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# PREVENTIVE ACTION PLAN

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# General information

## Preparation of the preventive action plan

The preventive action plan is an element in complying with the security of gas supply EU Regulation ("the Regulation").[1] The preventive action plan is prepared by the Danish Transmissions Operator, Energinet, and it is approved by the Danish Competent Authority, the Danish Energy Agency.

In Article 8(2) of The Regulation it is stated that the national competent authority shall establish: *"a preventive action plan containing the measures needed to remove or mitigate the risks identified, including the effects of energy efficiency and demand-side measures in the common and national risk assessments and in accordance with Article 9"*.

According to Article 8 of the Regulation the "*competent authorities of neighbouring Member States shall in due time consult each other with a view to ensuring consistency between their preventive action plans and their emergency plans"* and "*The preventive action plans and the emergency plans shall be made public and notified to the Commission by 1 March 2019.*"

The preventive action plan must, according to The Regulation, be updated every four years (at the latest 1 March 2023). This preventive action plan thus covers the period where the main supply source to Denmark and Sweden, the Tyra complex, is closed due to reconstruction. Production from the Tyra complex is expected to be completely terminated from 1 November 2019 to 1 July 2022 but will start to decrease gradually from spring 2019.

The security of supply situation varies from year to year during the reconstruction period. However, in this plan the focus has been on the years 2020 and 2021, which is expected to be the most critical years for the Danish and Swedish market.

## Regional cooperation

In Article 3(7) it is stated: *"In accordance with Article 7(2), major transnational risks to the security of gas supply in the Union are to be identified and risk groups are to be established on that basis. Those risk groups shall serve as the basis for enhanced regional cooperation to increase the security of gas supply and shall enable agreement on appropriate and effective cross-border measures of all Member States concerned within the risk groups or outside the risk groups along the emergency supply corridors."*

The risk groups have been established, and Denmark is involved in 3 risk groups. A thorough analysis of the work in the risk groups and compliance with the infrastructure standard for Denmark can be found in the national risk assessment for Denmark and the common risk assessment for the risk groups.

[1] REGULATION (EU) 2017/1938 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2017 concerning measures to safeguard the security of gas supply and repealing Regulation (EU) No 994/2010.

The Member States in the risk groups are as follows:

Risk group Denmark:
Denmark, Germany, Luxembourg, the Netherlands, Sweden

Risk group Baltic Sea:
Belgium, Czech Republic, Denmark, Germany, France, Luxembourg, the Netherlands, Austria, Slovakia, Sweden

Risk group Norway:
Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, the Netherlands, Portugal, Sweden, United Kingdom

# 1. Description of the gas system

A thorough description of the Danish gas system and the regional gas systems that include Denmark can be found in the national risk assessment for Denmark and the common risk assessments for the risk groups that Denmark is included in.

## 1.1 Description of the Danish gas system

The Danish gas system (figure 1) consists of gas production facilities and pipelines in the Danish part of the North Sea, a transmission system, where gas is transported across the country, and a distribution system through which gas is delivered to the gas customers. Moreover, the gas system consists of a gas treatment facility (Nybro), two underground storage facilities (Stenlille aquifer and Ll. Torup salt caverns) and a compressor station (Egtved). The compressor station at Egtved was established in 2013 in order to enable transportation of gas from Germany to Denmark.

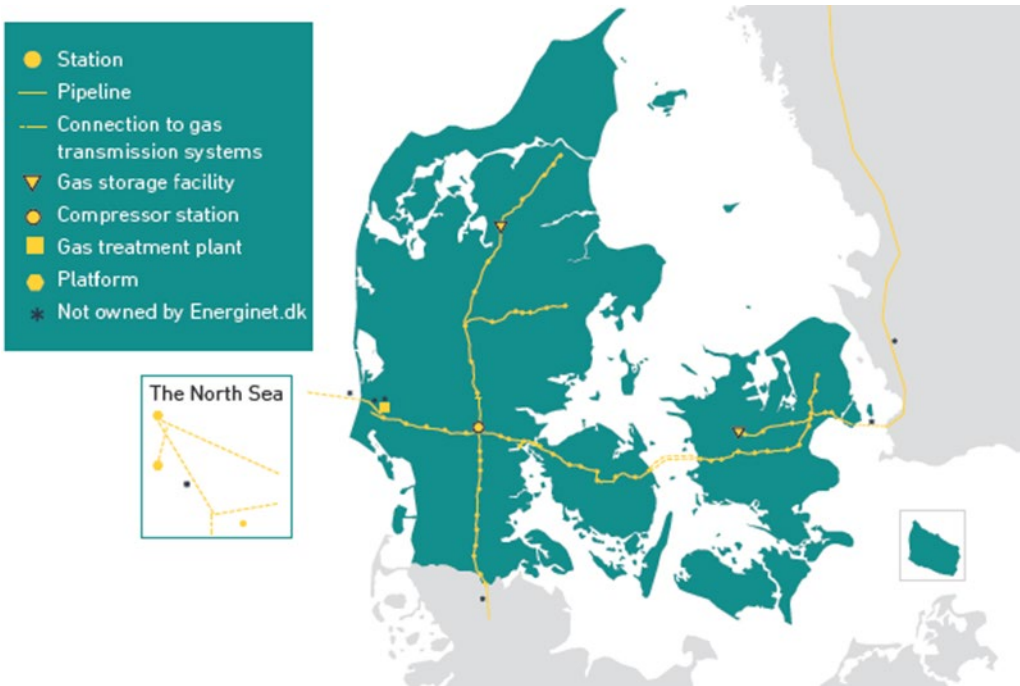


*Figure 1. The Danish Gas system.*

The Danish gas system has three physical entry/exit points (Nybro, Ellund, and Dragør) through which gas can be supplied to or from the Danish gas market, with Ellund being the only point with physical reverse flow. Furthermore, there are a number of virtual entry/exit points for gas traded within the system (bilateral contracts or gas exchange) and for biomethane.

From Nybro (landfall of Danish North Sea gas) and Ellund (Germany), the gas is transported to customers in Denmark and Sweden or stored at one of the two underground storage facilities.

An overview of capacities and utilisation of the Danish transmission system in 2017 is shown in table 1 below.

| Point | | Capacity mcm/day | Maximum daily flow 2017 mcm/day |
|---|---|---|---|
| Nybro | Entry | 32.4[(1)] | 14.0 |
| Ellund | Entry/Exit | 10.8[(2)]/20.0 | 4.9/5.2 |
| Dragør Border | Exit | 7.2[(3)] | 4.7 |
| The Danish Exit zone | Exit | 25.5 | 16.7 |
| Ll. Torup Gas Storage Facility[(4)] | Injection<br>Withdrawal (100 %)<br>Withdrawal (30 %)<br>Injection/Withdrawal | 3.6<br>8.0<br>8.0 | 3.8/7.6 |
| Stenlille Gas Storage Facility[(4)] | Injection<br>Withdrawal (100 %)<br>Withdrawal (30 %)<br>Injection/Withdrawal | 4.8<br>8.2<br>8.2 | 4.8/6.3 |

*Table 1. Capacities and utilisation of the gas transmission system in 2017. Note 1: Total capacity of the receiving terminals at Nybro. The potential supplies are smaller today as the Tyra-Nybro pipeline is subject to a capacity constraint of approx. 26 mcm/day, and large volumes cannot be supplied from the Syd Arne pipeline. Note 2: At a calorific value of 11.2 kWh/Nm$^3$. Note 3: The Swedish system is not designed to receive the firm capacity at the assumed minimum pressure at Dragør of 44 barg in normal operation (Interconnection agreement). Note 4: The Danish storage company dimensions the commercial injection capacity conservatively in relation to the pressure in the gas transmission grid. When the pressure occasionally increases, it is possible to inject more gas into the storage facilities than the specified injection capacity.*

## 1.2 Reconstruction of the Tyra offshore platform complex

The Danish and Swedish gas market is primarily supplied with gas from the Danish part of the North Sea. Since 1987, the Tyra complex has been the most important source of supply for Danish and Swedish gas customers. The Tyra complex has sunk approx. 5 meters since its establishment and waves are getting taller and more powerful. Therefore, the owners of the Tyra complex DUC (Danish Underground Consortium) has decided to reconstruct the complex in order to continue the gas production in the Danish part of the North Sea in the future.

