett (the joint Norwegian, Swedish and Finnish balance settlement company) in order to develop an effective and resilient process. The project is expected to be implemented in 2019.

Intraday market platform
After years of preparation, the common European intraday market platform XBID (Cross-border Intraday) was successfully launched on 14 June 2018. That puts Energinet and therefore Denmark among the first 14 Member States in which intraday trading is now possible across borders. Apart from Denmark, the other Nordic countries, the Baltic states, Austria, Germany, Netherlands, Belgium, France, Spain and Portugal are involved. The plan is for more countries to follow suit in a second and third wave of implementation, as soon as their TSOs and power exchanges are ready.

XBID is the official intraday market platform, so all European exchanges and TSOs have entered into agreements requiring them to collaborate in the operation and ongoing development of the XBID platform.

At the heart of XBID is a shared order book that will eventually cover the whole of Europe. Energinet Elsystemansvar and other European TSOs make intraday capacity in the international connections available by transferring it to a single capacity management module in XBID. In addition, the order books of all the exchanges are combined into a shared European order book. In this way, the XBID system matches bids depending on the available capacity and continuously optimises the allocation of available capacity across Europe.

XBID links the Nordic intraday market to large parts of Europe, ensuring greater liquidity and providing a much larger trading area for Danish and Nordic market players.

Regional calculation of net transfer capacity in the electricity system
The CACM network code requires the TSOs to cooperate in several initiatives, including the establishment of capacity calculation regions (CCRs). A capacity calculation region is an area in which a single, cross-border calculation of net transfer capacity is performed. The aim is to harmonise calculation methods in order to increase transparency in the electricity market and optimise capacity allocation. At present, capacity is release on the basis of bilateral agreements and individual TSO calculations. The introduction of regional calculations of net transfer capacity is the first step on the way to a single capacity calculation for the whole of Europe, and the capacity calculation regions are expected to become the natural focal point for the development of regional electricity markets.

Energinet participates in two capacity calculation regions – CCR Nordic, which covers the established cooperation with the Nordic TSOs, and CCR Hansa, which involves Norway, Sweden, Germany, the Netherlands and Poland with their respective borders with the

Nordic countries. The Hansa region acts as a kind of buffer between the Nordic countries and the continent, and is only intended as a temporary structured. In April 2018, all the European TSOs applied to the European utility regulators to add the Western Denmark-Netherlands bidding zone boundary to CCR Hansa in anticipation of the commissioning of COBRAcable in the third quarter of 2019.

Under the CACM network code, the TSOs in the individual capacity calculation regions are generally required to introduce a new capacity calculation method that is more explicitly based on the physical energy flows when equilibrium quantities and equilibrium prices are calculated in the intraday and day-ahead markets – this is known as flow-based market coupling. The flow-based method is expected to increase economic welfare in the Nordic system by optimising the flow in the grid on the basis of the physical reality and thereby allocating the capacity where there is the greatest economic value.

In September 2017, the Nordic region and the Hansa region submitted proposed new capacity calculation methods to the national utility regulators for approval. CCR Nordic proposed a flow-based capacity calculation, which was approved in July 2018, whereas CCR Hansa, which comprised just three international connections in 2017 and is therefore unable to benefit from the more advanced flow-based method, proposed a capacity calculation method based on the coordinated net transfer capacity approach. The method for the Hansa region has not yet been approved. The goal is to implement the capacity calculation method for CCR Nordic in 2021 after a period of parallel operation of the existing calculation method and the future flow-based method.

Exports from Denmark to Germany

The availability of export capacity on the Danish-German border between Western Denmark and TenneT Germany's grid area has been very low in recent years. The reason for this capacity constraint is a combination of very high production from renewable energy sources in Northern Germany and insufficient network expansion between Northern and Southern Germany. The domestic German bottlenecks will be further exacerbated by a temporary reduction in grid capacity due to the ongoing grid expansion work taking place in Northern Germany.

Energinet and TenneT Germany have been in close contact in recent years, and have been working with market players and regulators on both sides of the border in an effort to resolve the issues. However, these initiatives are only set to deliver a very small amount of extra capacity.

"The availability of export capacity on the Danish-German border between Western Denmark and TenneT Germany's grid areas has been very low in recent years"

In June 2017, the Danish Ministry of Energy, Utilities and Climate issued a joint declaration with the German Federal Ministry for Economic Affairs and Energy requiring a minimum level of capacity to be made available for trade in electricity between Jutland and Germany. The joint declaration between the two countries will gradually increase the minimum capacity for the day-ahead market in both directions to 1,100 MW in 2020. In 2018, the minimum capacity is 700 MW. Energinet and TenneT in Germany are responsible for implementing the joint declaration and must guarantee these minimum capacities in the day-ahead market by means of an operating agreement. Depending on the performance of the day-ahead market, each TSO decides whether the minimum capacities necessitate countertrading due to internal grid congestion.

Energinet and TenneT are also discussing a possible extension of the existing operating agreement to handle more capacity and countertrading on the border, and have jointly analysed a number of possible countertrading models. On the basis of these analyses, Energinet conducts countertrading under a special regulation in Western Denmark, and TenneT uses the intraday market on the German side. The capacity constraints and countertrading by the TSOs mean that very little electricity is physically exported.

In early 2018, DG COMP (the Directorate-General for Competition of the European Commission) launched an investigation into TenneT's cross-border capacity reductions. As part of the process, the Commission presented TenneT's commitment to increase cross-border capacity, which was then put out to consultation. Energinet is not party to the negotiations between TenneT and the Commission, and is not aware of the result of this consultation.

Trading with Sweden
From the point of view of Energinet and the market players, the reductions in the Danish-Swedish international connections are unsatisfactory, and Energinet and Svenska Kraftnät are in constant dialogue to address the issue and identify possible solutions.

The capacity of the West Coast cross-section is expected to be boosted when the planned 400 kV transmission line between Stenkullen and Skogssäter is commissioned in 2021. However, there are several factors which may have an impact on the current situation on the borders. Among the issues are the expansion of the new Hansa PowerBridge international connection between Sweden and Germany, reinvestments in the connections between Finland and Sweden, a number of internal expansions, the phase-out of nuclear power in Sweden, and the expansion of wind capacity, all of which will have an impact, although the precise nature and extent are uncertain at this time.

