Member State	Name of competent authority
Denmark	Danish Energy Agency

Name of body preparing the risk assessment on behalf of the Competent Authority
Energinet, System Operator

NATIONAL RISK ASSESSMENT 2022 - DENMARK

1. Introduction

To comply with the security of supply regulation (EU) 2017/1938 ("the Regulation") concerning measures to safeguard the security of gas supply[1], the regulation lists the requirements to the risk assessment in Article 7 along with requirements on content in the national risk assessment in Annex V.

The infrastructure standard sets the requirements to document that the gas system can deliver the necessary capacities in case of interruption of the single largest infrastructure during a day with exceptionally high gas demand occurring with a statistical probability of once in 20 years.

The risk assessment must be updated at least every four years. This risk assessment covers the period where supply from the North Sea is shut down due to reconstruction. The reconstruction was planned to take place in the period November 2019 until July 2022, but the period of reconstruction has been prolonged due to effects of the Covid-pandemic on supply chains and global production. The Tyra complex will according to plan come on stream in Winter 2023/2024.

This risk assessment will form the basis of both the preventive action plan including the necessary measures for mitigating the identified risks, cf. Articles 8 and 9 in the Regulation, 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 8 and 10. The preventive action plan and the emergency plan have to be updated in March 2023.

1.1 Short resume

The Danish gas system consists of gas production facilities and pipelines in the Danish part of the North Sea, a transmission system and a distribution system. Moreover, the gas system consists of a gas treatment facility, underground storage facilities and compressor stations.

After having declined for many years, the Danish annual gas consumption has been relatively stable in the last years with steadily growing amounts of biomethane entering the gas system. In the past year, gas consumption in Denmark has fallen among other as a reaction to the high gas prices.

The gas transmission infrastructure in Denmark is robust and has a high level of reliability.

The single largest infrastructure as per 1. October 2022 is identified as the North Sea Entry point. During the period, Tyra is still out for reconstruction and is expected back in operation winter 2023/2024. The N-1 calculation is made for two scenarios. The first scenario shows N-1 calculation with North Sea Entry exclusive flow from the Tyra fields, and the second scenario shows the N-1 calculation with North Sea Entry including flow from the Tyra field. The N-1 calculation shows that Denmark complies with the infrastructure standard in both the scenarios.

The identified main risks during the assessed period are:

- Incidents that can affect the supply to Denmark. The causes of such incidents can be both technical and non-technical. Geopolitics have a special focus within Europe due to the war in Ukraine as well as prior to the Russian invasion. The ultimate consequence of the war could be an EU Gas Supply Crisis. Union-wide simulation of gas supply and infrastructure disruption (scenario S-1), shows that the EU will have sufficient gas to supply the protected customers with a full disruption of Russian gas supply and under normal market conditions. The simulations also emphasize the importance of storage filling and demand-reduction of supply.

- Other risks to mention which could potentially influence the security of supply could be IT related, especially seen in the light of an increased level of cyber-crime, espionage, activism, and terrorism as well as destructive cyberattacks in the aftermath from the Russian invasion of Ukraine and increased level of IT-threats from other countries outside Europe. IT Risks entail attacks on control systems within the Danish gas system, although measures are in place, the potential consequences from IT risks, are mainly economic in character.

[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) 994/2010 and REGULATION (EU) 2022/1032 of the European Parliament and of the Council of 29 June 2022 amending Regulations (EU) 2017/1938 and (EC) No 715/2009 regarding gas storage

1.2 Descriptions and conclusions from regional risk groups

Denmark participates in the following six risk groups:

- **Denmark**: Denmark, Germany, Luxembourg, Netherlands, Poland, Sweden
- **Norway**: Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Netherlands, Poland, Portugal, Sweden
- **Baltic Sea**: Belgium, Czechia, Denmark, Germany, France, Luxembourg, Netherlands, Austria, Slovakia, Sweden
- **Belarus**: Belgium, Czechia, Denmark, Germany, Estonia, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Slovakia, Finland, Sweden
- **North-Eastern**: Czechia, Denmark, Germany, Estonia, Latvia, Lithuania, Poland, Slovakia, Finland, Sweden
- **Ukraine**: Bulgaria, Czechia, Denmark, Germany, Greece, Croatia, Italy, Luxembourg, Hungary, Austria, Poland, Romania, Slovenia, Slovakia, Sweden

1.2.1 Risk Group Denmark (Denmark, Germany, Luxembourg, Netherlands and Sweden)

Figure 0 Risk Group Denmark

Russian dependency in the risk group

While there is some gas production in the risk group, primarily in the Netherlands and Denmark the Risk Group is as most of the European Union, extremely dependent on gas imports.