In April 2016, DUC announced that the reduced distance from the Tyra platforms to the surface of the sea has become critical, and that this situation will require remedial action. In 2017 it has been decided to reconstruct the platform complex in the period 1 November 2019 to 1 July 2022. The existing Tyra facilities are planned to terminate production completely from 1 November 2019 but the supply from Tyra will gradually decrease from March 2019.

Denmark and Sweden will mainly be supplied from Germany for a period of more than 2½ years. Denmark will however, also be supplied with a little gas from the offshore South Arne field and biomethane facilities.

## 1.3 The role of the Danish gas 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, the deliveries are supplemented with 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 with-

drawal from and injection into the storage facilities. The storage facilities are also used for emergency supply.

The withdrawal capacities of the Stenlille and Ll. Torup gas storage facilities are today 8.2 mcm/d and 8.0 mcm/d respectively (table 1, section 1.1.) in situations with both full storage levels (100 %) and low storage levels (30 %). The total volume of working gas in the storage facilities is approx. 890 mcm. In 2020 the working volume will be reduced to approximately 800 mcm as the storage facilities are filled with gas from Germany with a lower calorific value. The capacities will be reduced with approximately 7% (difference in calorific values)

## 1.4 Gas consumption

Gas is consumed by a number of different sectors in Denmark: households, industry (including service industries), district heating, and electricity generation. Furthermore, gas is consumed in oil and gas production in the Danish North Sea. In 2016, the total gas consumption including the gas used for production in the North Sea was approx. 3.1 bcm.

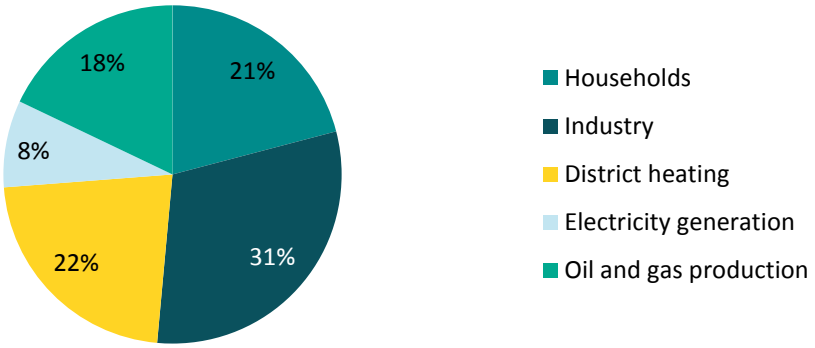


*Figure 2. Gas consumption by sector, 2016. Source: Energinet based on data from the Danish Energy Agency.*

## 1.5 The Danish security of supply model

The security of supply in Denmark has been based on the following dimensioning incidents:

1) 3 consecutive gas days with an average temperature of -13°C (1 in 20 years), even in case of interruption of the biggest gas supply source, and supply to the total Danish market (called “hydraulic incident”).
2) The duration of the supply to the protected customers depends on the location of the single largest infrastructure. If the infrastructure is located offshore (North Sea) the period for repairing the pipeline is set to last 60 days and the supply standard is thus increased to 60 days. If the infrastructure is located onshore, the period for supplying the protected customers is set to last 30 days as stated in the Regulation (called “volume incident”).

The gas market plays a key role in the Danish security of gas supply. Energinet supports security of supply by use of the Danish security of supply model. The security of supply model is based on the framework of the Regulation. The overall intention is to avoid situations in which the market is unable to supply gas to customers.

The model contains specific tools which Energinet may use to increase the probability of the market being able to continue to supply the customers during a gas shortage. The particular situation being dealt with at the time will largely determine the way the tools are used. The choice of tools therefore depends on both effect and cost. Some tools can also only be used in certain situations. The tools available during Early Warning and Alert must support the market's ability to handle a crisis situation and supply Danish gas customers on its own. If the market is unable to handle a crisis situation on its own, it may be necessary to declare an Emergency. In an Emergency Energinet may use non-market based tools to safeguard supplies to protected customers, and as an absolute last resort it might be necessary to fully or partially interrupt non-protected customers.

The tools available in the different crisis levels and how they are used are described in the Emergency Plan.

The different tools can be used in either "hydraulic incidents" in which it is necessary to take action immediately to maintain balance in the transmission system or in "volume incidents" in which it is not necessary to act immediately.

- "Hydraulic incidents" are normally national technical incidents, i.e. sudden failure of a compressor station, a storage facility, or an offshore production supply. However, during the reconstruction period of the Tyra complex an incident in the northern German transmission system can also be a hydraulic incident in which instantaneous interruption of customers might be necessary.

- A "volume incident" is typically expected to be a Union/regional slowly developing incident.

The security of supply model is further described at the Energinet homepage[2].

[2] https://en.energinet.dk/Gas/Security-of-Supply

# 2. Summary of the risk assessment

## 2.1 Conclusions from the Danish risk assessment

The single largest infrastructure is identified as Inter Connection Point (IP) Ellund – the single source of supply in the analysed period. The N – 1 calculation shows that Denmark complies with the infrastructure standard during the period of reconstruction of the Tyra complex with the recent expansion of the capacity in the Ll. Torup storage facility where N – 1 = 100 %. This compares to 88 % before the Ll. Torup storage facility was expanded.

The identified main risks during the reconstruction of the Tyra complex are:

1. Incidents that affect the supply to Denmark:
    a. Technical incidents in the northern German transmission system
    b. A Union/regional gas supply crisis
2. Incidents that affect the functioning of the Danish gas system:
    a. The Stenlille Storage Facility
    b. The Egtved Compressor Station
    c. The pipeline Egtved to Dragør
    d. Failure of the Interconnection point Dragør (supplies to Sweden, see Swedish Risk Assessment[3])

## 2.2 Conclusions from regional risk groups

### 2.2.1 Risk Group Denmark

(Denmark, Germany, Luxembourg, Netherlands, and Sweden)

Denmark and Sweden are facing a period where the supply might be tight in the event of exceptional high demand or in case of a serious technical incident due to the upcoming reconstruction of the Tyra complex in the Danish North Sea. Denmark and Sweden will from November 2019 to July 2022 be almost fully dependent on gas supplies from Germany via the interconnection point Ellund.

ENTSOG's SoS simulations (volume incidents, not sudden hydraulic incidents) based on a technical interruption of all supplies from Germany under normal weather conditions indicate that it will be possible to supply the Danish and Swedish market. It is a precondition that the market actors have sufficient gas in storage to handle such a critical situation.

Energinet and Gasunie Deutschland have analysed a situation where 35 % of the gas supply from Germany is interrupted. Even with reduced supply from Germany it will be possible to supply the Danish and Swedish market for 30 days in extreme weather conditions.

The worst case will be a situation with no supplies from Germany due to a technical failure. In such a situation it will not be possible to supply the total Danish and Swedish market and it will be necessary to immediately declare Emergency in Denmark and Sweden in order to reduce the consumption and thereby ensure supplies to the protected marked in Denmark and Sweden.

In order to mitigate the risks the following steps has been taken:

[3] http://www.energimyndigheten.se/trygg-energiforsorjning/naturgas/definitioner-av-krisnivaerna-enligt-nationell-krisplan-for-sveriges-naturgasforsorjning/

- Investment in increased withdrawal capacity at Ll. Torup storage facility. (To be completed in 2019)
- Energinet has been in dialog with Gasunie Deutschland (GUD) on technical issues to increase the firm capacity at Ellund. This resulted in an extra 1 GWh/h offered by GUD in a PRISMA auction in July 2018. The capacity was not booked. However, GUD has decided to increase the capacity, which will be available for the distribution company in Schleswig-Holstein. The capacity available in Ellund to Denmark and Sweden offered by GUD today (2018), continues to be available.

