EU Risk Assessment Report
- Security of Gas Supply, Regulation No 944/2010, article 9

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Executive summary

In compliance with Article 9 of the EU Regulation no. 994/2010 on security of gas supply, Denmark has made an assessment of the risks affecting the security of gas supply.

According to Article 9, the risk assessment must
- use the infrastructure and supply standards specified in Articles 6 and 8,
- take into account all relevant national and regional circumstances, in particular market size, network configurations, actual flows, production and storage facilities, the role of gas in the energy mix, and safety and gas quality considerations,
- run various disruption scenarios,
- identify the interaction and correlation of risks with other Member States,
- take into account the maximum interconnection capacity of each border entry and exit point.

This report is the third version of the 2012 risk assessment of the Danish gas system following the Regulation, and it provides a description of the present and future Danish gas system, including gas quality and present and future standards of infrastructure and supply, and an outline of the role of gas in the energy mix with particular focus on district heating, electricity generation and the operation of industries. A number of incidents potentially threatening the gas supply have been identified, and probabilities and likely consequences of these have been analysed.

The risk assessment concludes:
- during a one-day disruption of the single largest gas infrastructure (Article 6.1) on a day characterized by exceptionally high gas demand, the gas supply will be sufficient to cover all Danish gas customers and all protected customers in Sweden,
- during a period of 7/30 days characterized by exceptionally cold weather (Article 8.1 a) and b)), the gas supply will be sufficient to cover all protected customers in Denmark and Sweden,
- during a 30-day disruption of the single largest gas infrastructure under average winter conditions (Article 8.1.c)) – the gas supply will be sufficient to cover all protected customers in Denmark and Sweden.

To demonstrate the expected handling of the identified risks, the gas demand and gas balances in 2017-18 have been calculated in accordance with the scenarios described in Articles 6 and 8, defining the calculated area as the interconnected Danish and Swedish gas transmission systems and taking into consideration each Member State’s obligations, cf. Article 6.10.

The results of the risk assessment will be used in the national Preventive Action Plan containing the measures necessary in order to remove or mitigate the risks identified, and in the Emergency Plan describing the measures to be taken to remove or mitigate the impact of a gas supply disruption.
1. Aim

This report accounts for the results of the Risk Assessment of the Danish gas system in 2016 in accordance with Article 9 of Regulation (EU) No 994/2010 concerning measures to safeguard the security of gas supply.

This is the second update (third version) of the Risk assessment of the Danish gas system elaborated in 2012 and is to be approved by the competent Danish authority (Danish Energy Agency) on 30 September 2016 at the latest. The Risk assessment must subsequently be used for updating the preventive action and emergency plan not later than 3 December 2016.

The Risk Assessment, including any updates, must be made available to the Commission without delay.

2. Process and conclusions

2.1 Working process

Energinet.dk has prepared the Risk Assessment in relation to the security of supply in the Danish gas system for the competent Danish authority, ie the Danish Energy Agency. The report has been elaborated in the same form as and applies the same method and procedure as the preceding Risk Assessment. The Risk Assessment describes the situation as foreseen in the period 01.01.2017 - 31.12.2018 and has been prepared on the basis of the expected infrastructure and supply situation for the period. Moreover, the report has been written in English to enhance the cooperation with the neighbouring countries.

2.2 Conclusions

The risk assessment concludes:
- during a one-day disruption of the single largest gas infrastructure (Article 6.1) happening on a day characterized by exceptionally high gas demand, the gas supply will be sufficient to cover all Danish gas customers and all protected customers in Sweden,
- during a period of 7/30 days characterized by exceptionally cold weather (Article 8.1 a) and b)), the gas supply will be sufficient to cover all protected customers in Denmark and Sweden,
- during a period of 30 days disruption of the single largest gas infrastructure under average winter conditions (Article 8.1.c)), the gas supply will be sufficient to cover all protected customers in Denmark and Sweden.

2.3 Contact with neighbouring countries

The Swedish gas system is supplied 100 % via Denmark and, for that reason, a process of meetings and an ongoing exchange of information has been agreed with the Swedish Energy Agency (Energimyndigheten), the competent Swedish authority under the Regulation.
On 24 May 2016, a meeting took place between the Swedish Energy Agency, the Danish Energy Agency and Energinet.dk, during which a mutual exchange of information on the status of the work on the Regulation took place. All the parties concerned have subsequently kept each other informed during the working process.