Two of the four main gas pipelines from Russia to the EU is entering the member states (MS) of Risk group Denmark directly. The North Stream Pipeline connecting directly from Russia to Germany and the Yamal Pipeline, connecting Russia to Poland through Belarus. Due to the ongoing conflict in Ukraine, Russia halted the gas deliveries to Poland in late spring 2022. The North Stream pipeline were exploded and damaged beyond usability in the fall of 2022 resulting in no Russian import of gas to the risk group utilizing these pipes.

Connectivity of the Risk Group

Risk group Denmark consists of six interconnected member states.

- *Sweden* in the north is solely interconnected with Denmark and is completely dependent on the import of gas from Denmark.
- *Denmark* is historically a net exporter to Germany and Sweden, but is currently net importer due to renovation work in the Tyra gas-site in the North Sea. While the Tyra site is in being renovated, most of the offshore gas from Danish gas fields is transported to The Netherlands. These quantities are approximately equivalent to 1/3 of the total yearly Danish gas consumption. In late 2022 a new pipeline "Baltic Pipe" was set in operation. Baltic Pipe functions as an import point added to the existing Europipe II (NO->DE). The Baltic Pipe will primarily serve with flow from Norway to Poland through Denmark, but generally ensures a higher resilience in the gas system of the region with the new transfer possibilities.
- *Germany* has interconnection points with all their neighbors MS and are in this risk group area highly dependent on import from Norway through Europipe II and the Netherlands as the Nord Stream Pipeline is out of service.
- *Poland* is interconnected to risk group members Germany and Denmark. Gas is imported to Poland from both member states, and from LNG facilities in Poland. All these import routes ensure supply, as there is currently no flow in the Yamal pipeline that historically delivered large amounts of gas to Poland and the rest of the EU from Russia.
- *The Netherlands* is producing and importing gas from the North Sea and UK as well as LNG from overseas. The country export large amounts of gas to Europe and is home of the TTF gas hub. In the view of risk group Denmark, the Netherlands primarily exports to Germany.
- *Luxembourg* is directly connected to Germany, but is mainly supplied by gas from Belgium (not MS in Risk Group Denmark).

Current functionality

As the gas flow from Russia has been reduced dramatically, the member states are looking for new sources of gas to their own supply and the European gas system. LNG terminals are being established and used to their max capacity. The biggest interconnector (Europipe II) is being used at large capacity and the regional production in the North Sea is being imported to the Netherlands, while the biggest Danish gas field (Tyra) is under reconstruction.

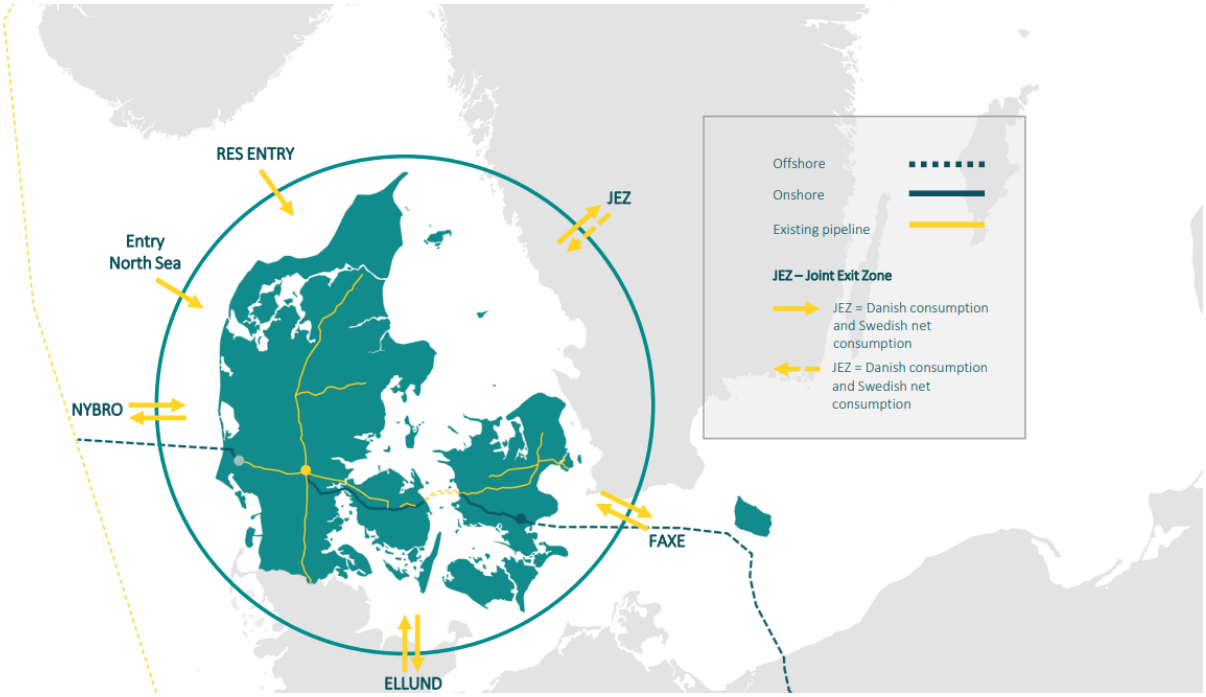
In Europe as a general, the reduced import of Russian gas has reversed the flows from being east towards west. Now the gas is flowing from west towards east and the supply of the Eastern European countries is at greater risk than before, should the Russian gas flows come to a complete halt. No MS in the risk group is certain of avoiding possible curtailment in case of a gas supply crisis but the potentials risk of curtailment in the member states of the group is greatly reduced with demand reductions and high gas storage inventory levels at the European gas storage facilities.