### 2.2.2 Risk Group Baltic Sea

(Austria, Belgium, Czech Republic, Denmark, France, Germany, Italy, Luxembourg, Netherlands, Slovakia, and Sweden)

Denmark is solely connected to continental Europe at the Inter Connection Point (IP) Ellund at the German border. In principal Denmark can import H-gas original either from the Netherlands, Germany, Norway, or Russia. In the period of the reconstruction of the Tyra complex the Danish and Swedish market relies close to 100 % on available transport capacity in the German transmissions system and sufficient firm capacity at IP Ellund.

The conclusion of the analyses in Risk Group Baltic Sea is that the Member States' infrastructure is well developed and interconnected in the region. The simulations show no effects on the Danish and Swedish market. Various transport routes and gas resources are available to ensure the gas supply in the Risk Group. In addition there is access to a large number of storage facilities with large working gas volume and withdrawal capacity. The available storage capacity is mainly used for seasonal and daily balancing of the system as well as emergency supply.

The German gas infrastructure is an important key to the European gas transport system as the German system can deliver gas in all directions from North to South and East to West. Furthermore, planned investment measures in the gas infrastructure play an important role to further improvement of security of gas supply. The majority of the investment measures in Germany have a direct positive impact on the various IP's capacities to neighbouring Member States. Additional transport capacity creates opportunity for the market actors and allows varying routes and access to sources of supply.

The liquid gas in this region has a positive impact on the security of supply to the gas markets. The TTF in the Netherlands as well as the market areas Gaspool and Net Connect Germany are among the trading points with the highest liquidity in Europe.

The region fulfils the N-1 standard. The calculation was performed for two entry points into the region, Greifswald as well as Velke Kapusany. Both calculations show that the region lies well above the 100%. This will in the future even be further improved due to investment in the infrastructure.

The Risk Group did not identify a particular high risk exposure. Of course, risks exist and cannot be avoided with certainty. Especially technological risks can cause several infrastructure failures as recent events in Baumgarten in December 2017 have shown. But at the same time it is important to highlight that significant levels of resilience are built into the region's infrastruc-

ture. In the further analysis representative scenarios and disruption duration have been defined in order to cover a wide range of potential consequences of risks and failures.

The analysis showed that every Member State of the Risk Group is in a position to handle the effects of these disruption scenarios with the existing infrastructure and access to alternative sources including access to storage facilities. The capacity reduction would not cause any demand curtailments of customers. The missing capacity can be compensated by other means such as alternative import points, LNG, storages etc. Also, the analysis showed that the Member States could handle these disruption scenarios with their own means. No repercussions on neighbouring Member State have been identified.

The resilience of the North-West European gas network is supported by local production, imports, and storage, and supported by a mature and liquid gas market which has demonstrated its ability to deliver even during the most extreme combination of infrastructure failure and increased demand.

### 2.2.3 Risk Group Norway

(Belgium, Denmark, France, Germany, Italy, Ireland, Luxembourg, Netherlands, Slovakia, and Sweden)

The analysis demonstrates that the gas supply infrastructure is resilient to all and the most unlikely combinations of supply shocks. The upper ends of supply ranges are sufficient to maintain supplies to protected customers in all scenarios.

Based on the analysis the Norwegian gas supplies may be considered to be reliable for the foreseeable future. Nevertheless the foreseeable decline of Norwegian production from a current level of 122 bcm to approximately 90 bcm/y in 2030 may be taken into account when preparing measures related to the future security of gas supply.

This analysis is the first one, and further analysis may benefit from:

- Detailed exchanges with Gassco on impact of an outage of production facilities in Norway and simulation of its impacts of flows;
- More detailed analysis on the impact of a disruption on gas flows within the group;
- Interactions with other risk groups.

To avoid duplications of data from the Baltic Sea Risk Group and Risk Group Norway for further information about the analysis in carried out in the groups, please see the common risk assessments for the risk groups.

# 3. Infrastructure standard (Article 5)

## 3.1 The single largest infrastructure in Denmark

This preventive action plan covers a period, where the main source of gas in Denmark, the Tyra complex, will be reconstructed and the gas supply capacity to Denmark will therefore be significantly reduced.

The main gas source during the reconstruction period is imported gas from Germany. The single largest infrastructure for Denmark is therefore the Ellund entry point.

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

*The N – 1 formula*

$$N - 1[\%] = \frac{EP_m + P_m + S_m + LN_m - I_m}{D_{max}} \cdot 100, N - 1 \geq 100\ \%$$

The parameter values based on the current capacities are shown in table 2.

| Parameter | Mcm/d | Description |
|---|---|---|
| $D_{max}$ | 18.0 | Total daily gas demand on an exceptionally cold day (20 year-incidence with an average temperature of -13$^0$C). The Danish gas demand is expected to be 18.2 mcm/d (including biomethane). This figure is reduced with the expected consumption of Danish commercial interruptible customers that can be interrupted within 3 hours |
| $EP_m$ | 10.3 | Total technical capacity for all entry points that can supply the calculated area, excluding production, storage and LNG facilities. The value of this parameter is equal to the entry capacity at the Danish side of the Ellund point based on the maximum existing capacity at the German side (the capacity at the Danish side is much higher). |
| $P_m$ | 1.0 | Maximum technical production capacity. The forecast for the gas production in the Danish part of the North Sea is used instead of the maximum technical production capacity. In the period 2020-2022 the value of this parameter is expected to decrease significantly from 10.1 mcm/d to 0.5 mcm/d. Furthermore, $P_m$ includes the Danish biomethane production, which is expected to be 0.5 mcm/d in 2020. |
| $S_m$ | 15.2 | Maximum existing technical withdrawal capacity from all storage facilities. The value of this parameter is the sum of the withdrawal capacity at the two Danish storage facilities: Stenlille 7,7 mcm/d and Ll. Torup 7,5 mcm/d. The withdrawal capacities for the two storages are the same irrespective of a storage level of either 30 % or 100 % of the maximum working volume. |
| $LNG_m$ | - | Maximum technical capacity at all LNG facilities. There are no LNG facilities connected to the gas grid in Denmark. |
| $I_m$ | 10.3 | Technical capacity of the single largest infrastructure. Danish Ellund Entry point. |

*Table 2. Demand and capacities before realization of initiatives.Values can be converted to energy (kWh) by multiplying with 12.1*

The capacity of the Ll. Torup storage facility has been expanded which means that the Ll. Torup storage facility can ensure a larger withdrawal rate during the reconstruction period of the Tyra complex. The withdrawal capacity will increase from 7.5 mcm/d to 9.6 mcm/d. The total withdrawal capacity after the expansion is shown in table 3.

| Parame-ter | Mcm/d | Description |
|---|---|---|
| $S_m$ | **17.03** | Maximum existing technical withdrawal capacity from all storage facilities. The value of this parameter is the sum of the withdrawal capacity at the two Danish storage facilities: Stenlille 7.7 mcm/d and Ll. Torup 9.6 mcm/d. The withdrawal capacities for the two storages are the same irrespective of a storage level of either 30 % or 100 % of the maximum working volume. |

*Table 3. Storage withdrawal capacity after expansion of Ll. Torup storage facility*

A summary of the results from the calculations of N – 1 are shown in table 4.

| Largest infrastructure: Ellund | $I_m$ (mcm/d) | N – 1 |
|---|---|---|
| N – 1 without expansion of the Ll. Torup storage facility | 10.3 | 88 % |
| N – 1 with expansion of the Ll. Torup storage facility | 10.3 | 100 % |

*Table 4. Summary of the results from the calculations of N – 1*

The calculation of N – 1 for Denmark shows that N – 1 < 100 % in the scenario without expansion of the withdrawal capacity at the Ll. Torup storage facility but N – 1 become ≥ 100 % in the scenario where the withdrawal capacity is made available in 2019. Therefore, when the withdrawal capacity is increased Denmark will comply with article 5 (Infrastructure standard) of the Regulation during the period of reduced Danish national production due to the reconstruction of the Tyra complex.

## 3.3 Bi-directional capacity

### 3.3.1 Bi-directional capacity Denmark-Germany

Bi-directional capacity is established between the Danish and the German gas system in Ellund. In both directions the capacity is restricted by the capacity in the German system. From Denmark to Germany the firm capacity is 8.2 mcm/day. From Germany to Denmark the firm capacity is 10.3 mcm/day.