2.4 The future process

This Risk Assessment will form the basis of both the Preventive Action Plan including the necessary measures for mitigating the established risks, cf. Articles 4 and 5, and of the Emergency Plan, which will include measures to be taken to eliminate or mitigate the consequences of a disruption of the gas supply, cf. Articles 4 and 10.

3. The purpose of the Regulation

In recent years, security of supply has become an increasingly important subject in the EU, due to events such as the crises in Belarus in 2008 and in Ukraine in 2009. Regulation 994/2010 was adopted by the European Parliament and the Council of the European Union to strengthen the security of gas supply of the EU as a whole and of the individual Member States.

The aim of the Regulation is to create regional solidarity, to strengthen the cooperation between the Member States and to create a common preparedness in the event of a crisis likely to affect the supply of gas. According to the Regulation, this will be achieved primarily through a harmonisation of the standards for infrastructure, through supply and crisis management and through the Member States’ preparation of Emergency Plans and Preventive Action Plans for the national gas systems and, where relevant, the regional gas infrastructure. Furthermore, it paves the way for the conclusion of binding agreements between the Member States.

A central element in the Regulation is Article 9, which sums up the requirements expected to be met by risk assessments in relation to the supply of gas:

‘running various scenarios of exceptionally high gas demand and supply disruption, such as failure of the main transmission infrastructures, storages or LNG terminals, and disruption of supplies from third country suppliers, taking into account the history, probability, season, frequency and duration of their occurrence as well as, where appropriate, geopolitical risks, and assessing the likely consequences of these scenarios:’

The Regulation also extends its focus to include geopolitical and commercial risks, whereas the previous risk assessments of the Danish gas system have focused to a greater extent on technical and natural risks.
4. Basis provided by the Regulation

The Risk Assessment has been prepared with reference to Articles 6, 8 and 9 of the Regulation. The specific requirements of the individual articles are summed up below.

Article 6 - Infrastructure standard

In accordance with Article 6, each Member State must ensure that the infrastructure standard is complied with. This means that the necessary measures are to be taken so that, in the event of a disruption of the single largest infrastructure, the capacity of the remaining infrastructure, determined according to the N – 1 formula (Annex I, point 2) will be able to total gas demand of the calculated area during a day characterized by exceptionally high gas demand occurring with a statistical probability of once in 20 years.

The assessment of supply to the Danish gas market is based on the above, but on a regional level, ie including both Denmark and Sweden. On a regional level article 6, paragraph 2, is also relevant. Article 6, paragraph 2, states that "The obligation to ensure that the remaining infrastructure has the capacity to satisfy total gas demand, as referred to in paragraph 1, shall also be considered to be fulfilled where the Competent Authority demonstrates in the Preventive Action Plan that a supply disruption may be sufficiently compensated for, in a timely manner, by appropriate market-based demand-side measures. For that purpose, the formula provided in point 4 of Annex I shall be used."

The Danish gas transmission system is not designed to supply the Swedish market in the Emergency stage. As a result of this, it will not be possible to maintain the supply to the entire Swedish market in all scenarios of a failure in the single largest infrastructure. This is one of the reasons why Sweden is excluded from the regulations article 6. In the preventive action plan for Sweden it is stated that: "According to Article 6.1, the infrastructure standard must be fulfilled by 3 December 2016. Sweden is not bound by, but shall endeavour to meet; the obligations set in the standard and guarantee gas supplies to protected customers in accordance to article 8."

Article 8 - Supply standard

Article 8 defines a supply standard that must also be complied with. This means that gas supplies to the Member State’s protected customers must be secured in the following cases:

a) extreme temperatures during a 7-day peak period occurring with a statistical probability of once in 20 years;

b) any period of at least 30 days characterized by exceptionally high gas demand, occurring with a statistical probability of once in 20 years; and

c) for a period of at least 30 days in case of the disruption of the single largest gas infrastructure under average winter conditions.
Article 9 – Risk Assessment

In accordance with Article 9, each Member State must make a full assessment of the risks affecting its security of supply, based on the infrastructure and supply standards and taking all national and regional circumstances into account, running various scenarios of exceptionally high gas demand and supply disruption and identifying the interaction and correlation risks in relation to other Member States, considering the maximum interconnection capacity of each border entry and exit point.