2. The Danish gas system

2.1 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, where gas is delivered to the gas customers. Moreover, the gas system consists of a gas treatment facility (Jutland), underground storage facilities (Zealand aquifer and North Jutland salt caverns) and compressor stations (Jutland and South Zealand). The compressor station in Jutland supports the transport of gas from Germany to Denmark; the compressor station in South Zealand supports the gas transit from Norway to Poland.

Figure 1 The Danish gas system and market model



Source: Energinet

The Danish gas transmission system is based on a simple entry-exit model, which allows market players to commercially move gas in and out of Denmark. The gas system has several entry/exit points where gas can be supplied either as import or export:

- Danish North Sea gas (Nybro Entry)
- German gas import and export (Ellund Entry/Exit)
- Gas transit from Norway (North Sea Entry)
- Gas transit to Poland (Faxe Entry/Exit)
- Joint Exit Zone[2]
- RES Entry

Ellund and Faxe are constructed with options for physical reverse flow. Furthermore, there are virtual transfer points for gas traded within the system (bilateral contracts or gas exchange) and for upgraded biomethane (RES[3]-entry).

[2] Single exit zone for delivery of gas to Danish and Swedish customers

[3] Renewable Energy Source i.e., biomethane

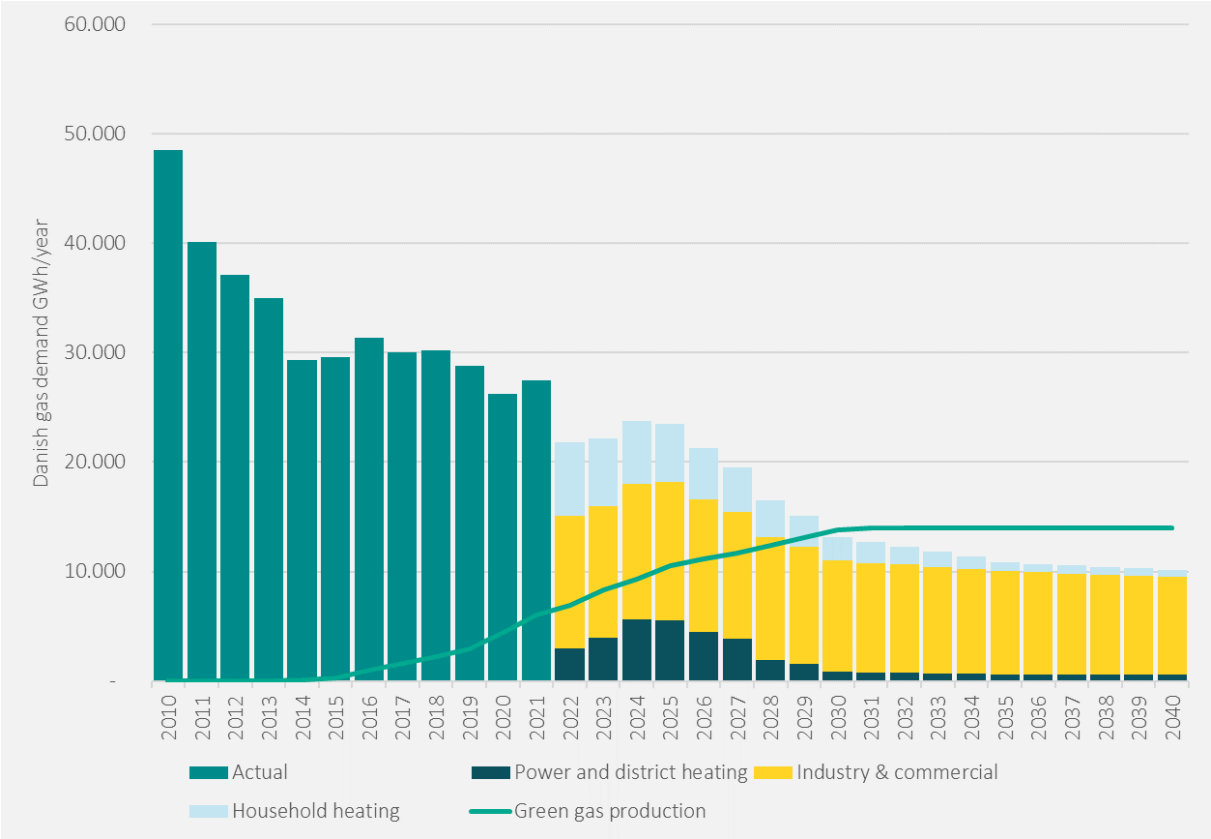
The Danish gas distribution system distributes the gas via 18.000 km gas pipes. Evida, owned by the Danish state, is the sole distribution company. Evida is responsible for maintaining the regional and local gas distribution system, which transports gas to the consumers. The gas distribution system is originally designed to receive natural gas from the transmission system, though the development of increasing production of biomethane in Denmark have resulted in, that biomethane plants delivers local produced gas directly to the distribution system.