### 3.3.2 Bi-directional capacity Denmark-Sweden

Sweden is only supplied with gas from IP Dragør, with no physical reverse flow possibilities from Sweden to Denmark established. The technical capacity from Denmark to Sweden is 8.6 mcm/day whereof 7.2 mcm/day is firm capacity.

In the interconnection agreement between Energinet and Swedegas a minimum pressure of 44 barg is assumed at Dragør where the Swedish transmission system can receive less than the firm capacity.

# 4. Compliance with the supply standard (Article 6)

## 4.1 Protected customers in Denmark

Regardless of the crisis level, protected customers are ensured gas supplies under the Regulation. All private households are protected. Other customer groups may be included in order to achieve the best possible protection of the gas customers. In Denmark, the Danish Energy Agency has decided that small and medium-sized enterprises, district heating installations, and vital institutions such as hospitals and schools also have the status of protected customers.

Approximately 75 % of the total consumption in Denmark is consumed by the protected customers. Figure 3 below shows an estimate of the distribution of the customers in Denmark per customer category.

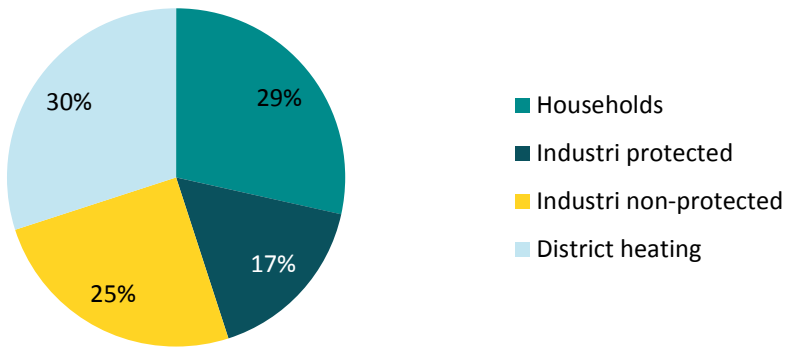


*Figure 2. Distribution between non-protected and protected customers.*

## 4.2 Capacity and gas volumes needed to supply the protected customers

According to the Regulation Article 6(1) the protected customers shall be ensured gas in the following three cases:

a) extreme temperatures during a 7-day peak period occurring with a statistical probability of once in 20 years
b) any period of 30 days of exceptionally high gas demand, occurring with a statistical probability of once in 20 years
c) for a period of 30 days in the case of disruption of the single largest gas infrastructure under average winter conditions

During the reconstruction of the Tyra complex the main supply point is Ellund. A repair of an onshore connection is less extensive compared to offshore repairing, so the period for supplying the protected customers will be reduced to 30 days, cf. the Regulation, during the reconstruction of the Tyra complex. Under normal circumstances the Danish supply standard is 60 days, which is the expected repair time for the offshore pipelines in the North Sea.

### 4.2.1 Analysis of the three cases of supply to the protected customers

The three cases in Article 6(1) where the protected customers shall be ensured gas are analysed for the Danish gas market below.

A general assumption in the three cases in Article 6(1) is that the protected customers in Denmark and Sweden are supplied with gas. The Danish “protected consumption” is 75 % of the

Danish consumption as stated above and the Swedish "protected consumption" is 2 % of the Swedish consumption.

Furthermore, it is assumed in the calculations below that the market is supplied with gas from Ellund (import), Syd Arne (North Sea) and biomethane and that the utilisation of this supply is maximized before gas is withdrawn from storage. The analysis thus calculates the storage volumes needed to cope with the demand and if the capacities are available in the system to access necessary gas to supply the protected customers.

#### 4.2.1.1 Case a) 7 days peak period (1 in 20 years)

This case a) assumes seven consecutive days with a daily demand equal to the peak day with exceptionally high gas demand applied in the N – 1 calculation (Article 5). The demand used is equal to the demand for the protected customers on a day with an extreme mean temperature of -13°C for all seven days, which is equivalent to 75 % of $D_{max}$ in table 2 above. The Swedish demand of the protected customers is assumed to be 0.2 mcm/d.

| Point | Daily flow (mcm/d) | Volume for 7 days (mcm) |
|---|---|---|
| Danish protected customers' demand | -15.0 | -105,0 |
| Swedish protected customers' demand | -0.2 | -1,4 |
| **Net demand** | **-15.2** | **-106,4** |
| Ellund | 10.3 | 72,1 |
| South Arne | 0.5 | 3,5 |
| Biomethane | 0.7 | 4,9 |
| Storage withdrawal | 3,7 | 25,9 |
| **Net inflow** | **15,2** | **106,4** |

*Table 5. Sources: Danish protected customers' demand from "Prognosemodellen": See Energinets winter-outlook in the Security of gas supply report: https://en.energinet.dk/Gas/Security-of-Supply; Expected production from "Analyseforudsætninger 2018": https://ens.dk/service/fremskrivninger-analyser-modeller/analyseforudsaetninger-til-energinet*

The table shows the demand from the protected costumers in the Danish and Swedish market. The calculation indicates a storage need of 3.7 mcm/d or 25.9 mcm over the seven days period. However, the storage facilities can supply up to 15.2 mcm/d.

#### 4.2.1.2 Case b) 30 days exceptionally high gas demand (1 in 20 years)

This case b) assumes 30 consecutive days with an exceptionally high gas demand. The demand used is equivalent to the highest daily demand in a year with exceptionally high gas demand. The Danish demand is equivalent to the protected customers' consumption. The Swedish demand of the protected customers is assumed to be 0.2 mcm/d.

| Point | Daily flow (mcm/d) | Volume for 30 days (mcm) |
|---|---|---|
| Danish protected customers' demand | -8,1 | -243 |
| Swedish protected customers' demand | -0.2 | -6 |
| **Net demand** | **-8,3** | **-249** |
| Ellund | 6.8 | 204 |
| South Arne | 0.5 | 15 |
| Biomethane | 1,0 | 30 |
| Storage withdrawal | 0 | 0 |
| **Net inflow** | **8,3** | **249** |

*Table 6. Source: Danish protected customers' demand and expected production from "Analyseforudsætninger 2018": https://ens.dk/service/fremskrivninger-analyser-modeller/analyseforudsaetninger-til-energinet*

The table shows the demand of the protected costumers in the Danish and Swedish market. The results in the table indicate no need for gas withdrawn from storage and that consumption by the protected customers can be covered by gas from Syd Arne, biomethane and import from Ellund. However, the storage facilities can supply up to 15,2 mcm/d.

#### 4.2.1.3 Case c) 30 days average winter with disruption of the single largest gas infrastructure

This case c) assumes 30 consecutive days under average winter conditions. In the example the demand used is equivalent to the highest daily off take in a year with an average winter. The Danish demand in the table below is equivalent to the protected customers' consumption. The Swedish demand of the protected customers is assumed to be 0.2 mcm/d.

| Point | Daily flow (mcm/d) | Volume for 30 days (mcm) |
|---|---|---|
| Danish protected customers' demand | -7.1 | -213 |
| Swedish protected customers' demand | -0.2 | -6 |
| **Net demand** | **-7.3** | **-219** |
| Ellund | 0 | 0 |
| South Arne | 0.5 | 15 |
| Biomethane | 1,0 | 30 |
| Storage withdrawal | 5,8 | 174 |
| **Net inflow** | **7,3** | **219** |

*Table 7. Source: Danish protected customers' demand and expected production from "Analyseforudsætninger 2018": https://ens.dk/service/fremskrivninger-analyser-modeller/analyseforudsaetninger-til-energinet*

The table shows the demand of the protected costumers in the Danish and Swedish market. The calculation indicates a storage need of 5.8 mcm/d or 174 mcm over the seven days period which can be covered by the emergency storage and filling requirements. The storage facilities can supply up to 15.2 mcm/d.

## 4.3 Measures to comply with the supply standard

This section describes the measures put in place in order to ensure the gas supply to the protected customers and compliance with the supply standard. The Danish TSO has implemented the following measures:

1. Emergency storage volume
2. Filling requirements

### 4.3.1 Emergency storage

The maximum withdrawal capacity in the storage facilities is dependent on a minimum level of gas. In order to ensure the maximum withdrawal capacity, the Danish gas TSO reserves emergency gas, which comply both with the infrastructure standard and the supply standard.