FIGURE 20: OUTLINE OF EXPECTED DEVELOPMENTS IN THE ANCILLARY SERVICES MARKETS, LISTED BY EXPECTED COMMISSIONING YEAR.

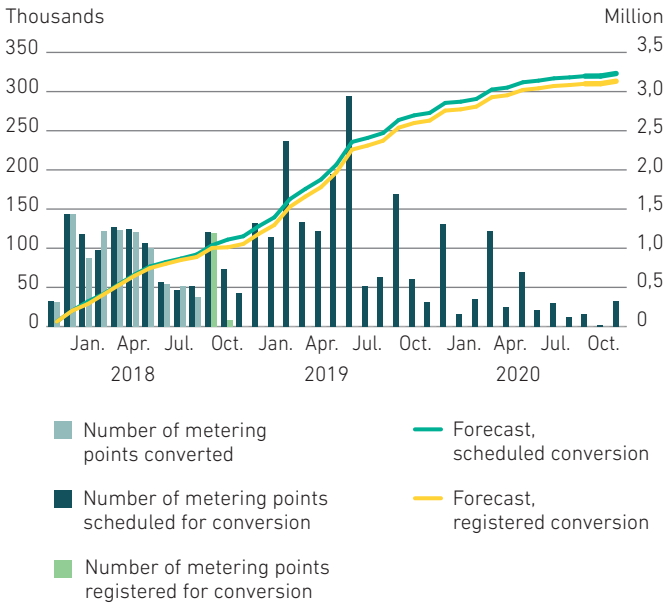
2019	2020	2021
Nordic market for aFRR capacity	15 minutes imbalance settlement period	Nordic market for aFRR activation
Nordic market for mFRR capacity	Modified imbalance settlement	European Market for aFRR activation
DK1 introduction to European FCR market		European Market for mFRR activation

The Nordic TSOs Fingrid, Statnett, Svenska Kraftnät and Energinet jointly publish a quarterly capacity report presenting the average capacity of interconnections in the Nordic countries and the causes of any reductions. This report and other reports are discussed by the Nordic TSOs and NordREG, the organisation in which the Nordic national regulators cooperate. Potential initiatives will be presented and discussed with the market players and other stakeholders in a NordREG workshop in late 2018 in Stockholm.

Transmission rights
Energinet currently offers physical transmission rights in the form of annual and monthly contracts in the connections between Western Denmark-Germany and Eastern Denmark-Germany, and monthly contracts in the Great Belt Power Link The contracts are auctioned off in the Joint Allocation Office (JAO). The purpose of transmission rights is to give the market the opportunity to hedge against price differences between two areas. The current contracts relate to the physical delivery of electricity between two price areas, which in practice is not used. Instead, the rights are sold back to the TSOs for use in the day-ahead market, and the price difference between the two price areas, which is equal to the congestion rent for the connection, is received in payment. In 2019, the Western Denmark-Germany and Eastern Denmark-Germany products will be converted into financial transmission rights. This means that market players will no longer be able to make a physical delivery, but will instead receive a payment corresponding to the price difference between the two areas. Energinet does not expect this to affect the market as it simply consolidates the existing practice.

In 2018, Energinet has also obtained approval for a method of securing

FIGURE 21: FORECAST AND STATISTICS ON ROLL-OUT OF FLEXIBLE SETTLEMENT.



cross-border price hedging opportunities on the Danish-Swedish borders. This will improve the risk management options available to players in the Nordic market and is likely to increase the volume of transmission rights sold in respect of Germany. Primarily, it is expected to mean the reintroduction of transmission rights in the northbound direction on the Western Danish-German border, and the introduction of financial transmission rights in COBRAcable during the summer of 2019.

2.8 The ancillary services market

Energinet, in discharging its duties, must contribute to ensuring that the best possible conditions are established for competition on the markets for electricity production and trade, see section 31 of the Danish Electricity Supply Act. Ancillary services are an area experiencing considerable market development as a result of implementation of the European network codes and the green transition in the electricity system.

Internationalisation is an essential component of Energinet Elsystemansvar's role in developing the market in ancillary services, because it creates more competition and larger and more resilient markets. Two important internationalisation projects are the establishment of pan-European activation platforms for balancing energy based on the European network code Electricity Balancing Guideline (EBGL) and on the Nordic Balancing Concept (NBC).

Electricity Balancing Guideline (EBGL)

The EBGL came into effect on 18 December 2017 with a fixed schedule for the introduction of common European platforms for activating frequency restoration reserves (FRR). Platforms will be set up for manual reserves (mFRR) and automatic reserves (aFRR), and they will operate independently of each other. The platforms are due to go live in December 2021, but the preliminary design of the platforms will be released as early as December 2018.

The European TSOs are all jointly responsible for developing the design proposals, and Energinet Elsystemansvar is actively involved. The goal is to create regional European marketplaces allowing activation of balancing energy bids for automatic and manual reserves.

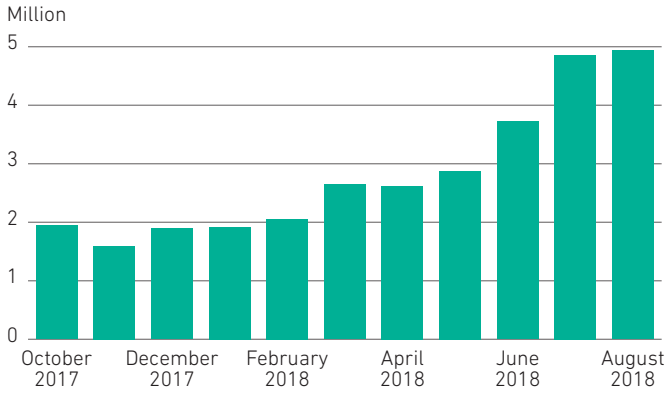
Nordic Balancing Concept

In March 2018, the five Nordic TSOs – Svenska Kraftnät, Kraftnät Åland, Statnett, Fingrid and Energinet – entered into an agreement to develop and implement the 'Nordic Balancing Concept', which includes the following milestones:

- Pan-Nordic capacity market for aFRR (Q2 2019).
- Pan-Nordic capacity market for mFRR (Q4 2019).
- Introduction of 15-minute imbalance settlement periods (ISP) (Q2, 2020).
- Nordic modernised ACE balancing (Q1, 2021).