2.2 Renewable Energy Sources (RES) - Biomethane

Since 2005 the consumption of natural gas in Denmark has been decreasing. The Danish Energy Agency projects the production and consumption of biomethane phasing out natural gas consumption for household and district heating, while converting the industry to consume more biomethane to reduce emissions from the use of coal and oil.

The amount of biomethane in the Danish system along with the future projections until year 2035 is shown in Figure 2 below.

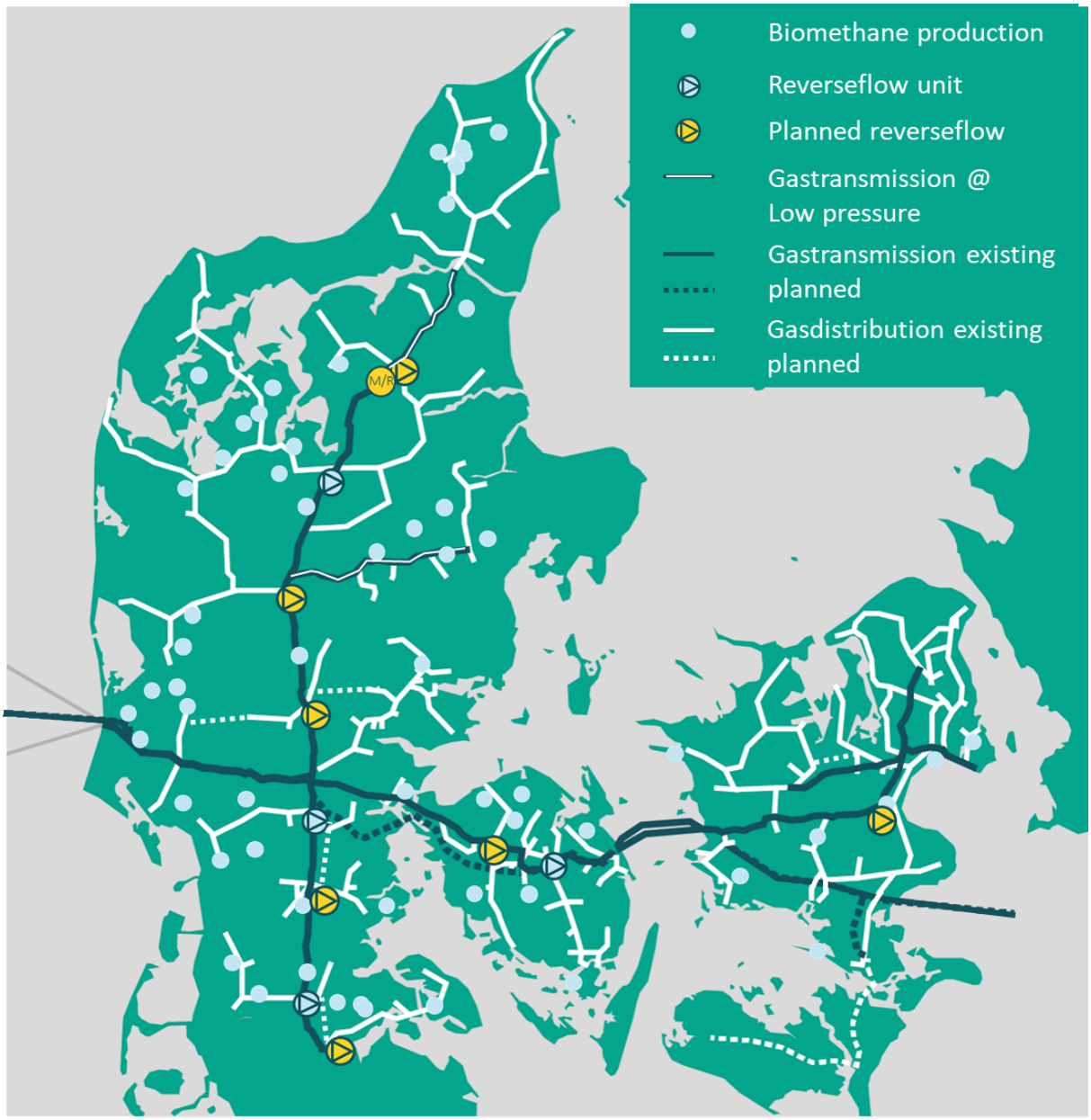
Figure 2 Historic and projected development in Danish consumption of natural gas and production of biomethane



Source: Energinet based on AF 22-data from the Danish Energy Agency

The amount of biomethane is expected to significantly grow over the coming years. The current projection (see figure 2) indicates that 100% of the gas consumption in Denmark will be covered by biomethane in app. 2029. By September 2022 app. 30 % of the Danish gas supply is covered by biomethane.