4.1 Protected customers

All household customers connected to a gas distribution network are to be protected. Moreover, the Member State may include other customers as well if they decide so. As Competent Authority, the Danish Energy Agency has decided to include the following points in the definition of protected customers according to regulation BEK no. 962 of 2012/09/27.

a. essential social services, provided that they are connected to a gas distribution or transmission network, and small and medium-sized businesses, provided that they are connected to a gas distribution network and whose yearly natural gas consumption does not exceed the prevailing cubic meter limit, and provided that all these additional customers do not represent more than 20 % of the final consumption; and/or

b. district heating installations to the extent that they deliver heating to household customers and to the customers referred to in point a) provided that these installations cannot switch to other fuels and are connected to a gas distribution, town gas or transmission network. Businesses that deliver excess heat to a joint heating supply grid are treated according to the cubic meter limit referred to in point a).

On a daily basis, the protected customers in Denmark account for approximately 75 % of the total expected maximum consumption.

4.2 Current standards of supply

Energinet.dk secures the supply to all Danish customers and all protected Swedish customers during a three-day supply disruption at -13°C (statistical probability of occurring once in 20 years).

Energinet.dk secures the supply to all protected Danish and Swedish customers during a 60 days’ supply disruption happening in a normal year (statistical probability of once in 50-100 years in case of rupture of an offshore pipeline).
5. Description of the existing Danish gas infrastructure

The Danish gas transmission system consists partly of a number of pipelines in the Danish part of the North Sea and partly of transmission and distribution pipelines onshore.

The transmission pipelines are laid out from north to south (Aalborg to Ellund) and across the country from west to east (Nybro to Dragør), and the distribution pipelines consist of a network of pipe systems transporting the gas from the transmission network to the consumers. Moreover, the gas transport system consists of a gas treatment facility (Nybro), two underground storage facilities (Stenlille and Lille Torup) and a compressor station at Egtved, see Figure 5.

Figur 5: The Danish Gas Transmission System.

Natural gas from the Danish part of the North Sea is transported at a pressure of up to 138 bars, in two offshore pipelines from the Tyra and the Syd Arne fields on to the mainland close to Esbjerg. The majority of the gas is produced at the Tyra fields. During summer, when less gas is consumed, the pressure is reduced in order to minimise the energy consumption for compression.

Onshore, the gas passes through a gas treatment facility at Nybro. Here the gas quality is checked and metered, and the pressure is reduced to the maximum land pipeline pressure of 80 bars. The plant can also mix gas from the two offshore pipes and, if necessary, reduce the amount of pollutants such as heavy hydrocarbons and hydrogen sulphides so the gas complies with the required specifications.

From Nybro and Ellund (Germany), the gas is transported to customers nationally and abroad or to be stored at one of the two underground storage facilities.
The storage facilities are usually filled up during the summer when gas consumption is low. When it gets colder and consumption exceeds the daily gas deliveries from the North Sea, they are supplemented by gas from the storage facilities. In addition to seasonal levelling, trading in gas may have an effect on gas export and import and consequently on withdrawal from and injection into the storage facilities. It is mainly shippers who, on account of their daily nominations within the reserved capacity, determine the input and output of the system on an hourly basis (the commercial system), whereas it is Energinet.dk that ensures the physical balance in the system, based on its use of the storage facilities, gas trading and line pack. Furthermore, the storage facilities are also used for emergency supply.

The compressor station at Egtved has been constructed in order to enable transport of gas from Germany to Denmark. Using the compressor station, it is possible to increase the pressure in the western part of the transmission network towards the eastern part of the transmission network.

The metering and regulator stations (M/R stations) have been established along the transmission pipeline, to supply the local gas distribution network. They serve to filter and heat the gas so that it does not become too cold during the next stage, which consists in pressure reduction to the level of the distribution network, metering of the gas flow through the station and addition of smelling agents to the gas. There are 42 metering and regulator stations and four dedicated metering stations owned by Energinet.dk.

In 2016, the transportation capacity from Germany to Denmark is estimated by Energinet.dk at 124 GWh/d (11.1 mio. Nm³/d). The capacities of the Stenlille and Lille Torup gas storage facilities are 99 GWh (8.2 mio. Nm³/h) and 96 GWh (8.0 mio. Nm³/d) respectively. The total gas volume in the storage facilities is approx. 12,300 GWh.

5.1 Gas consumption in Denmark

The gas consumption in Denmark has been decreasing since 2006, see Figure 5.1. In 2014, consumption in Denmark was approx. 2.5 billion Nm³. Year 2010 was an exception. This was partly due to 2010 being a very cold year, accounting for 9 % more degree days than a normal year, and partly to a high consumption at the central power plants.
5.2 The role of gas in the Danish energy mix

Natural gas accounted for 17% of the total gross energy consumption in 2014, cf. figure 5.3, and thus remains a central energy supply source in the Danish energy system.