These new market initiatives are shown in figure 20 with the anticipated year of

FIGURE 22: CHANGE IN NUMBER OF QUERIES PER MONTH BY THIRD PARTIES AND CONSUMERS.



implementation. The table also sets out the anticipated start of participation in the European FCR market from Western Denmark.

2.9 The retail market

According to the Danish Electricity Supply Act, Energinet supports well-functioning markets and formulates regulations that are necessary for electricity market functioning. In discharging its duties, it must contribute to ensuring that the best possible conditions are established for competition on the markets for electricity production and trade.

The wholesale model was launched in 2016 as part of the development of the retail market. The wholesale model was the starting point for a new retail market with new regulations and revised executive orders and legislation, in which the electricity supplier was given a central role, handling all customer contact and all billing of end customers. Generally speaking, the wholesale model was used as the basis for new features and future initiatives in the retail market, including hourly settlement of small consumers known as flex-settlement. The wholesale model's framework conditions, which were defined in Energinet regulations, were re-evaluated in 2017 and the resulting adjustments were made in the summer of 2018.

Flex-settlement

The most significant change in the retail market in 2018 is the start of hourly settlement of electricity consumers with an annual consumption of less than 100,000 kWh. This scheme is called flex-settlement and Energinet is required to develop a model for it, see Danish Executive Order No. 1358 of 03/12/2013. Roll-out began in December 2017 and the pace picked up in the first half of 2018.

In 2013, the Danish Executive Order on Remote-Read Meters (bekendtgørelsen om fjernaflæste elmålere) required the grid operators to introduce smart meters, and instructed Energinet to introduce a model for hourly settlement for all electricity consumers (approximately 3.3 million). The aim was to ensure greater flexibility in Danish electricity consumption so it can match the fluctuating renewable energy production resulting from the green transition. Hourly settlement allows electricity consumers to be billed for their electricity consumption hour by hour, meaning they can reap rewards by reducing consumption in hours with high electricity prices. The development of an hourly settlement model was part of implementation of the wholesale model in 2014-2016. The model (which was given the name flex-settlement) was developed jointly with industry and in consultation with the Danish Energy Agency.

The model meant an extra cost for the 85,000 or so electricity consumers in net settlement group 6 (autogenerators with yearly settlement, particularly small solar cell systems), because this group could no longer be billed for their net annual electricity consumption, but instead for their hour-by-hour electricity consumption and generation. Exemptions for the net settlement

10 The formal title is Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). The Regulation is also often referred to simply by its abbreviation GDPR.

group have been discussed with the authorities and industry. The Danish Energy Agency recently ruled that there were no alternatives to flex-settlement for net settlement group 6. Following the Danish Energy Agency's ruling, Energinet has resumed implementation of the planned flex-settlement method for autogenerators with yearly net settlement, to start on 1 January 2019. The situation in the first three quarters of 2018 is that approximately 30 per cent of previously profile-settled energy has been switched o hourly settlement, giving consumers the opportunity to react to price signals and contribute to demand flexibility, and thereby improve security of supply. In total, this will affect around one million electricity consumers.

DataHub
Energinet's primary focus is to ensure efficient and structured operation and development of DataHub, including supporting and collaborating with the players. Through its core activities, the business unit must provide direct assistance to the electricity market, and DataHub plays a central part. The market players in the Danish electricity market are the primary users of DataHub, which ensures that they have the information they need to bill each other and their customers.

Energinet tries hard to the involve industry in dialogue, and helps the players safeguard operation and make the necessary adjustments to optimise procedures. In 2018, particular attention has been paid to supporting the real-world switch to flex-settlement and its subsequent management. Dialogue with the players takes place in various forums: Technology and implementation meetings are held six times a year, involving representatives from the market and their IT suppliers. The meetings discuss topical issues, initiatives and solutions to any challenges that arise. Dialogue also takes place in regional meetings, which are organised by representatives from Energinet once or twice a year across the country, and in which operation is a permanent item on the agenda. Weekly Skype meetings are held in which Energinet reports on operating status, and in which the player are able to submit comments.

Data in the retail market
Energinet is experiencing an increase in demand for data and also for digital data presentation solutions. Energinet has also seen greater interest from abroad in DataHub solutions and presentation solutions for the collected data. Meanwhile, implementation of General Data Protection Regulation9 has had a considerable impact.

It has been a major task to ensure that all data and processes comply with the GDPR. DataHub was designed from scratch to comply with privacy-by-design principles, so it already complied with the GDPR in large parts. All employees who work with data in the retail market at Energinet have completed a course on the GDPR in order to ensure that the data of individuals and businesses is protected.

Energinet makes detailed data available to the public in one of two ways. The first is the website eloverblik.dk, in which electricity consumers are able to access their own data in DataHub. This solution has managed to increase the number of unique users and the number of lookups by more than 50 per cent compared to the year before. The second solution, for third parties, allows electricity consumers to grant access to their data to other parties at the retail level. This solution, too, has also experienced a massive increase of over 50 per cent in the amount of downloaded data compared to the previous year.

Energinet presents public data via its website energidataservice.dk. This website publishes the data which must be made available to the public and which does not compromise personal data security. This could be data about grid area consumption, CO2 figures in energy consumption, or how much energy is exchanged with other countries. Everyone in Denmark and abroad is able to access this data, and it is possible to communicate directly with Energinet via the service's user forum, in which requests for new data sets can be made. The data sets that are deemed to be the most useful for the Danish market or Danish consumers are then implemented.

Energinet is also active internationally with regard to data sharing. In 2018, for example, a research project looking into data sharing was carried out with Elering in Estonia. In a new pilot project, Elering and Energinet are attempting to solve a tricky problem that is absolutely critical in allowing electricity consumers to become flexible electricity consumers: making it possible for consumers to grant outsiders access to their power consumption data in a simple and secure way. The solution must be an open standard and must be technology-neutral. Everyone must be able to use it, both in Denmark and abroad.