Figure 3 The Danish gas system including biomethane plants connected to the gas system (2021)



Source: Energinet

The biomethane production in Denmark is a significant contributor to the security of supply both in relation to the increasing share of the total gas consumption and in relation to the location of the biomethane plants. Biomethane contributes to a more decentralized and dispersed gas supply to the Danish gas customers. Decentralization of gas supply will, to a certain extent, help protect consumers in the event of supply shortages of natural gas, as they do not become dependent only on the primary sources of supply from the Danish North Sea and import from Germany and Norway, respectively.

2.2.1 Biomethane and increased levels of oxygen in the transmission grid

Biomethane produced in Denmark may contain a higher concentration of oxygen if comparing with neighboring countries, Germany, Sweden, and Poland. The large quantities of biomethane fed back from the distribution grid to the transmission grid, pose challenges in relation to gas export from Denmark.

The measures put in place to handle the concentration of oxygen is by sectioning the system and mixing the gas within the system, respectively. The gas system is sectioned to ensure gas with a low concentration of oxygen from the North Sea can be sent to Germany, without being mixed with biomethane. In practice, this means that one of the transmission lines to Germany is kept free from biomethane. For the same reason this means that biomethane is not supplied to the western transmission grid in Denmark.

North Sea entry (gas from Norway) will flow all year round, with the exemption for short periods due to planned maintenance and be a supplement to mix the gas to lower concentration levels of oxygen.

2.2.2 Biomethane and capacity constraints between the distribution – and transmission grid

The instability in Europe due to the Russian invasion of Ukraine contributes to the acceleration of biomethane production in Denmark. The current system capacity cannot fully accommodate for the increased biomethane production. To ensure the full potential from biomethane to benefit the security of supply in Denmark, a lot of ongoing collaboration happens across the system to investigate market- as well as finding sustainable technical solutions to handle these challenges.

2.3 Main gas consumption figures

According to Statistics Denmark[4] the total energy consumption in 2021 in Denmark was 686 petajoules, equivalent to 19 bcm natural gas, distributed across several energy sources, such as oil products, renewable energy, and natural gas. The consumption of gas transported in pipes was 86 petajoules, which corresponds to around 13 percent of the total energy consumption. In 2021, the share of natural gas in Denmark's energy consumption was at the lowest level measured over the past 30 years.

Table 1 Gas consumption figures by year (bcm/year)[5]

	2018	2019	2020	2021
Natural gas incl. biomethane	2,50	2,44	2,31	2,46
Biomethane[6]	*0,18*	*0,25*	*0,40*	*0,54*

Source: Danish Energy Agency

Gas is consumed by 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 2021, the total gas consumption including the gas used for production in the North Sea was 2,81 bcm. The natural gas consumption in Denmark, excluding oil and gas production, in 2021 was 2,46 bcm. After having declined for many years, the Danish annual gas consumption has been relatively stable in the last years, and at the same time, as mentioned in section 2.2, with steadily growing amounts of biomethane entering the gas system. The amendment to the Regulation on coordinated demand-reduction measures[7] sets out requirements to Member States to voluntarily or mandatory in the case of a Union Alert to reduce gas by at least 15% in the period from 1 August 2022 to 31 March 2023 compared to the average gas consumption in the same period the five consecutive years.

[4] www.statistikbanken.dk

[5] Gas consumption in oil and gas production is not included.

[6] The share of Biomethane is included in the natural gas figures

[7] REGULATION (EU) 2022/1369 of 5 August 2022 concerning coordinated demand reduction measures for gas.

In the past year, consumption in Denmark has decreased 10-20% as a reaction to the high gas prices and the security of supply situation. The reduction of consumption of natural gas alone (without offshore and biomethane) was 61 % in the months August – October 2022. Consumption reached a level corresponding to the needed demand-reduction already in the reference period 2021-2022, and during 2022 a further decrease in consumption has been observed (see section 3.3.4).

The gas consumption divided by sectors is shown in Table 2.

Table 2 Gas consumption and utilization figures by sector (bcm/year (percent))[8]

	2018	2019	2020	2021
Households	0,64 (26%)	0,64 (27%)	0,61 (29%)	0,60 (27%)
Industry	0,99 (40%)	0,96 (41%)	0,95 (45%)	1,09 (48%)
District heating	0,34 (14%)	0,27 (11%)	0,25 (12%)	0,31 (14%)
Electricity generation	0,49 (20%)	0,49 (21%)	0,28 (13%)	0,22 (10%)

Source: Danish Energy Agency

Approximately 75% of the annual gas consumption is consumed by protected customers (of which approx. 33% are solidarity-protected) while the remaining 25% of the annual gas consumption is delivered to unprotected customers.