If the single largest infrastructure should fail (as described in case c) above) during the reconstruction of the Tyra complex, it is necessary to have access to more stored gas in order to supply the protected customers. The Danish TSO therefore has to reserve more gas in storage than normal in order to comply with the supply standard.

The distribution of the emergency gas in storage is critical in the event of an incident that leads to an Emergency. For instance, if the supply from the western part of Denmark to the eastern part of Denmark is interrupted, there is a risk that the eastern part of Denmark could lack gas. Therefore, the distribution of emergency gas between the two storages has to be considered every year.

The current (2018/2019) emergency gas volume is approx. 100 mcm. The gas volume is adjusted every year in May depending on the current situation (expected flows into the system and expected demand in Denmark and Sweden). The emergency gas volume will increase during the years when the Tyra complex is out of production. It is expected that the emergency gas volume will almost double in May 2019 compared to the current level.

The total storage volume in Denmark is today 890 mcm, which is equivalent to 10.7 TWh.[4] But during the reconstruction of the Tyra complex the storages will be filled with gas with a lower calorific value. This can be translated into a drop in storage volume of approximately 800 mcm. With the increase in the TSO storage volume there will still be storage volume available to the market.

### 4.3.2 Filling requirements

Energinet can include natural gas volumes in storage covered by the storage customers in the security of supply model as the so called filling requirements.

The filling requirements are a way of utilising synergies between the gas stored for normal supply and for security of supply. Energinet uses filling requirements to ensure that the storage customers keep certain volumes of gas in storage at certain points in time. It is common practice that the storage customers keep excess quantities of gas in the storage facilities, and it is not until the end of the storage season (March) that filling requirements restrict the actual use of the storage facilities.

[4] Information from Gas Storage Denmark's homepage.

Energinet pays storage customers to keep gas in the storage facilities for a given period of time, normally November-March. The gas will be made available to Energinet in Emergency in case of gas deficit in the system (volume incident). The maximum total filling requirement in the period November-March 2019/2020 is approx. 120 mcm.

### 4.4 Increased supply standard or additional obligation

According to the Regulation, gas supply to protected customers must be ensured for a period of 30 days in case of disruption of the single largest gas infrastructure.

Under normal circumstances when the Tyra complex is fully operational, the North Sea production is the single largest infrastructure. The expected repair time if the supply from the North Sea is interrupted is 60 days (disruption of the Tyra-Nybro submarine pipeline).

During the period when the Tyra complex is reconstructed this increased supply standard decreases to 30 days as stated in the Regulation.

# 5. Preventive measures

In accordance with the Regulation, this preventive action plan must contain a description of preventive measures adopted in accordance with the risk assessment. The risks identified in the national risk assessment for Denmark as being the most essential were summarized to:

1. Incidents that affect the supply to Denmark:
    a. Technical incidents in the northern German transmission system
    b. A Union/regional gas supply crisis
2. Incidents that affect the functioning of the Danish gas system:
    a. The Stenlille Storage Facility
    b. The Egtved compressor station
    c. The pipeline Egtved to Dragør
    d. Failure of the Interconnection point Dragør (supplies to Sweden, see the Swedish risk assessment plan)

In the Danish natural gas system, a great number of measures have already been taken, both with regard to the configuration of the gas infrastructure and to the design of a market model etc. in order to address a large part of the most significant risks. The already implemented measures as well as those planned will have an impact on the main risk scenarios identified in the risk assessment.

Denmark has been privileged in comparison with most of its neighbouring countries by having ample reserves of its own. There are four main supply sources in the Danish gas system today:

1. The North Sea (Nybro)
2. Germany (Ellund)
3. Stenlille Gas Storage Facility (Zealand)
4. Ll. Torup Gas Storage Facility (North Jutland)

During the period covered by this preventive action plan, the gas supply from the North Sea is significantly reduced.

## 5.1 Preventive measures in accordance with the risk assessment

### 5.1.1 Storage facilities

The storage facilities are an integrated part of the Danish market model, both in relation to the market, capacity, security of supply and operation.

The gas storage facilities at Stenlille and Ll. Torup have a total storage volume of approx. 880 mcm and presently (2018) a total withdrawal capacity of 16.2 mcm/day. The storage facilities are used for seasonal adjustments, for emergency storage, and for commercial flexibility.

Energinet reserves withdrawal capacity from the storage facilities for Emergency situations and stores gas for this purpose.

Energinet has estimated the need for storage dedicated to load adjustment in the Danish and Swedish markets. It is estimated that the commercial players' volume requirement for load adjustment throughout the period 2015-2030 may vary between 300 and 800 mcm, depending on the market parameters and the need for flexibility.

#### 5.1.1.1 Increased withdrawal capacity at Ll. Torup Storage Facility

Different measures to improve the supply situation during the reconstruction of the Tyra complex have been analysed. The analysis has led to the decision to increase the withdrawal capacity from 8.0 mcm/d to 10.3 mcm/d at the Ll. Torup Storage Facility which will be available in 2019 before the beginning of reconstruction of the Tyra complex.

The expansion of the Ll. Torup Storage Facility will improve the integrity of the system if the supply from Germany should fail fully or partly.

### 5.1.2 Reverse flow between Denmark and Germany

Since 2010, there has been a physical as well as a commercial flow both ways through the interconnection between Germany and Denmark (Ellund-Egtved).

Physical flow both ways will still be possible in the period 2019-2022 where the Tyra complex is being reconstructed. However, Germany will be the only major supply source to Denmark, and no physical flow from Denmark to Germany is expected.

### 5.1.3 The compressor at Egtved

The compressor station at Egtved has been built with the main purpose of supporting the need for compressing gas imported from Germany. The compressor station consists of 4 units where one functions as a redundancy unit.

In principle, the compressor station at Egtved makes it possible to increase the pressure in the gas system in all directions. Such flexibility is necessary in order to safeguard the security of supply for customers in Denmark and Sweden when the production of gas in the Danish part of the North Sea declines.

Together with looping of the pipeline from Ellund to Egtved, the compressor station contributes to increasing the import capacity, bringing it up to the present 0.7 mcm/h on the Danish side. However, the German system cannot supply such substantial quantities.

### 5.1.4 Precautions specific to installations

In accordance with, for instance, stipulations laid down in Regulation[5] No. 1025 of August 21, 2007 about; “preparedness in the natural gas sector”, individual owners of installations have taken steps to protect their installations and to prevent crisis situations from arising. Examples of this are the installation of security systems, bypass options, emergency procedures, etc.

The national preventive action plan does not contain a description of these measures specific to installations or an estimate of their effect on the risk scenarios.

### 5.1.5 Emergency plans

The preparedness in the Danish gas system is described in Emergency Plan[6] for the Danish gas transmission system, which describes, for instance, the distribution of responsibility and the roles to be filled in the sector. See the Emergency Plan for a detailed review of tools and instructions.

[5] Danish law: Bekendtgørelse nr. 1025 af 21. august 2007 om beredskab for naturgassektoren.

[6] Danish website: https://energinet.dk/Gas/Forsyningssikkerhed. English website: https://en.energinet.dk/Gas/Security-of-Supply.

### 5.1.6 Preparedness plans and exercises

Energinet has the responsibility for the general coordinating tasks, both with regards to planning and operation. Therefore, Energinet has worked out a collection of plans containing instructions for the handling of incidents in the Danish gas system. Instructions have been elaborated on the basis of the existing infrastructure and the market conditions applicable at any time. The plans are therefore revised whenever these undergo relevant changes – however, as a minimum every three years cf. the Danish regulation No. 1025 of 21 August 2007 concerning preparedness in the natural gas sector.

In accordance with the Danish regulation No. 1025 Article 21(2 and 3) of the Regulation, exercises based on the use of the Sector Preparedness Plans must be arranged at least once every 2 years and, over a 5-year period, exercises must be held to cover all essential elements of the sector's preparedness. Energinet is responsible for sector exercises being held and annually revises its 5-year tentative exercise plan[7], which comprises sector exercises as well as the relevant company's own exercises.