Energinet is also working on 'data as a service' in the retail market. This is about extracting socially beneficial data for further analysis, for example for industry organisations or public authorities and similar bodies. These data extracts are made available as required. If a needs assessment indicates that the data may be of interest to the public, it is presented either in one of the regular public reports which Energinet publishes, or as part of the EnergiDataService.

GAS

The Danish gas system is facing a number of events which in one way or another affect Energinet's responsibility to maintain a high level of security of supply and efficient gas transport

The main events are the reconstruction of the Tyra platform, the establishment of a transmission connection between the Norwegian gas fields and Poland, and the integration of green gas in the grid.

To prepare for the period when Tyra is to be reconstructed and supplies from Danish production will be drastically reduced (starting next year), a number of system and market initiatives have been agreed. On the system side, the withdrawal capacity of the Lille Torup gas storage facility is to be increased. In addition, extra northbound capacity on the German side of Ellund was put up for auction in July 2018. However, the extra capacity was not sold. On the market side, Energinet is placing greater emphasis on communication with the market, and is encouraging the market players to optimise capacity utilisation in Ellund. Energinet is also striving to reinforce the balancing concept.

Energinet and the Polish TSO Gaz-System are collaborating on the Baltic Pipe project. The Baltic Pipe project is a new gas transport route which makes it possible to transport up to 10 billion m3 of gas per year from Norway through Denmark to Poland. The project gives Denmark an extra source of gas and the additional gas volumes are expected to help keep the transport tariffs stable in future, when Danish gas consumption is predicted to fall. The project will result in an expansion of the existing gas system in Denmark, making it possible to transport large volumes of gas through Denmark. The final investment decision will be made by the end of 2018.

The increase in the number of biogas plants connected to the gas grid presents new challenges and investments for Energinet. They partly relate to the traditional use of the grid in the past, when the gas was transported to the consumers from a small number of sources. In future, the gas is expected increasingly to be produced and consumed locally, with an opportunity to return gas from the distribution grid to the transmission grid.

In addition, Energinet needs to invest in the gas grid as part of ongoing maintenance or as a result of other socio-economic factors affecting the gas grid, such as the construction of new railway lines. For new construction projects and normal maintenance alike, the economics and the environment must be taken into account, and gas grid operation must be optimised, for example by switching to more energy efficient components.

Energinet Gas TSO is in regular contact with the market participants and involves them when new market initiatives are developed or new rules are implemented in the gas market. The reconstruction of the Tyra complex is a good example – Energinet involved relevant market participants in user groups at an early stage in an effort to find the best way of safeguarding supplies to gas customers throughout the reconstruction period.

FIGURE 23: THE DANISH GAS TRANSMISSION NETWORK.

Market dialogue is constantly prioritised. For example when the European gas balancing code was introduced, the market was consulted early in the process, and the players were subsequently involved whenever the balancing rules were improved. This was noted by the European regulator ACER in its annual report on gas balancing systems in the EU, which praises Energinet for the ongoing development of the balancing system in collaboration with the market players.

"Energinet purchases gas for storage so it can supplement supplies to protected customers in Emergency situations"

3.1 Security of gas supply

Energinet has overall responsibility for security of supply in the Danish gas transmission system. In order to discharge this responsibility, Energinet provides a well-developed infrastructure and identifies market initiatives applicable gas market players, enabling them to offer Danish consumers the quantity of gas they need. Energinet's ongoing assessments of security of supply in Denmark are published annually in the Security of Gas Supply Report, and on an ad hoc basis when serious incidents occur. Since the previous edition in December 2017, two factors in particular have arisen with relevance to security of gas supply – adoption of the revised EU Security of Gas Supply Regulation, and developments concerning the reconstruction of the Tyra platform in the North Sea.

EU Security of Gas Supply Regulation

There is now a revised Regulation (EU) 2017/1938 of 25 October 2017 concerning measures to safeguard the security of gas supply and repealing Regulation (EU) No 994/2010. Key elements of this revision are a stronger solidarity principle, common risk assessments with a more uniform structure, preventive action plans and emergency plans in all countries with four-year validity.

The revision builds on a more regional approach to supply crises, with stricter requirements being introduced for helping neighbouring countries to maintain supply to protected customers in regional gas supply crisis situations. This can be done by releasing gas from neighbouring countries to countries at the Emergency level (the highest crisis level which occurs very rarely) and by disconnecting customers which are not 'solidarity-protected'. Disconnected customers must be financially compensated.

According to the Regulation, inter-regional agreements must be negotiated during the course of 2018, but work across the EU did not begin in earnest until the spring of 2018, and they are complex agreements requiring clarification of a number of fundamental issues. The expectation, therefore, is that final agreements will not be concluded until 2019.

Regional risk assessments must also be prepared by the competent authorities, to ensure better coordination between countries. Denmark is in the following three groups: Denmark, Norway and Baltic Sea. The result of the regional risk assessments must also be incorporated into the national risk assessments.

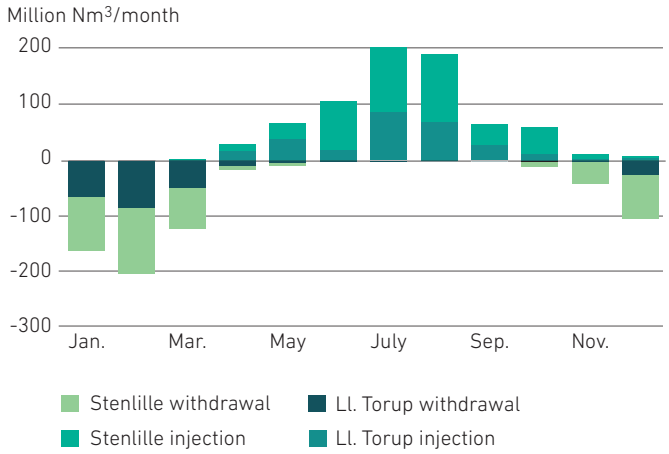
And finally, a new preventive action plan and emergency plan are due for publication on 1 March 2019.

Developments concerning Tyra

The final decision on the reconstruction of Tyra was made by DUC in December 2017. The most recent schedule, from July 2018, indicates that the shutdown is planned for March 2019, with production ramped down slowly and complete shutdown from late 2019. The reconstruction is expected to be completed in July 2022. Total's takeover of Maersk's activities in the North Sea does not change the schedule created by DUC.