Table 3 Peak demand (mcm/day)

	2018	2019	2020	2021
Denmark	17.0	14.5	11.8	17.1
Sweden	5.6	4.0	3.1	5.1

Source: Energinet

Table 4 Entry/Exit point's technical capacity (mcm/y)[9]

	2018	2019	2020	2021
Nybro Entry	11.945	11.945	11.978	11.945
Ellund Entry	5.575	5.575	5.618	6.468
Ellund Exit	9.706	9.706	9.706	9.706
Joint Exit Zone	9.399	9.399	9.425	9.399

Source: Energinet

The technical capacity at North Sea Entry will be 27 mcm/d, corresponding to 10 bcm/y.

Table 5 Entry/Exit point's commercial capacity (mcm/y)

	2018	2019	2020	2021
Nybro Entry	3.957	2.471	93	68
Ellund Entry	2.338	2.627	3.120	3.146
Ellund Exit	712	282	33	129
Joint Exit Zone	2.526	3.627	3.258	3.895

Source: Energinet

8 Gas consumption in oil and gas production is not included.

9 Values are converted from GWh to MNm^3 using 12,1 kWh/Nm3 as calorific value

Table 6 Entry/Exit point's volume flow (mcm/y)

	2018	2019	2020	2021
Nybro Entry	3.500	2.325	77	44
Ellund Entry	242	936	2.373	2.300
Ellund Exit	654	269	21	78
Joint Exit Zone	2.326	2.389	2.164	2.287

Source: Energinet

Table 7 Entry/Exit point's commercial utilization rates

	2018	2019	2020	2021
Nybro Entry	88%	94%	83%	65%
Ellund Entry	10%	36%	76%	73%
Ellund Exit	92%	95%	65%	60%
Joint Exit Zone	92%	66%	66%	59%

Source: Energinet

Table 8 Entry/Exit point's technical utilization rates

	2018	2019	2020	2021
Nybro Entry	29%	19%	1%	0%
Ellund Entry	4%	17%	42%	36%
Ellund Exit	7%	3%	0%	1%
Joint Exit Zone	25%	25%	23%	24%

Source: Energinet

In Table 5 - Table 8 the low values for Nybro Entry and Ellund Exit in the period from 2020 are due to the shutdown of the Tyra Complex during the reconstruction period from ultimo 2019. Similarly, the increase in values for Ellund Entry, during the reconstruction period, are due to the increase in import gas from Germany.

2.4 Key infrastructure relevant for the security of gas supply

The gas transmission infrastructure in Denmark is robust and has a high level of reliability, because of the high monitoring and maintenance standards in Energinet. The high level of monitoring includes onshore and offshore constructions, and both observed and potential damages are repaired immediately. Energinet continuously provides information to external parties on planned repairs and maintenance activities on the gas transmission infrastructure. If there are activities that affect the transport capacity, the affected transport customers will be notified directly via ENTSOG Transparency Platform.

Construction work in the vicinity of Energinet's gas pipelines is carefully monitored and controlled by Energinet's in-house surveyors. In Denmark, the Danish Register of Underground Cable Owners (LER) is available to seek information on underground cables, to ensure construction work can be performed safe and without posing unnecessary damages to the pipelines. The purpose of LER is to proactively prevent accidental damages to underground cables, lower administration costs in the contracting sector and to increase the security of supply.[10]

2.4.1 Onshore and offshore transmission pipelines

The onshore transmission pipelines are in total approx. 1100 km. All transmission pipelines are buried underground and marked above ground with marking poles to prevent unintended influence from excavation works etc. The offshore

[10] The Danish Register of Underground Cable Owners (LER) (www.ler.dk)

transmission pipelines connect Jutland, Funen, and Zealand. These pipelines are buried in the seabed and protected by rock-dumping. All pipelines are inspected/surveyed at regular interval to ensure a high level of integrity. All pipelines in Denmark are constructed, manufactured, maintained, and operated as per requirements in the Guide for Gas Transmission and Distribution Piping Systems.[11]

2.4.2 Line-valve stations

Approx. every 10-20 km along the transmission pipeline there are remotely operated line-valve stations. These stations can isolate parts of the pipeline as well as function as pressure relieve, should there be a need, e.g., in case of a rupture.

2.4.3 Metering and Regulating stations

The transmission pipelines are supplied with several measuring and regulator stations. Among other functions these stations ensure pressure alignment between the transmission system and distribution system.

2.4.4 Reverse flow stations from distribution to transmissions system

Reverse flow stations are installed at the transmission system's Metering and Regulating stations, where reverse flow from distribution to transmission system is needed. The reverse flow stations are designed with compressor units, metering unit, deodorization unit and gas quality measuring unit.