5.2.1 Gas consumption distributed on consumers

In 2014, the total gas consumption including the gas used for production in the North Sea was 33,000 GWh (120 PJ). The gas consumption for household use accounted for 20% of the total gas consumption.
5.2.2 Gas-fired electricity and district heating generation

The production of electricity in Denmark is generated at central power plants, decentralised power and heating plants, wind power plants and via secondary production. In 2014, the electricity production amounted to 32,000 GWh, of which 6.5 % was produced from natural gas.

District heating generation in Denmark is conducted at large, centralised combined heat and power (CHP) plants, decentralised CHP plants, district heating plants and with secondary producers, ie industrial factories, market gardening and waste treatment plants. From the end of the 1980s and up through the 1990s, the share generated at decentralised CHP plants increased, whereas purely heat-generating district heating plants were being converted to decentralised CHP plants. At the same time, there was a significant restructuring of the use of fuel in the generation of district heating. In 2014, the distribution of fuel used for this purpose was 48 % coming from renewable energy, 19 % from natural gas, 20 % from coal and 1 % from oil.

The total production of heating in 2014 was 34,000 GWh.
5.2.3 Energy consumption of the production and service sectors

Production activities comprise agriculture and forestry, market gardening, fishing, manufacturing companies (excluding refineries) and building and construction companies, whereas trade and service activities include retail and wholesale trade and private and public services. 19% of the energy consumed in production and service comes from natural gas, cf. figure 5.2.3.


5.3 Gas quality

The gas in Energinet.dk’s transmission system is delivered either from the Danish part of the North Sea, from Germany via Ellund, from the gas storage facilities or as biomethane from local biomethane production. The quality of the gas that is supplied to Denmark is a mixture of North Sea gas, gas from Germany and biomethane.

Danish North Sea gas belongs to the 2nd gas family, group H, and its composition is characterised by being very uniform. Danish natural gas has always had a very high Wobbe index in comparison to the surrounding systems. This is due to the fact that the Danish gas contains relatively high amounts of ethane, propane and butane, and that these are not eliminated from the gas.

The gas from Germany also belongs to the 2nd gas family and will usually have a lower Wobbe index than the North Sea gas. This will also be the case in future scenarios with Norwegian, German, Dutch, Russian and LNG gas or a combination of these.

Injection of biomethane at transmission level has triggered a gas quality barrier for oxygen between the Danish and German transmission system because the limit in the German system is much lower than in the Danish system. This difference in requirements will either introduce a capacity barrier or attribute unnecessary cost to the biomethane, i.e. the cost of decarbonisation of the gas.
Over the last 8 years, the Wobbe index value for distributed Danish gas has been between 14.1 and 15.5 kWh/Nm³ (50.8-55.8 MJ/Nm³). The gas regulation allows the distribution of gas with a Wobbe index interval of 14.1-15.5 kWh/Nm³ (50.76-55.8 MJ/Nm³). In case of special supply situation, gas with a Wobbe index of 13.9 - 15.5 kWh/Nm³ (50.04 to 50.76 MJ/Nm³) may be supplied. This requires a preparedness plan approved by The Danish Safety Authority (Sikkerhedsstyrelsen). A preparedness plan for a situation involving Ellund as entry point has been approved.

6. The future Danish/Swedish gas infrastructure

The Danish Risk Assessment only covers the national gas system. However, as the Swedish gas system is 100 % supplied via Denmark, the Swedish gas system is included in the calculations of demand for gas, cf. infrastructure and supply standards.

The risk assessment, and thus the compliance with the standard for infrastructure and supply, is based on the outlook for the gas market as well as the gas transmission system in 2017-18. Furthermore, the assessment also takes into account Sweden’s exception to the infrastructure standard.

6.1 The 2016-2020 period

From 2016 to 2020, it is assumed that the gas production from the Danish part of the North Sea will remain more or less at today’s level, ie 123 GWh (10.1 mio. Nm³/d). After 2020, the decline in gas production will continue as prior to 2016, cf. figure 6.1. The 2016-2025 outlook for the Danish gas transmission system’s expected supply and demand is illustrated in figure 6.2.
The platforms at the Tyra field are sinking gradually along with the seabed as the gas is removed from the underground. DUC (owner) has announced that the distance from the Tyra platform decks to the sea level is critical and will require remedial action within the next few years. DUC is working on two potential solutions. One is to renovate the Tyra platforms. This means that the Tyra field will be shut down for 2 years. The other option is to cease production and remove the entire Tyra complex. This means that the Tyra platforms will be decommissioned. Two years later, facilities for processing and exporting the associated gas volumes from the southern oil fields will be established and are expected to deliver 1.8 million m$^3$/day. DUC is yet to announce their decision.