The latest findings about the supply situation were published in August 2017, and the conclusion is that supplies for Danish and Swedish consumers will remain resilient during the reconstruction of Tyra, but that a combination of a cold winter and technical incidents involving disruption of supply sources may pose a challenge to supplies. In this context, there are two significant critical elements in the supply situation: the available storage volume in the Danish gas storage facilities, and capacity in the connection to Germany.

FIGURE 24: INJECTION INTO AND WITHDRAWALS FROM STORAGE FACILITIES 2017.



The impact of biomethane on security of supply
So far, the contribution to security of supply from biomethane has been negligible, as the share in the natural gas grid has been very small, and as there have been ample opportunities for natural gas supplies from the North Sea and Germany. In 2018, biomethane is expected to amount to almost 8 per cent of gas supplies to Danish customers, and with an expected increase to about 15 per cent in 2020, the contribution is becoming more noticeable. This will be more pronounced while Tyra is reconstructed, when supplies to Denmark and Sweden will mainly come from a single source – Germany.

The impact of gas storage facilities on the overall supply situation
The two Danish gas storage facilities, Lille Torup and Stenlille, have a total volume capacity of 890 million Nm³, or just under 11 GWh. This corresponds to almost one third of Danish annual consumption. The Danish gas storage facilities are an essential and integral part of the Danish gas system, in relation to the market, capacity, security of gas supply and daily operation. This will be especially true during the reconstruction of Tyra, when Germany will be the only major source of supply.

In Lille Torup, the volume capacity is still down by 60 million Nm³. This is because one of the caverns is filled with water as part of a maintenance programme. The Danish Environmental Board of Appeal has ruled that the water from the cavern must not be discharged, in a reversal of the Danish Environmental Protection Agency's previous approval.

Gas consumption varies over the year and over each 24-hour period. Market players use the Danish gas storage facilities to store gas between seasons and to supply the gas required over each 24-hour period. During the summer, when gas consumption is low, gas is injected into the gas storage facilities. In winter, when supplies from the North Sea or Germany can no longer cover Danish consumption and exports to Sweden and Germany, gas is withdrawn from the storage facilities again. If supplies from the North Sea or Germany are disrupted, the two gas storage facilities can also cover the shortage.

In 2019, Energinet estimates that the storage requirements of commercial users for seasonal adjustments will be 400-600 million Nm³. Energinet expects demand for withdrawal capacity in normal situations to vary between 13 million Nm³/day and the current capacity of around 16 million Nm³/day. In March 2018 the withdrawal capacity was fully utilised.

Energinet purchases gas for storage so it can supplement supplies to protected customers in Emergency situations. Due to the reconstruction of Tyra, purchases are expected to increase in 2019 from about 100 million Nm³ at present to about 200 million Nm³ in order to safeguard supplies to protected customers for up to 30 days in the event of loss of the largest source of supply (Germany). Note that the working volume in the storage facilities will decrease by around 12 per cent in 2020 when the storage facilities will be filled with gas from Germany, which has a lower calorific value than North Sea gas.

Capacity of the connection to Germany
The existing capacity from Germany must ensure that adequate volumes can be supplied over the year, and the storage volume in the Danish gas storage facilities must ensure that volumes are available for seasonal adjustments and that supplies to the Danish and Swedish markets are maintained during the exceptional loss of sources of supply, primarily Germany. The players' utilisation of capacities in the gas system is therefore crucial in safeguarding security of supply from 2019/2020. A long and hard winter is thought likely to cause supply problems even if optimum use of is made of the system capacity.

In consultation with the players, Energinet is looking into various other options to improve security of supply with market measures or physical initiatives. The aim is to reduce the risk of disconnection of Danish and Swedish customers.

In the course of 2017 and 2018, Energinet has discussed, in a number of user groups and bilateral meetings, how market measures can be used to manage the situation when Tyra shuts down in autumn 2019, with operations not expected to be resumed until in mid-2022. In essence, the view among the market participants is that as far as possible, the market must be able to operate as it does today, and that any regulatory market interventions must only be used in a crisis situation. The bilateral meetings and user groups concluded in the following proposal for three categories of market measures:

- Communication
  - Day-by-day display of the supply situation for the relevant season in a fixed graph online (called Minimal Storage Filling).
  - The holding of so-called Emergency Workshops in which crisis situations are discussed actively with the market participants.
  - Increased focus on general market analysis and market monitoring, in cooperation with the Danish Utility Regulator.
- Capacity utilisation – Ellund
  - Introduction of new possibilities for shippers to trade capacity secondarily on PRISMA.
  - Introduction of an 'over-nomination' mechanism, so that shippers can nominate, without first booking capacity.
  - Focus on congestion management, depending on the competitive situation.
- Balancing
  - Removal of price cap/floor to ensure that the balance price always reflects the current supply situation.
  - New method for calculating the imbalance price if there is an imbalance throughout the market on a given day.
  - New mechanism for calculating the imbalance price in the event of an emergency supply incident.

In addition, Gas Storage Denmark has decided to increase the physical withdrawal capacity of Lille Torup storage facility by about 2 million m3/day before the reconstruction of Tyra, to make additional withdrawal capacity available if supplies from Germany are disrupted for example.

In addition to the above initiatives, the option for extra capacity at Ellund in the northbound direction has also been considered. However, this option is no longer possible, as Gasunie Deutschland did not receive sufficient capacity bookings on an annual basis in the Tyra period to justify increasing the Ellund capacity towards Denmark. As a result, the capacity to Denmark during the Tyra period will stay the same as today, at around 5.1 GWh/h.

When Tyra reopens, expected in mid-2022, the Danish Energy Agency anticipates higher gas volumes from the Danish part of the North Sea than today, and Energinet considers that security of supply will be higher than today.

3.2 Maintaining gas balance, including storage

Energinet is responsible for the physical balance in the gas transmission system in Denmark. This is primarily ensured via balancing rules that give the market players an incentive to balance their own gas portfolios. The majority of the natural gas transported via Energinet's transmission grid comes from the North Sea fields. Most of the gas from the North Sea is landed via the Tyra and Syd Arne pipelines and sold to Danish consumers or exported to Sweden and occasionally

Germany. Some gas is also exported to the Netherlands via the NOGAT pipeline system, which is outside the Energinet system.