2.4.5 Compressor stations

The compressor stations ensure an acceptable pressure level in the gas transmission system. The compressors are necessary to maintain the transport capacities in the gas system especially during periods with high demand.

2.4.6 Gas import sources

The annual gas production historically exceeded the annual Danish and Swedish consumption, and is expected to exceed consumption again in 2024. During the period November 2019 – ultimo 2023 the Tyra complex in the Danish North Sea is out for reconstruction. Due to COVID-19 the reconstruction period is prolonged until the winter period 2023/2024.

The Danish production of natural gas in the North Sea is either exported directly to the Netherlands or, when the Tyra complex is fully functioning, transported to Denmark where it is consumed by Danish customers, stored in storages, and exported to Sweden and Germany. The commercial withdrawal capacity from the storage facilities is 185 GWh/d. If the gas storage inventory level is at least 25 %, the Danish consumption can be covered by storage withdrawal and biogas production for consumption corresponding to daily average temperatures down to – 4˚C.

The Danish gas production is an important part of the Danish and Swedish gas market since it covers the gas demand most of the year. Denmark and Sweden were until 2011 fully dependent on gas supplied from the Danish North Sea, but investments in the Danish gas system have enabled import of large amounts of gas from Germany (Ellund Entry). This has made the Danish and Swedish gas market less dependent on the Danish gas production, but instead created dependence on imported gas.

Table 9 Gas import sources per country of origin (bcm)

	2018	2019[12]	2020	2021
Germany	0,09	0,94	2,53	2,37

[11] Published by the American Gas Association

[12] The Tyra Complex shut down for reconstruction in November 2019. Since then all gas import comes from Germany via Ellund Entry (with small amounts of gas from the South Arne field to Nybro Entry)

Norway	0,27	0,14	0	0

Source: Danish Energy Agency

The Danish gas production has decreased significantly since its peak period (9-10 bcm annually in 2005-2007). The commercial utilization rates are shown in table 7 and the corresponding technical capacity utilization rates are shown in table 8Table 8.

2.4.7 The Baltic Pipe corridor

From October 2022, the Baltic Pipe has been in operation. The Baltic Pipe will allow transport of gas from Norway to the Danish and Polish markets, as well as to customers in neighboring countries in the Baltic Region and Eastern Europe. At the same time, the Baltic Pipe enables the supply of gas from Poland to the Danish market, which will contribute to the security of supply in Denmark and Sweden as more supply points are introduced to the Danish Gas system. With the new connections in Nybro and Everdrup, new supply points are added in both eastern and western part of the system.

2.4.8 Gas storage facilities

The Danish gas storages are located in Ll. Torup, in North Jutland, and in Stenlille, in Zealand (see map below). The underground gas 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 Danish North Sea, the deliveries are expected to be supplemented by gas from the storage facilities. In addition to seasonal leveling, gas trading may influence gas export and import and affect gas flows to the storage facilities. The storage facilities are also used for emergency supply. The injection and withdrawal capacities of the Zealand aquifer and North Jutland salt caverns storage facilities are shown in table 10.

Table 10 Injection/Withdrawal capacity (mcm/day)[13]

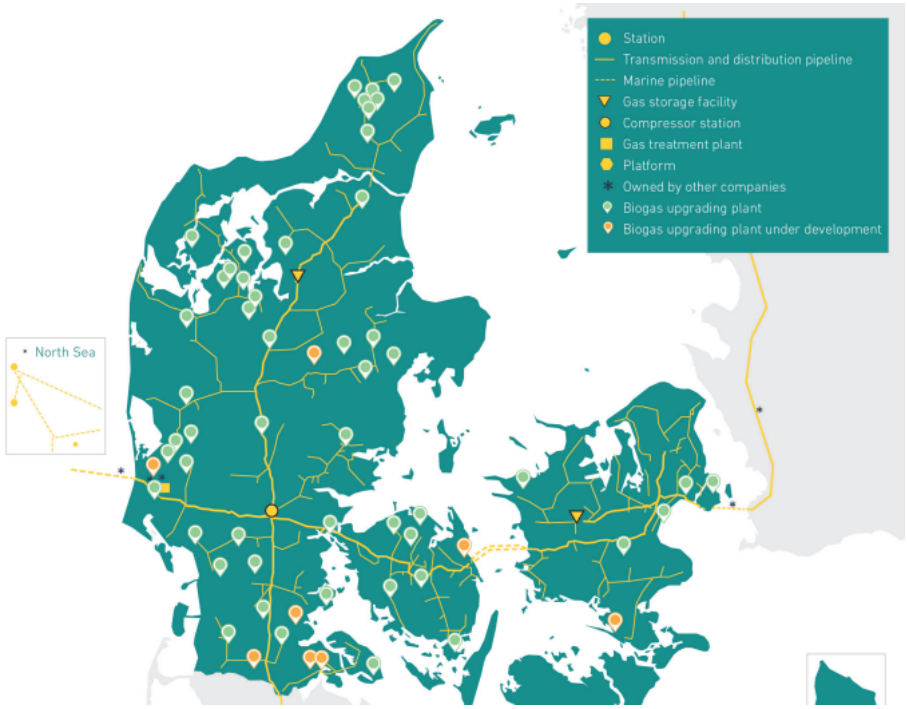
	Injection	Withdrawal
Zealand aquifier	4,8	8,2
North Jutland salt caverns	3,6	8,0