## 5.2 Other preventive measures

### 5.2.1 Additional diversification of gas supply sources

Energinet is together with the Polish TSO GASZ-SYSTEM investigating the possibility of establishing a connection from Norway through Denmark to Poland (the Baltic Pipe Project). The connection is expected to be in operation in October 2022 after the Tyra complex has been reconstructed. The Baltic Pipe Project is described in more detail in chapter 7.1.

### 5.2.2 Increased market integration

In cooperation with the Swedish TSO Swedegas, Energinet will establish one common balancing zone for the Danish and Swedish gas market towards 1 April 2019. The common balancing zone will bring the Swedish and Danish gas systems closer together, both in terms of physical operation as well as commercially. One benefit of the common market zone is that it will increase the security of supply for Sweden, as the linepack level in Sweden will be increased.

### 5.2.3 The use of market-based tools with Swedish participation

Energinet applies a commercial interruptibility tool, by which Energinet buys the right to reduce or interrupt a customer's gas supply. As a result, Energinet is able to reduce the demand for gas in situations where there is a need of capacity in the transmission system. The Swedish customers can make bids at the auction equally with the Danish customers. The commercial interruptibility tool may contribute to remedying capacity problems that leave the Swedish market particularly exposed to a number of incidents, for instance in the form of an outage at the Stenlille gas storage facility lasting longer than a few hours. The tool supports maintained supply to non-protected customers over a longer period of time and may even prevent interruption of supplies entirely.

The tool Commercial Interruptibility in the Alert crisis level will reduce the risk of the Swedish system escalating into the Emergency stage.

### 5.2.4 Market based measures

It has been identified as a risk that shippers do not have a strong enough incentive to secure supply for the end-customers through the whole winter season. This risk was identified at an Emergency Workshop in January 2018, where Energinet together with the market participants

[7] Dok. nr. 16/07338-1 Øvelsesplan 2016-2021 opdateret juni 2016.

went through the current rules in Emergency in the Rules for Gas Transport. The Early Warning period a month later (February-March 2018), proved that this risk is higher than Energinet will tolerate, in order to keep a satisfactory security of supply level.

In order to give shippers a stronger incentive to save gas and to have sufficient gas deliveries during a cold winter, and thereby reduce the identified risk occurring, Energinet has submitted suggestions for change of method towards the Danish Utility Regulator, with regards to market based balancing prices. The three main changes are:

1. To remove the price caps that are currently implemented, in order to secure that the balancing price can increase freely when security of supply is under pressure
2. To change the adjustment step 2 price, relating it to the pricing of different supply sources, presenting a stronger incentive for shippers to balance, instead of using Energinet
3. To change the price formula for emergency gas, to be the highest market price set during the whole season, to ensure a strong incentive to secure deliveries and/or keep sufficient gas in storage through the whole season.

The Danish Utility Regulator has approved the initiatives and the changes will be implemented towards 1 April 2019.

# 6. Other measures and obligations

## 6.1 Roles in the Danish gas market in general

The players in the Danish gas market have different roles, each of them encompassing certain key tasks and responsibility. This means that different companies own and operate the physical infrastructure, transport the gas and commercially buy and sell energy up till the point when it is made available to the individual customers.

There are three "roles" that own the physical infrastructure:

- Transmission: The gas transmission company in Denmark is Energinet (transmission owner and operator). Energinet offers transportation and balancing service, supports the development of the gas market, and manages a register of market players (Register of Players). The register contains information on all the companies in the gas sector and it is regularly updated with new information. In order for a shipper or a gas supplier to enter the Register of Players, he must conclude a framework agreement, and in the case of a storage customer, he must conclude a storage customer agreement. Finally, Energinet is responsible for volume balancing in the Danish natural gas system and for the security of supply.
- Distribution: The distribution companies are Dansk Gas Distribution, HMN GasNet, and the Municipality of Aalborg. They own and operate the distribution systems in their respective distribution area. The distribution companies collect payment for the use of the distribution systems as well as energy taxes and other taxes.
- Storage: The storage company is Gas Storage Denmark. This company owns and operates two gas storage facilities (Stenlille on Zealand and Ll. Torup in Northern Jutland). A standard storage agreement between the storage company and the storage customer regulates the relationship between a maximum stored volume and the maximum injection and withdrawal capacities.

Three roles are filled by the commercial users of the physical infrastructure:

- Shippers are commercial players that are in charge of wholesale transport of gas via the transmission system. In order to deliver the gas to one or more gas suppliers in the distribution systems the shippers buy from Energinet the right to use the transmission system. In some cases, the same player has the role of both shipper and gas supplier. The shippers delivers gas into the transmission system from Danish or foreign producers or from shippers operating in adjacent systems. The shipper is responsible for balancing what he delivers into the Danish transmission system (from the North Sea, from Germany, from a storage facility) and what he delivers out of the transmission system (to the distribution systems, to Germany, to Sweden, to a gas storage facility)
- Gas suppliers deliver natural gas to the gas customers and issues the pertaining invoices to the customers. In some cases, a gas supplier may have the supply obligation in relation to the customer. Gas suppliers must conclude a gas supply agreement with the distribution company in order to supply gas to customers in the relevant distribution area.
- Storage customers own the gas which they have had delivered to them in the gas storage facilities by the shipper. The storage customer may sell the gas in the gas storage facility to a shipper in the transmission system. Alternatively, the storage customer may choose to sell gas (perhaps in combination with capacity) to another storage customer in the same storage facility. The storage customer must, in order to act

as such, conclude a framework agreement for storage customers with Energinet and moreover be registered in the Register of Players.

Finally, there is the role of the gas customer. Customers are those who buy and use natural gas for own consumption. A distinction is made between hourly metered customers and non-hourly metered customers:

- Typically, hourly-metered customers are companies that buy at least 0.3 mcm natural gas annually per consumption site.
- Non-hourly-metered customers are all ordinary households and companies with consumption less than 0.3 mcm. Their consumption is read on a monthly or annual basis.

## 6.2 Obligations in the Danish gas market

Energinet is responsible for the security of supply in the Danish gas system as described in the Natural Gas Supply Act.

Security of supply in the Danish gas market comprises mainly the following aspects:

1. Availability of gas, by which is understood that the accessibility of gas supplies (including gas from storage facilities) must be sufficient to meet the Danish customers' gas requirements in normal as well as extreme weather conditions
2. Sufficient network capacity, which means that the transmission system must have sufficient network capacity to cover the customers' gas requirements in both normal and extreme weather conditions
3. System integrity, which means that the operational functionality of the system from production to customer must be secured.

Energinet has the joint tasks of safeguarding the security of supply in the Danish gas market and the responsibility as transmission system operator. Being the only Danish transmission company, Energinet is responsible for the system integrity (point 3.) in the Danish transmission system, i.e. the interaction between the 80-bar transmission system and the adjacent systems.

The availability of gas (point 1.) is the market players' responsibility, whereas Energinet carries the responsibility for securing the necessary infrastructure (point 2.) that makes gas delivery to and from adjacent systems possible. To avoid Emergency situations, Energinet is committed to using market-based balancing tools. If it is impossible to maintain the balance in the transmissions system by means of market-based balancing tools, Energinet will declare a situation of Emergency and proceed to safeguard the gas supply in accordance with the Emergency Plan and the Danish emergency-supply model to counteract to that extent where the shippers prove unable to fulfil their obligations.

Energinet is specifically responsible for securing adequate network capacity in the transmission system (point 2.), including transportation capacity to and from the storage facilities and to the distribution systems via the M/R-stations.

The storage company is committed to cooperating with the gas transmission company with regard to security of supply. The gas transmission company has priority of access to reserving capacity in the gas storage facilities.

The distribution companies are responsible for the security of supply in the distribution systems from immediately downstream of the transmission system's M/R-stations to the individu-

al customer. The distribution companies must deliver data about the gas customers' consumption to the transmission company. In case of an Emergency situation in which Energinet estimates that interruption or reduction of the non-protected customers' consumption is necessary, the distribution company must stop the gas supply to any such customers that do not comply with the request for interruption/reduction of their consumption.

Energinet’s responsibility and commitments following the Regulation and the Natural Gas Supply Act are described in further detail in the Emergency Plan.