7. Calculated gas demand in 2017-18

7.1 Gas demand according to the Regulation

Gas demand in Denmark and Sweden in the relevant periods is estimated in relation to the Regulation based on gas market expectations.

7.2 Denmark

All consumers (Article 6.1)

The maximum demand for gas in Denmark in 2016 on a cold winter’s day, ie a day with an exceptionally high gas demand, with a statistical probability of happening once in 20 years, is estimated at 231 GWh/day (19.2 million Nm$^3$/day). This includes all Danish gas customers.

Supply of protected customers (Article 8.1)

On a daily basis, the protected customers in Denmark account for approximately 75 % of the total expected maximum consumption cf. section 4.1.
**Article 8.1, a)**

Gas demand of protected customers during a 7-day peak period occurring with a statistical probability of once in 20 years, is estimated at 166 GWh/day (corresponding to 13.9 million Nm³/day), ie a total of 1,163 GWh. The average temperature for the period is -9.5°C.

**Article 8.1, b)**

The average gas demand of protected customers for any period of at least 30 days of exceptionally high gas demand, occurring with a statistical probability of once in 20 years, is calculated at 156 GWh/day (corresponding to 13.0 million Nm³/day) - a total of 4,669 GWh for the 30 day-period. The average temperature for the period is -6.0°C.

**Article 8.1, c)**

The gas consumption of protected customers for a period of at least 30 days in case of the disruption of the single largest gas infrastructure under average winter conditions is calculated at 3,827 GWh (corresponding to 320 million Nm³). The average temperature for the period is 0°C.

**Increased supply standard**

In accordance with Article 8, Member States may increase the supply standard beyond the 30-day period. At the moment, Denmark expects, to maintain its current supply standard of 60 days in the event of a disruption of the single largest gas infrastructure under average winter conditions. This supply standard is established on the assumption that it takes an average of 60 days to repair a rupture of the offshore pipeline between the North Sea platforms and Nybro.

**Disruption affecting non-protected gas customers**

Non-protected customers will be given three days' notice in the event of an incident in the Danish gas system or an adjacent gas system that necessitates a reduction of gas supply to Danish customers.

The duration of the notice is established on the basis of the assessment that, in practice, remedy in three days of a complete disruption affecting the entire non-protected market cannot be guaranteed in three days. This could, for example, happen if an Emergency situation occurred on a Friday afternoon after normal working hours as many non-protected customers do not have 24-hour contact. Moreover, it should be possible to clarify any questions and establish practical measures in relation to a physical disruption affecting the non-protected customers within 3 days.

As regards security of supply, it is important to give non-protected customers a realistic notice of a disruption by dimensioning the supply standards. Otherwise, the risk is that there will not, in practice, be sufficient supply to meet the protected customers' demand.
Commercial interruptible customers

Energinet.dk buys interruptible services from Danish and Swedish customers. The commercial interruptible customers can be activated in the crisis level Alert. This implies that Energinet.dk is entitled to reduce gas supply to suppliers of this service according to the agreed level in case of an Alert situation. The purpose of there being commercial interruptible customers is to avoid escalating the crisis level to Emergency and interrupting non-protected customers.

Commercial interruptible customers must reduce their required supply after 3 hours and remain interrupted for up to 69 hours when being called for after a declaration of Alert.

All customers can provide the interruptible service if they comply with the following conditions:

- An annual gas consumption of minimum 2 million Nm$^3$,
- The gas delivery point is connected to the eastern part of the transmission system (East of Egtved).

7.3 Sweden

One of the main points in the Regulation is the inclusion of regional conditions. Therefore, Denmark and Sweden are considered as one region as Sweden can only be supplied gas from Denmark.

All consumers (Article 6.1)

The maximum gas demand in Sweden on a cold winter's day (20-year incident) is estimated at 85 GWh/day (7.1 million Nm$^3$/d). However, in contrast to Denmark, Sweden is exempt from compliance with the infrastructure standard, cf. Article 6(10) but must ensure supply to protected customers. The maximum gas demand in Sweden under Article 6(1) is thus dimensioned under the supply standard in Article 8(1), cf. below.

Supply of protected customers (Article 8.1)

Sweden expects to define protected customers as being all private customers connected to the gas distribution network (Article 2(1)). Small and medium-sized businesses, essential social services and district heating installations connected to the gas distribution or transmission network will not be protected customers.