To the extent there is a need for additional balancing, Energinet uses available linepack12, storage facilities and the purchase and sale of gas.

3.3 Gas transit and transport capacity
Under the Danish Natural Gas Supply Act, Energinet can enter into agreements reserving capacity for security of supply for transit. With regard to Sweden, firm capacity is guaranteed in Dragør in normal situations. Energinet has also ensured that there is capacity in Dragør to supply the Swedish protected market at Emergency level (the highest crisis level). This capacity is safeguarded by including a flow corresponding to the protected Swedish consumption in Energinet's calculation of capacity requirements in the Danish transmission system. When the common balance zone is established with Sweden, there will in practice be no more capacity bookings to Sweden (more details in section 3.7).

When Tyra reopens in 2022, the Danish Energy Agency expects higher gas volumes from the Danish part of the North Sea than today. This means that there will be natural gas for transit to Sweden, Netherlands and Germany, plus the option of supplies from Germany.

Energinet has also started planning the Baltic Pipe project and a connection to the Norwegian offshore gas system. When the project is complete, Denmark will be connected to Poland with transit of up to 10 billion Nm³ per year in 2022, with the option of supplies from Poland to Denmark. The project gives Denmark an extra source of gas and is expected to be able to keep the transport tariffs stable in a future in which Danish gas consumption is predicted to fall. The final investment decision will be made by the end of 2018.

The new EU Gas Security of Supply Regulation is aimed at increasing solidarity between neighbouring countries. For Denmark, this could mean solidarity obligations with Sweden, Germany and the Netherlands. In 2018/2019, bilateral agreements must be entered into concerning the solidarity obligations, including payment for providing solidarity to a neighbouring country. The Danish Energy Agency will also ensure that natural gas legislation and other rules are amended so that the principles of solidarity can be achieved.

3.4 Planning
Energinet is responsible for coordinated grid planning in the Danish

11 Linepack is the 'store' in the gas grid that permits a certain time lag between supply and offtake in the gas grid.

FIGURE 25: EXISTING AND POTENTIAL UPGRADE FACILITIES.

gas system. This is intended to ensure the cost-conscious development of a gas system that supports the green transition and the various opportunities and requirements in the way the gas grid is used, culminating in connections of different kinds for offtake and production.

In this context, Energinet's role is to analyse gas-related developments in order to carry out holistic planning. The purpose of the analyses is to ensure that any change to the gas transmission system is adequately examined in relation to possible alternatives.

This work is published in the international network development plan (Ten Year Development Plan or TYNDP) and in the lower-level regional plans (Gas Regional Investment Plan or GRIP), for which Energinet is in the North-West region (NW) and the Baltic region (BEMIP). The Baltic Pipe project is a good example – it has been included in the Baltic regional plan (BEMIP) and the TYNDP since 2012-2013.

In addition to the TYNDP and the lower-level regional network development plans, the Security of Gas Supply Report assesses the security of supply of natural gas, including infrastructure changes in the past year, the next winter and the next 10 years.

Finally, the Installation Report provides a technical and financial overview of completed, ongoing, approved and planned gas projects in Denmark. The Installation Report includes all of Energinet's gas facilities, including gas storage facilities. It covers the next 5-10 years, and documents the short-term and medium-term parts of the planning effort. In addition to pipeline rerouting and maintenance, the Installation Report also contains plans to connect biogas plants with upgraded biogas to the transmission system.

3.5 Connection of new gas facilities

Examples of new facilities that are connected to the transmission grid include biogas upgrading plants, LNG liquefaction plants and other major consumers or producers. The most important new gas facilities to be connected to the transmission grid in the next few years are biogas plants or gas return plants to handle situations in which more gas is supplied to the local grid than is consumed there.

Biomethane has been injected into the grid since 2011, and could account for 15 per cent of gas supplies to Danish gas customers by 2020. Most biomethane is injected into the distribution grid.

Thirty-one plants upgrading biogas to natural gas quality are connected to

the distribution grid. One plant is connected directly to the transmission grid. About 15 new plants and plant expansions are expected to be connected by the end of 2019. As more and more biogas upgrading plants are connected, gas is increasingly being delivered directly to the distribution grid. Some distribution grids are therefore changing role, from only receiving gas from the transmission grid, to also receiving gas from local production.

Upgraded biogas has combustion characteristics which are chemically similar to natural gas, but may contain residual oxygen from desulphurisation. The limit value for oxygen content in the Danish gas system is higher than the requirements in the German transmission system, where the limit values for certain facilities, such as storage facilities, can be as low as 10 ppm. As a result, in the summer of 2016, Energinet faced some difficult issues with oxygen from upgraded biogas in the southbound flow via Ellund. The issues were dealt with operationally by reducing capacity at the point.

The oxygen content in upgraded biogas is still a focus point. Energinet is working towards a balanced approach as regards capacity and infrastructure risk on the one hand and access for upgraded biogas on the other. Energinet has actively raised the issue in the European standardisation organisation CEN. CEN set up a working group in September 2018 to look into the issue.

3.6 Conversion, expansion and maintenance of the gas grid
Europe's gas systems are becoming more and more integrated across national borders, as individual countries support each other in safeguarding security of supply, cost-effectiveness and availability of more climate-friendly solutions. In the coming period, Energinet is planning a number of conversions and a possible large-scale expansion, and there is an ongoing need for substantial renewal and modernisation of the technical grid components so that the same high level of security of supply can be maintained.

Conversion
Work has started on modernisation of the electrical installations, instrumentation, measurement and remote control systems, and optimisation of gas preheating in the 11 meter stations and meter and regulator stations, which still have components dating back to the 1980s. The work will last four years and is expected to finish in 2022.

Expansion
Baltic Pipe is the name of a new project for a gas transmission pipeline from the Norwegian gas fields, across Denmark, and via the Baltic Sea to Poland. The project will help to support security of supply in Central and Eastern Europe and to keep tariffs down for use of the Danish gas grid.

Poland and the other Central and Eastern European countries have long faced challenges due to their dependence on Russian gas for growth and prosperity. That is why Poland and Denmark are jointly exploring the potential for greater diversification of supply, for example by establishing an alternative supply route from the Norwegian continental shelf by 1 October 2022, when the current gas supply agreement with the Russian Gazprom expires. The pipeline could carry gas produced in Norway to replace the Russian gas on which Poland and neighbouring countries are currently dependent.