# 7. Infrastructure projects

## 7.1 Future infrastructure projects – The Baltic Pipe

The Danish and Polish TSO's, Energinet and GAZ-SYSTEM, has decided a joint project called the Baltic Pipe project. The Baltic Pipe project comprises the establishment of a connection from the Norwegian gas infrastructure in the North Sea to the Danish gas system, an enhancement of the Danish gas system and further on through the Baltic Sea to Poland. The Baltic Pipe will enable the transportation of up to 10 bcm gas per year from Norway to Denmark and Poland and 3 bcm gas per year from Poland to Denmark. The Baltic Pipe Project is planned to be fully operational by 1 October 2022.

The Baltic Pipe Project is included in the ENTSOG TYNDP and has gained PCI status (Projects of Common Interest), which means that the project has common European interest as it will help to diversify European gas supplies, increase security of supply and integrate European markets. Like other countries in Central and Eastern Europe, Poland is predominantly dependent on gas from Russia. The Baltic Pipe project will give Poland, Denmark, and other countries in the region more direct access to Norwegian gas. The Baltic Pipe will also give Denmark indirect access to the global market for liquefied natural gas (LNG) via the Polish receiving terminal.

# 8. Public service obligations related to the security of supply

No public service obligations are imposed.

# 9. Stakeholder consultations

The players are frequently informed about the reconstruction period for the Tyra complex. Energinet informs about the development in the demand and supply situation at different forums (Shippers Forum, Industrial Forum and Offshore Forum) and Total informs about the actual status of the project (time schedule and reduction of supply) in REMIT's.

In august 2018 Energinet has published an analysis to inform the players in detail about the situation. The analysis can be found at Energinet's website[8].

The players have been informed about the market based initiatives, and the Danish Utility Regulator has consulted the market about the application for mitigation initiatives.

[8] https://en.energinet.dk/Gas/Tyra/Supply-situation

# 10. Regional dimension

Each Member State shall according to the Regulation ensure that in the event of a disruption of the single largest infrastructure the necessary measures are taken in order to continue to supply the gas market. This is the infrastructure criteria. It must be noticed that Sweden has an exemption from the infrastructure criteria. Sweden has only one supply source which is a single offshore pipeline (Øresundsledningen) connected to Denmark. If this pipeline fails Sweden is not able to supply the whole market but only the protected Swedish market (2% of the-Swedish gas demand).

## 10.1 Calculation of regional N-1 for risk group Denmark

The common risk assessment for risk group Denmark covers a period, where the main source of gas in Denmark and Sweden, the Tyra complex, will be reconstructed and the gas supply to Denmark will therefore be significantly reduced. The main gas source during the reconstruction period is imported gas from Germany. The single largest infrastructure of the area relevant for risk group Denmark is therefore the Ellund entry/exit point. The parameter values based on the current capacities are shown in table 8 below.

| Parameter | Mcm/d | Description |
|---|---|---|
| $D_{max}$ | 25.5 | Total daily gas demand on an exceptional cold day (20 year-incidence with an average temperature of -13 degrees Celsius). The Danish gas demand is expected to be 19.5 mcm/d (including biomethane) and the Swedish gas demand is expected to be 6 mcm/d. |
| $EP_m$ | 10.3 | Total technical capacity for all entry points that can supply the calculated area, excluding production, storage and LNG facilities. The value of this parameter is equal to the entry capacity at the Danish side of the Ellund point based on the maximum existing capacity at the German side (the capacity at the Danish side is much higher). |
| Pm | 1.0 | Maximum technical production capacity. The forecast for the gas production in the Danish part of the North Sea is used instead of the maximum technical production capacity. In the period 2020-2022 the value of this parameter is expected to decrease significantly from 10.1 mcm/d to 0.5 mcm/d. Furthermore, this parameter includes the Danish biomethane production, which is expected to be 0.5 mcm/d in 2020. |
| Sm | 16.2 | Maximum existing technical withdrawal capacity from all storage facilities. The value of this parameter is the sum of the withdrawal capacity at the two Danish storage facilities: Stenlille 8.2 mcm/d and Ll. Torup 8.0 mcm/d. The withdrawal capacities for the two storages are the same irrespective of a storage level of either 30 % or 100 % of the maximum working volume. The capacity of the Swedish Skallen storage facility is not included as it mothballed and will only be commissioned again if it is commercially viable. |
| LNGm | - | Maximum technical capacity at all LNG facilities. There are no LNG facilities connected to the gas grid in Denmark or Sweden. An LNG facility will be available in Gothenburg. However, it is not assumed connected to the Swedish transmission system |
| Im | 10.3 | Technical capacity of the single largest infrastructure. Danish Ellund Entry point. |
| Deff | 0.5 | The amount of gas demand that can be covered with market-based demand-side measures. The Danish concept of “commercial interruptibility” entails Energinet to pay gas customers in Denmark and Sweden to voluntarily reduce their gas consumption within 3 hours if the crisis level Alert has been declared in the Danish gas system. Today’s level has been chosen as a conservative level. |

*Table 8. Demand and capacities before realisation of initiatives.*

The increased storage withdrawal capacity (Sm) is shown in the table below.

| Parameter | Mcm/d | Description |
|---|---|---|
| $S_m$ | 18.5 | Maximum existing technical withdrawal capacity from all storage facilities. The value of this parameter is the sum of the withdrawal capacity at the two Danish storage facilities: Stenlille 8.2 mcm/d and Ll. Torup 10.3mcm/d. The withdrawal capacities for the two storages are the same irrespective of a storage level of either 30 % or 100 % of the maximum working volume. The capacity of the Swedish Skallen storage facility is not included as it mothballed and will only be commissioned again if it is commercially viable. |

*Table 9. Increased storage withdrawal capacity*

A summary of the results from all the calculations are shown in the table below.

| Largest infrastructure | Im (mcm/d) | N – 1 (%) |
|---|---|---|
| N – 1 based on current capacities | 10 | 67 |
| N – 1 based on current capacities with demand-side measures | 10 | 69 |
| N – 1 based on new capacities | 12 | 76 |
| N – 1 based on new capacities with demand-side measures | 12 | 78 |

*Table 10. Summary of the results*

The calculation of the regional N – 1 for the calculated area in risk group Denmark shows that N – 1 < 100 % for all scenarios. Therefore, the calculated regional area does not comply with article 5 (Infrastructure standard) of the Regulation during the period of reduced Danish national production due to the reconstruction of the Tyra complex.

However, it must be noticed that Sweden has an exemption from the infrastructure criteria and can only supply the protected market in case of a major incident.

### 10.2 Calculation of regional N-1 for risk group Baltic Sea

The N – 1 calculation for the risk group Baltic Sea is included in the common risk assessment version from the 26 September 2018.

For the calculation of the N-1 standard it is assumed that the entire region is seen as one “calculated area”. This means that only the entry points connecting the region with countries outside the region are taken into account. Cross-border capacity points inside the region are not included.

The single largest infrastructure in this region is the Slovakian entry point Velke Kapusany. The analysis we will conduct further focuses on the Greifswald entry point, which is slightly smaller than Velke Kapusany. The calculation of N-1 will be performed for both entry points.

| Member State | $EP_m$ [GWh/d] | $P_m$ [GWh/d] | $S_m$ [GWh/d] | $LNG_m$ [GWh/d] | $I_m$ [GWh/d] | $D_{max}$ [GWh/d] | $D_{eff}$ [GWh/d] |
|---|---|---|---|---|---|---|---|
| Austria | 0.0 | 40.4 | 470.6 | 0.0 | | 595.2 | 0.0 |
| Belgium | 1247.5 | 0.0 | 169.5 | 461.6 | | 1356.8 | 0.0 |
| Czech Republic | 0.0 | 4.3 | 754.9 | 0.0 | | 709.4 | 0.0 |
| Denmark | 0.0 | 12.1 | 196.0 | 0.0 | | 236.0 | 0.6 |
| Germany | 3915.3 | 272.5 | 7453.0 | 0.0 | 1776.0 | 5202.0 | 0.0 |
| France | 795.0 | 0.0 | 2400.0 | 1330.0 | | 4020.0 | 0.0 |
| Luxembourg | 0.0 | 0.0 | 0.0 | 0.0 | | 52.0 | 0.0 |
| Netherlands | 2266.0 | 2156.0 | 3421.0 | 399.0 | | 3678.0 | 0.0 |
| Slovakia | 2204.8 | 2.1 | 560.2 | 0.0 | 2028.0 | 470.9 | 0.0 |
| Sweden | 0.0 | 1.9 | 0.0 | 0.0 | | 78.0 | 0.0 |
| ∑ Sum | **10428.6** | **2489.3** | **15425.2** | **2190.6** | **3804.0** | **16398.3** | **0.6** |