The protected customers in Sweden represent approx. 2 % (0.16 mio. Nm$^3$/d) of the total Swedish gas consumption.

Article 8.1, a)

Protected customers’ maximum gas demand during a 7-day peak period characterised by extreme temperatures has been assessed by Energinet.dk as being totally 11 GWh (corresponding to 0.9 million Nm$^3$) for the period.
Article 8.1, b)

Protected customers’ maximum gas demand during a 30-day period with exceptionally high gas demand has been assessed by Energinet.dk as being totally 44 GWh (corresponding to 3.5 million Nm³) for the period.

Article 8.1, c)

Protected customers’ maximum gas demand during a 30-day period under normal winter condition has been assessed Energinet.dk as being totally 35 GWh (corresponding to 2.8 million Nm³) for the period.

8. Identifiable risks

As regards Article 9.1, scenarios can be identified in which a critical disruption of the gas supply may be caused from one of the four entry points. Furthermore, the expected consequences of the scenarios and the probability of them occurring have been described. The results of this analysis can be found in Annex A (confidential).

The identified relevant risks are:
- EU gas supply crisis,
- Disruption of supply from the Stenlille Gas Storage facility on an extremely cold day,

9. N-1 Incidents in the Danish gas transmission system

The calculated area has been defined as the combined Danish and Swedish gas transmission systems, taking into account the applicable infrastructure standards for each country.

In the analysis of disruption of the single largest infrastructure, it is assumed that the expected amount of gas is available and will be delivered to the defined delivery points. The amount will not necessarily reflect the actual supply situation because it is dependant on the specific supply situation, including the market conditions.

9.1 Hydraulic simulations

The technical entry capacities used in the analysis have been checked by use of hydraulic simulations taking system integrity and the operational requirements of the transmission network into account.

A disruption of a supply point will under normal conditions not decrease the entry capacities of the remaining supply points. Thus the technical entry capaci-
ties can be used for assessing the gas balance in a scenario of disruption. Energinet.dk has used the firm entry capacities of the supply points in the gas balance calculations of the disruption scenarios.

The Danish gas transmission system has a bottleneck within the network, which is not reflected in an analysis solely focusing on entry-exit capacities in the transmission system. The bottleneck is located between the western and eastern parts of the network and results in transport capacity towards the Eastern system being lower than the total entry capacity in the west. This means that it cannot be taken for granted that the gas entering the system in the west can be transported to gas consumers in the east.

The hydraulic simulations of the west-east transport capacity show that the transport capacity exceeds gas consumption in the east in the emergency stage. This means that the bottleneck in the system is not a hindrance to compliance with the security of supply regulation no. 944/2010.

The hydraulic simulations show that the gas consumers can be supplied according to the security of supply regulation no. 944/2010. Therefore, in an emergency situation with disruption of a supply point (N-1), the response time of the system operator and the operation of the compressor station will be the decisive factors.

### 9.2 Technical capacity (Article 6)

The N-1 Formula in Annex 1 of the Regulation describes the technical capacity of the gas infrastructure to meet the total gas demand in the calculated area in the event of a disruption of the single largest infrastructure during a day of exceptionally high gas demand with the statistical probability of once in 20 years.

\[
N - 1[\%] = \left( \frac{E_{P_m} + P_m + S_m + LNG_m - I_m}{D_{\text{max}}} \right) \times 100
\]

Moreover, the protected customers should be able to remain protected during a period of at least 30 days in the event of a disruption of the single largest infrastructure under average winter conditions.

#### 9.2.1 Calculation of the N-1 formula for Denmark

A calculation for all four supply points is given below, ie Nybro from the North Sea, Ellund from Germany, the Lille Torup Gas Storage Facility in Northern Jutland and the Stenlille Gas Storage Facility on Zealand. The Swedish gas transit is limited to covering the protected customers.

Calculations of the N-1 formula for Denmark:

<table>
<thead>
<tr>
<th>$D_{\text{max}}$ (million Nm3/d)</th>
<th>The combined daily gas demand (20 year-incidence), Danish and Swedish protected customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.5</td>
<td></td>
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</table>
Total technical capacity for all entry points that can supply the calculated area, excluding production, storage and LNG facilities

Maximum technical production capacity (North Sea)

Maximum technical extraction capacity from all storage facilities

Maximum technical capacity at all LNG facilities

Technical capacity of the single largest infrastructure

The North Sea (Nybro) - $I_m = 10.1$

Germany (Ellund) - $I_m = 11.1$

Stenlille Gas Storage Facility - $I_m = 8.2$

Lille Torup Gas Storage Facility - $I_m = 8.0$

N - 1 ≥ 100 % for all scenarios and Denmark thus complies with the requirements of the N -1 norm, irrespective of which main supply source is the largest single infrastructure on the given day.