With the proposed expansion, the costs of using the Danish transmission grid will be shared with consumers in Poland and neighbouring countries, making it possible to maintain low tariffs despite declining Danish gas consumption.

The gas pipeline has a total length of approximately 900 km and is scheduled to be ready for operation in 2022. The expansion will result in a capacity of up to 10 billion Nm^3 of gas per year. For comparison, the total Danish gas consumption in 2016 was 2.5 billion Nm^3. Baltic Pipe will comprise a new 120 km offshore gas pipeline in the North Sea from the Norwegian gas pipeline Europipe II in the North Sea to a receiving terminal north of Varde. The Danish transmission system will be expanded with approximately 220 km of new pipeline between Egtved in Jutland and South Zealand. A compressor station will be located close to the Baltic landing point in South Zealand to increase the pressure and therefore also the gas flow in the gas pipeline in the Baltic Sea. The Polish gas TSO Gaz-System is responsible for constructing a gas pipeline in the Baltic Sea between Denmark and Poland and the necessary expansion of the Polish transmission system.

The preliminary studies for the Baltic Pipe project, which were funded by the EU and completed in 2016, showed that the project will be able to unlock considerable economic benefits for both Denmark and Poland. In 2017, after concluding a cooperation agreement with the Polish gas TSO Gaz-System, Energinet proceeded with the next phase of the maturation project, which involved two invitations to submit bids for capacity in a so-called open season, and the final technical and financial business case was prepared for an investment decision. In the next open season, contracts were signed to purchase most of the capacity in Baltic Pipe for a 15-year period. On the Danish side, it is the Minister for Energy, Utilities and Climate who will make the final investment decision. At the end of 2018, Energinet and the Polish TSO Gaz-System are due to make the final investment decision.

Baltic Pipe is planned with a view to delivering a number of benefits:

- Lower prices: A new supply

FIGURE 26: BALTIC PIPE ROUTING.

connection from Norway will benefit consumers in the form of lower costs for using the gas grid once Polish consumers contribute too. In Denmark, Baltic Pipe will therefore provide billions in savings at a time when consumption of natural gas is falling and there would otherwise be fewer consumers to cover the operating costs of the gas transmission grid.

- Security of supply: The Baltic Pipe project will open up more sources of supply, thereby creating a more resilient gas system and increasing the security of supply.

- Increased competition: The Baltic Pipe project will pave the way for increased trade and more competition in the gas market.

- Important project for Europe: The project appears on the EU's list of projects of particular European interest known as PCI projects. The reason is that Baltic Pipe will contribute to the development of the internal market in gas and thereby improve security of supply and provide cheaper and more sustainable energy in several EU countries.

- Lower CO2 emissions: Baltic Pipe has the potential to reduce the use of coal as fuel for power stations in Poland, Central and Eastern Europe and the Baltic countries. In so far as gas replaces coal, the project will help to reduce European CO2 emissions relatively quickly, as coal typically produces twice the CO2 emissions per unit of energy. Meanwhile, lower coal consumption will improve the local air quality and will act to balance fluctuating renewable energy.

The Baltic Pipe project is also expected to affect the ability to support the integration of renewable energy sources such as biomethane in the gas pipeline network, as the lower transport costs facilitate transport between the producer and the consumer.

On 1 March 2018, the project moved from the maturation phase to the establishment phase as Energinet's Supervisory Board approved the business case of the project. This does not mean that the decision has been made regarding final project execution – the final decision rests with the Minister for Energy, Utilities and Climate (expected in December 2018).

In the meantime, Energinet and Gaz-System in Poland will continue planning and designing the project in order to keep the schedule on track. This also includes securing agreements with business partners concerning procedures for invited tenders.

"The Baltic Pipe project will pave the way for increased trade and more competition in the gas market"

In the context of the ongoing EIA process being performed by the authorities, Energinet has launched a number of initiatives to ensure that the many affected landowners are involved, and that a route is found with the least possible impact. Local authorities and landowners are involved in supplementary EIA consultations and ongoing adjustments of the project area.

The second public hearing phase of the EIA being carried out by the authorities is expected to take place at the beginning of 2019.

Return

Most biogas plants are connected to the distribution grid. As more biogas plants are connected to the distribution grid, there more cases where biomethane production exceeds local consumption. There is therefore a need to be able to return biomethane from the distribution grid to the transmission grid so it can be used in a larger area. This leads to the need for a number of return plants in the gas transmission system.

The amount of gas returned from the distribution grid to the transmission grid must be metered and the gas quality must be determined for correct billing and the parties' system balances. Gas in the transmission grid does not contain any odorant (the characteristic odour that ensures that leaks are noticed), so it must be removed from the gas when the gas is returned to the transmission grid.

At present there are gas return plants at the Aalborg and St. Andst meter and

regulator stations. A gas return plant compresses the gas from the distribution grid and injects it into the transmission grid at higher pressure. There is expected to be a need to return gas at three meter and regulator stations: Midtfyn, Viborg and Terkesbøl. Each project will be implemented in close cooperation with the distribution companies.

Maintenance activities
Planned inspections of the entire transmission system guarantee a high, but necessary, level of safety, and a detailed maintenance programme helps to keep the system in a sound state. Over the years, the executed maintenance programmes have delivered a gas supply with no outages and no accidents.
Pipeline inspections are carried out every year to check the condition of the pipes. In 2019, internal pipeline inspections (pigging) will be performed in two selected pipe sections:
- Nybro-Egtved Nord, about 57 km.
- Kongsmark-Dragør (Kalvebod), about 108 km.

As stated above, Energinet is carrying out a number of initiatives relating to the reconstruction of Tyra. One of them aims to guarantee high uptimes at the Egtved compressor station, as this facility is key to maintaining gas imports from Germany. The Egtved compressor station will be a critical asset, and during the period it will have more hours of operation than before. In addition, there will be less redundancy as it will probably be necessary to run two out of the four units at all times. In some operating situations, three units will be needed. This requires adjustments in the planned maintenance as well as enhanced callout arrangements in the event of a breakdown of the compressor station. In response to the reduced redundancy, Energinet is also looking into purchasing strategic spare parts for critical components with a long delivery time.