*Table 11. Entries for the N - 1 formula by each Member State.*

| N-1 for region with failure of: | $EP_{VK}$ [GWh/d] | $P_m$ [GWh/d] | $S_m$ [GWh/d] | $LNG_m$ [GWh/d] | $I_m$ [GWh/d] | $D_{max}$ [GWh/d] | $D_{eff}$ [GWh/d] |
|---|---|---|---|---|---|---|---|
| Velke Kapusany (SLO) | 10 428.6 | 2 489.3 | 15 425.2 | 2 190.6 | 3 804.0 | 16 398.3 | 0.6 |

$$N - 1\ [\%] = \frac{10\,428.6 + 2\,489.3 + 15\,425.2 + 2\,190.6 - 2\,028.0}{16\,398.3 - 0.6} * 100 = 174\%$$

*Table 11. N – 1: Single largest infrastructure.*

The common risk group infrastructure consists of several operational facilities. Even with the failure of the two largest infrastructures, the resulting figure from the N-1 formula remains distinctly above 100%. This proves that the security of gas supply does not depend on a few large facilities because the extensive infrastructure offers more possibilities to transport and distribute gas.

## 10.3 Calculation of regional N-1 for risk group Norway

The N – 1 calculation for the risk group Norway is included from the common risk assessment version from the 12 September 2018.

For EPm, interconnection between Member States within the risk group and interconnection with Switzerland have not been considered.

Indeed, those calculations do not take into account the possible limitation of flow within the risk group due to limited available capacity of TENP pipeline and related southbound flow to Italy trough Switzerland. Additional calculations have also been conducted considering only those Members' States directly connected.
For the calculation it has been considered the disruption of the largest pieces of infrastructure which supply Norwegian gas:

- Disruption of Emden station (from Norway to the continent);
- Disruption of Langeled pipeline (from Norway to the United Kingdom).

| | | | | Projected Data | | |
|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| | GWh/d | GWh/d | GWh/d | GWh/d | GWh/d | GWh/d |
| **Technical capacity of entry points (EPm)*** | **11 696** | **11 637** | **11 372** | **11 445** | **11 445** | **11 445** |
| **Maximal technical production capacity (Pm)** | **4 845** | **4 153** | **4 168** | **4 198** | **3 942** | **3 593** |
| **Maximal technical storage deliverability (Sm)** | **16 096** | **16 096** | **15 848** | **16 046** | **16 090** | **16 108** |
| **Maximal technical LNG facility capacity (LNGm)** | **5 978** | **6 497** | **6 508** | **6 447** | **6 447** | **6 447** |
| **1 in 20 gas demand (Dmax)** | **26 709** | **26 637** | **27 127** | **27 198** | **27 208** | **27 362** |
| **Market-based demand side response (Deff)** | **5** | **5** | **5** | **35** | **35** | **35** |

* only entry point from outside the risk group

| **Technical capacity largest gas infrastructures (Im)** | | | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| DE/NL | Norway | Emden EPT | 989 | 989 | 989 | 989 | 989 | 989 |
| UK | Norway | Langeled | 770 | 770 | 770 | 836 | 836 | 836 |

| **N-1 for region** | Historical Data | | | Projected Data | | |
|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| | GWh/d | GWh/d | GWh/d | GWh/d | GWh/d | GWh/d |
| Emden EPT | 141% | 140% | 136% | 137% | 136% | 134% |
| Langeled | 142% | 141% | 137% | 137% | 136% | 135% |

*Table 12. The N-1 calculation for risk group Norway.*

N-1 results are well above 100% meaning in case of disruption of a major infrastructure supplying Norwegian gas the other entry capacities shall be sufficient to cover peak demand as it may occur 1 in 20 years.

Regarding the issue of transit trough Switzerland, both N-1 calculations for Italy on one side and the others Member States in the risk group on the other side are above 100%.
Projected data is included in order to generate an indication regarding the evolution of N-1 in the future. In order to reduce the uncertainties projected data is limited to the period 2018-2020.

Some infrastructure developments are in progress such as Trans Adriatic Pipeline or Baltic Pipeline. These are not included in the data but may be commissioned in the coming years and likely leading to an increase in N-1 for Norway risk group.

## 10.4 Mechanisms developed for cooperation

Denmark is a member of the risk groups Denmark, Norway and Baltic Sea. Denmark is directly connected to the Swedish and German gas systems at the respective interconnection points at Dragør and Ellund. From a regional cooperation point of view close cooperation with Sweden and Germany is important to mitigate risk of curtailment of national gas supply and across the borders and to ensure an effective functioning of the internal gas market.

The Danish TSO has entered into operation agreements with the German TSO (Gasunie Deutschland) and the Swedish TSO (Swedegas). These agreements include among other things mutual obligations with regard to exchange of information and measures to tackle situations where the security of gas supply might be threatened on each of the three crises levels.

It is the intention to continue with regular consultations between the three competent authorities, regulators, and TSO's in order to exchange information and discuss all relevant issues in relation to security of gas supply. The Danish Energy Agency is responsible for contact to the authorities. Energinet has regular operational meetings with connected system operators.

### ReCo

Denmark is a member of the Regional Coordination Group for Gas (ReCo) North-West. The North West team covers incidents in the North West supply corridor with gas from Norway and

the North Sea. ReCo provides procedures for communication between TSO's in the event of a gas supply crises in order to support efficient crises management between TSO's.

Solidarity

According to the regulation Denmark shall enter agreements with Germany for delivery of solidarity gas in both directions and an agreement with Sweden for delivery of Danish solidarity gas to Sweden. Denmark works on a legal and a practical track in order to set up the needed national legal system and develop an integrated transport, allocation, and nomination system to ensure delivery of solidarity gas to Germany and Sweden. An amendment to the Danish Natural Gas Supply Act is in preparation and is planned to be presented to the Parliament in the beginning of 2019.

## 10.5 Preventive measures

### 10.5.1 Pressure reduction Ellund

The risk group has been in dialog with Gasunie about how much capacity can be utilised, if the Quarnstedt compressor station fails. If the pressure in Ellund is reduced to 55 barg (60 bar agreed), the available capacity would increase to 65 % at Ellund by utilising the Ellund compressor. This shows the very low probability of the capacity at Ellund to be zero.

### 10.5.2 Firm capacity at Ellund (OGE)

Capacity at Ellund Exit on the German side (northbound) is offered by two German TSOs: GUD and OGE. The capacity offered by GUD has been on firm terms while the capacity offered by OGE (0.9 GWh/h) has been on interruptible terms.

As of 1 January 2019 the capacity offered by OGE will also be on firm terms. This means that the total firm capacity at German Ellund Exit will increase from 101 GWh/d to 125 GWh/d, where the 101 GWh/d is offered by GUD and the 24 GWh/d is offered by OGE.

The capacity can be booked on yearly contracts at the yearly summer auction. Until then the capacity can be booked on shorter contracts.

This means that the firm capacity from both GUD and OGE will be available prior to the reconstruction of the Tyra complex.

### 10.5.3 Increase in capacity in North Germany (GUD)

Energinet has been in dialog with Gasunie Deutschland (GUD) on technical issues to further increase the total firm capacity at Ellund.

This resulted in an extra 1 GWh/h (or 24 GWh/d) offered by GUD in a PRISMA auction in July. The capacity was not booked. However, GUD has decided to increase the capacity, which will be available for the distribution company in Schleswig-Holstein.

The capacity available in Ellund to Denmark and Sweden offered by GUD today (2018), continues to be available. A total capacity of 5.2 GWh/h including OGE capacity will be available in Ellund.