9.3 Calculated gas balances (Article 8)

The protected customers must furthermore be protected for a period of at least 30 days in case of the breakdown of the single largest infrastructure under average winter conditions.

Below, the calculated gas balances for the scenarios in Article 6 (N– 1) and Article 8.1 c) will be examined for all supply points. The calculations of the gas balances below are solely volume calculations based on Energinet.dk’s model for gas consumption (Prognosemodel) for the Danish gas system.

The gas balances are illustrated in bar charts showing six columns: estimated consumption in normal operation, expected supply in normal operation, maximum entry capacity in normal operation, estimated consumption in the emergency stage, expected supply in the emergency stage, maximum capacity in the emergency stage. Each column is colour-coded for origin of consumption and supply. The columns showing maximum capacities are included to illustrate the surplus of capacity in the region. In all charts, it is assumed that the total gas storage capacities are available.

9.3.1 Disruption of gas supply from the North Sea (Nybro)

9.3.1.1 One days’ disruption (Article 6.1)

The total gas consumption for the region on a cold winter's day (20-year incident) is estimated at 316 GWh/day, and the consumption is expected to be supplied from the North Sea and the two gas storage facilities. The bar chart shows that the region has a surplus of capacity of 126 GWh/day, which is above the capacity of a single entry point. In the emergency stage, the gas

1 The forecast for the gas production in the Danish part of the North Sea is used instead of the maximum technical production capacity.
consumption of the Danish customers and all Swedish protected customers amounts to 233 GWh/day. The maximum capacity in the emergency stage is 319 GWh/day in a situation of disruption of the North Sea supply. That is well above the gas consumption in the emergency stage.

9.3.1.2 30 days’ disruption (Article 8.1 (c))

The total gas consumption for the region in 30 days under average winter conditions is estimated at 7,282 GWh/30days, and the consumption is expected to be covered from the North Sea and the two gas storage facilities. The bar chart shows that the region has a surplus of supply of 5,996 GWh/30days, which is well above the supply of a single entry point at full capacity for 30 days. In the emergency stage, the gas consumption of all protected Danish customers and all Swedish protected customers amounts to 3,862 GWh/30days. The maximum capacity in the emergency stage is 9,592 GWh/day in case of a disruption of the North Sea supply. That is well above the gas consumption in the emergency stage.
9.3.1.3 60 days’ disruption under normal winter conditions

I accordance with Article 8(1) c), gas supplies to protected customers must be ensured during a period of at last 30 days in the event of disruption of the single largest infrastructure under average winter conditions.

A disruption of supply from the North Sea due to rupture of an offshore pipeline is expected to involve a repair time of around 60 days. Similarly, it is believed that a technical incident on the Tyra platform (although less likely) would involve a repair time of more than 30 days and could potentially take months.

Therefore, in relation to disruption of supply from the North Sea, Denmark expects to be able to maintain the supply standard for 60 days, cf. Article 8(2).

With a 60-day disruption of supply from the North Sea, the Danish/Swedish system would also be dependent on a combination of gas from Germany and the gas storage facilities. The total gas demand would be around 7,410 GWh for this period (January-February), and it is essential that this amount is available.

9.3.1.4 Long-term disruption of supply from the North Sea

In addition to the above incidents, the Danish gas system is also vulnerable to the threat of long-term disruption (ie of more than a year) affecting the gas supply from the North Sea (eg Tyra platforms).

The Tyra platforms are gradually sinking as the gas is extracted from the subsoil and the seabed sinks. DUC (owner of the Tyra platforms) has announced that the reduced distance from the Tyra platforms to the sea level is critical and will, within the next few years, require remedial action. DUC is working on two potential solutions to this problem. One is the renovation of Tyra, which means that Tyra will stop production for an expected 2 years. The other option is the
removal of Tyra. Tyra will be decommissioned and production from Tyra will cease.

Apart from the technical and system-related consequences for the gas system and the associated systems, a disruption such as this is expected to have significant socio-economic effects that has not yet been analysed.