Asset management
The gas infrastructure is covered by a comprehensive Asset Integrity Management System (AIMS) to support secure and cost-efficient operation of the gas transmission system. Many service operations in gas facilities are mandated by law and are carried out in accordance with the law.

Asset management has three focus areas:
- Risk-based approach: We are dependent on our assets, and outages may have serious consequences.
- Efficiency: Focus on making things more efficient and constantly improving what we do.
- Methodology: Supporting effective procedures and transparency, and reducing the risk of outages.

"Energinet has started work to strengthen joint grid planning with the distribution companies with a view to safeguarding economically effective solutions and grid reinforcement"

3.7 Cooperation with other grid operators and countries

Under the Danish Natural Gas Supply Act, Energinet must enter into operational cooperation with all adjacent physical systems, i.e. storage facilities, the German TSO, the Swedish TSO, the upstream company, distribution companies and biogas producers. Operational cooperation agreements have been concluded with all adjacent systems, describing the framework for the operational cooperation.

Grid planning
Energinet is responsible for working towards developing the grid so that biomethane is integrated effectively and contributes to an economic green transition of the gas system. Apart from grid planning, the physical construction of connection facilities and grid reinforcement, this also includes market measures to support framework conditions and rules that safeguard efficient operation of the gas system and high security of supply as the gas system gets greener.

In 2017, Energinet started work to strengthen joint grid planning with the distribution companies with a view to safeguarding economically effective solutions and grid reinforcement. In accordance with the Danish Energy Agency's announcement of principles

Construction work Ellund-Egtved Gas Pipe

for the distribution of costs upon connection, Energinet is cooperating with the grid companies to develop joint decision-making criteria for decisions on connection, uniform service standards etc.

Operation

Coordination of maintenance work with the Swedish and German TSOs takes place at annual operational meetings. In addition, there is ongoing contact between the operational coordination units in the relevant companies and between the control centres to ensure optimum operational cooperation across the systems.

The preparation of the risk assessment, preventive action plan and emergency plan, as described in EU Regulation 994/2010, is coordinated with the German and Swedish TSOs, and there is close cooperation between all parties in crisis situations in order to safeguard gas supplies across borders.

Market

In terms of the market, effective and close cooperation with the adjacent systems is an important prerequisite for a well-functioning gas market.

Regarding Sweden, Energinet and Swedegas have intensified their cooperation in recent years as a result of the decision to analyse the possibility of a common balancing zone and market zone for the two markets (Joint Balancing Zone) with expected implementation in the spring of 2019. In 2018, Energinet and Swedegas decided to make the necessary investments in order to merge the Danish and Swedish balancing area. This is based on detailed analyses of assumptions concerning balancing and trade.

Over the summer, Energinet consulted the market on a method notification for the common balance zone. The Danish Utility Regulator will now form a view regarding the method notification. A decision is expected in the second quarter of 2019. The initiative will improve security of supply while also introducing more players into the gas market. This is in line with the EU's efforts to harmonise the markets within the Union.

Cooperation is being intensified with Germany, too, is it will become the primary source of supply during the renovation of Tyra. That is why Energinet and Gasunie Deutschland have launched a joint project examining the market measures and operational steps that can be taken to manage the period when Tyra is closed down.

There will potentially be more adjacent systems for Energinet to work with in future as a result of the Baltic Pipe project, namely Gaz-System in Poland and Gassco in Norway. Cooperation with these systems has been underway for some time in the context of feasibility studies and project maturation.

"One of the reasons for the increased trade is the cold period from end-February to mid-March in which Energinet declared an Early Warning. During this period, several records were set for the volume traded on a single day in relation to all previous years"

3.8 The wholesale market

Energinet, in discharging its duties, must contribute to ensuring that the best possible conditions are established for competition in the natural gas markets. Metrics for healthy market competition include the extent to which the price of gas correlates with prices in the surrounding markets, and the quantities traded.

Denmark is part of the North-Western European wholesale market in gas, which is a well-functioning market with more or less the same prices in the different gas exchanges. In addition, it should be noted that more and more gas exchanges in the EU have the same prices as North-Western Europe, and this is a general sign of the health of the internal market in gas.

With regard to the volumes traded in Denmark, Energinet has found that after the fall in volumes traded in the gas exchange in the winter of 2016/2017, trade picked up again in the winter of 2017/2018. On this basis, the traded volume for the 2018 calendar year is expected to end on a par with 2016, which was the best year to date for Gaspoint Nordic, with more than 60 per cent of consumption traded on the exchange.

One of the reasons for the increased trade is the cold period from end-February to mid-March in which Energinet declared an Early Warning. During this period, several records were set for the volume traded on a single day in relation to all previous years.

Gas network codes

Energinet has worked closely with market players to implement all the codes so far, and now only needs to implement the last of the major codes – harmonisation of tariffs (TAR NC) – to be completed in all Member States no later than the end of 2019. The status of TAR NC in Denmark is that the proposal to change the method has been sent to the Danish Utility Regulator for final approval. Discussions were held with the shippers as the new tariff method was being developed.

3.9 The retail market

In 2018, ownership of the largest gas supplier in Denmark was divided between two new owners, Eniig and SEAS-NVE, which shared the customers between themselves. The agreement covers 215,000 gas customers, of which the customers in Jutland and on Funen – about 53,000 of them – were transferred to Eniig, whereas the customers on Zealand switched to Seas-NVE.

At the end of 2018 there are expected to be 17 active gas suppliers in the Danish gas market. There are four large gas suppliers in the retail market, which have a combined market share of 91 per cent. There are two medium-sized gas suppliers with a total market share of 6 per cent, and the remaining approximately 3 per cent is distributed among the remaining 11 small gas suppliers in the market.

In 2019, all gas suppliers are expected to be able to offer their customers a single-invoicing solution, meaning that consumers only receive bills from the gas supplier and not the distribution company. This single-invoicing solution is a joint industry solution in the retail market allowing all consumers to have the option of receiving one bill from their gas supplier, which also covers the distribution charge. Energinet has participated in the preliminary work and contributed to further development of the model in collaboration with players in the retail market.

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