9.3.2 Disruption of gas supply from Germany (Ellund)

9.3.2.1 1 day’s disruption (Article 6.1)

The total gas consumption for the region on a cold winter’s day (20-year incidence) is estimated at 316 GWh/day, and the consumption is expected to be supplied from the North Sea and the two gas storage facilities. The bar chart shows that the region has a surplus capacity of 126 GWh/day, which is above the capacity of a single entry point. In the emergency stage, the gas consumption of the Danish customers and all Swedish protected customers is 233 GWh/day. The maximum capacity in the emergency stage is 319 GWh/day during disruption of the Ellund supply. That is well above the gas consumption in the emergency stage.

9.3.2.2 30 days’ disruption (Article 8.1 (c))

The total gas consumption for the region in a 30-day period under average winter conditions is estimated at 7,282 GWh/30days, and the consumption is expected to be covered from the North Sea and the two gas storage facilities. The bar chart shows that the region can reckon on a surplus supply of 5,996 GWh/30 days, which is well above the supply of a single entry point at full capacity in a 30-day period. In the emergency stage, the gas consumption of all protected Danish customers and all Swedish protected customers is 3,862 GWh/30 days. The maximum capacity in the emergency stage is 9,515
9.3.3 Disruption of gas supply from the Stenlille Gas Storage facility

9.3.3.1 1 day’s disruption (Article 6.1)

The total gas consumption for the region on a cold winter's day (20-year incidence) is estimated at 316 GWh/day, and the consumption is expected to be supplied from the North Sea and the two gas storage facilities. The bar chart shows that the region has at its disposal a surplus capacity of 126 GWh/day, which is well above the capacity of a single entry point. In the emergency stage, the gas consumption of the Danish customers and all Swedish protected customers is 233 GWh/day. The maximum capacity in the emergency stage is 344 GWh/day in a situation of disruption of the Stenlille Gas Storage supply. That is well above the gas consumption in the emergency stage.

The offtake in the eastern part of the transmission system is about 70% of the total offtake in the system. That is way a disruption of the supply point in east, Stenlille Gas Storage is particularly critical. The pressure will drop rapidly in east due to the large local deficit in gas. For this reason, a short response time of the system operator to use the remaining entry capacity and restore the gas balance in the system is crucial for the security of supply in east.
9.3.3.2 30 days’ disruption (Article 8.1 (c))

The total gas consumption for the region in a 30-day period under average winter conditions is estimated at 7,282 GWh/30 days, and the consumption is expected to be covered from the North Sea and the two gas storage facilities. The bar chart shows that the region can reckon on a surplus of supply of 5,996 GWh/30 days, which is well above the supply of a single entry point at full capacity for 30 days. In the emergency stage, the gas consumption of all protected Danish customers and all Swedish protected customers is 3,826 GWh/30 days. The maximum capacity in the emergency stage is 10,326 GWh/day in a situation of disruption of the supply from the Stenlille Gas Storage Facility. That is well above the gas consumption in the emergency stage.
9.3.4 Disruption of gas from the Lille Torup Gas Storage facility

9.3.4.1 1 day’s disruption (Article 6.1)

The total gas consumption for the region on a cold winter’s day (20-year incident) is estimated at 316 GWh/day, and the consumption is expected to be supplied from the North Sea and the two gas storage facilities. The bar chart shows that the region has a surplus capacity of 126 GWh/day, which is well above the capacity of a single entry point. In the emergency stage, the gas consumption of the Danish customers and all Swedish protected customers is 233 GWh/day. The maximum capacity in the emergency stage is 347 GWh/day in a situation of disruption of the Lille Torup Gas Storage supply. That is well above the gas consumption in the emergency stage.

![Bar chart showing gas consumption and supply](image)

9.3.4.2 30 days’ disruption (Article 8.1 (c))

The total gas consumption for the region in a 30-day period under average winter conditions is estimated at 7,282 GWh/30days, and the consumption is expected to be supplied from the North Sea and the two gas storage facilities. The bar chart shows that the region can reckon with a surplus supply of 5,996 GWh/30days, which is well above the supply of a single entry point at full capacity for 30 days. In the emergency stage, the gas consumption of all protected Danish customers and all Swedish protected customers is 3,862 GWh/30 days. The maximum capacity in the emergency stage is 10,401 GWh/day in a situation of disruption of the Lille Torup Gas Storage supply. That is well above the gas consumption in the emergency stage.
Figur 9.3.4.2: 30 days’ disruption of supply from Lille Torup Gas Storage.
Annex A: Risk identification

The risk identification section contains sensitive information and is therefore described in a separate document.

The risk identification is confidential and must not be handed out to unauthorised persons or distributed electronically.
Annex B: References

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