Source: Energinet

The storage capacity is dimensioned conservatively in relation to the "normal" pressure in the gas transmission system. When the pressure occasionally increases, it is possible to inject more gas into the storage facilities than the specified injection capacities given in table 10. The commercial withdrawal capacities of the Zealand aquifer and North Jutland salt caverns are today at 8,2 mcm/d and 8,0 mcm/day, irrespective of whether the storage levels are 100% (full storage level) or 30% (end of season level). The total storage capacity varies, but is currently app. 9,9 TWh WGV.

The storage facilities provide security of supply to the Danish gas customers. In the event the supply to the Danish market from external sources is reduced, the storage facilities and bio-methane production can partly or fully maintain the gas supply, depending on the offtake and the storage inventory gas level. Energinet buys emergency storage to ensure sufficient inventory gas inventory level during the winter. Emergency storage concists of emergency gas, owned by Energinet and individual filling requirements, where storage customers are paid to store gas during winter and Energinet has an option given by the contract to purchase the gas from the storage customer.

[13] See section 2.4.8 for insights to relevant restrictions to storage injection- and withdrawal capacities



Figur 1

2.4.8.1 Global filling levels; restrictions on injection and withdrawal capacities

During the storage year 2022-2023, 75% of the injection capacity is available when the gas storage facility is filled up to 95%. All injection capacity is available when the storage filling is below 95%. Withdrawal restrictions are imposed when filling levels go below 20% (close to the System Operator emergency volume). Thus at 20% filling level, 85% of the withdrawal capacity is available, at 15% filling level, 75% of the withdrawal capacity is available and so forth.[14]

2.5 The role of gas in electricity production

Table 11 Electricity production by source

Wind	41,8%
Biofuel (mainly biomass)	18,6%
Hydro	11,7%
Coal	10,8%
Natural gas	5,2%
Waste	4,6%
Solar	3,9%
Nuclear	2,3%
Oil	0,8%
Lignite	0,4%

Source: Energinet's environmental declaration for electricity, 2021

The electricity production in Denmark comes from many sources. Energinet's environmental declaration for electricity production shows that gas constitutes 5,2% of the energy used to produce the electricity consumed in Denmark. The largest share of Danish electricity production is made up from wind (41,8%) and biofuel (18,6%). From an electrical

[14] Please visit the Gas Storage Denmark webpage to see the latest figures; www.gasstorage.dk

point of view, Denmark is strongly connected to the neighboring countries and the consumption is not covered by Danish electricity production alone[15].

In relation to security of supply, power plants that use only gas constitute 26% of the total thermal production capacity. In addition to the gas-fired power plants, there are a few power plants that can use gas together with other fuels, e.g., biomass or waste. All gas-fired power plants can produce both electricity and heat.

In addition to the phasing out of thermal electricity production, there are several climate benefits to phasing out oil and natural gas in district heating. Although the risk of less power adequacy are increased, and the so called “brown outs” could be a possibility in an energy crisis, power shortages in Denmark are relatively rare. The lack of power has not yet led to interruptions in Denmark or neighboring countries electrically connected to Denmark[16], but the risk has increased and the focus on demand reduction has been maintained to mitigate this.

[15] Source: Miljøredegørelse 2021, Energinet (https://energinet.dk/El/Gron-el/Deklarationer)

[16] Source: Analysis prerequisites 2021, Danish Energy Agency https://ens.dk/service/fremskrivninger-analyser-modeller/analyseforudsaetninger-til-energinet

3. Infrastructure standard

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 dependent on the specific supply situation, including the market conditions.

3.1 The single largest gas infrastructure

The national risk assessment looks at the supply situation in 2023 where the main gas supply to Denmark is via gas transit from Norway (North Sea Entry). The Tyra Complex is expected to be back in operation in the winter 2023/2024. The expected flow direction will be from Norway to Poland, but the connection offers reverse-flow capacity from Poland via Faxe Entry.

The N-1 is thus a disruption of the interconnection point: North Sea Entry

3.2 Calculation of the N-1 formula for Denmark

The N-1 formula describes the technical capacity of the infrastructure to satisfy the total gas demand in the event of a disruption of the single largest infrastructure during a day with exceptionally high gas demand and with a statistical probability of once in 20 years. The N-1 formula:

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

To account for demand-side measures the N-1 formula is:

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

To ensure a continuous supply of gas, the infrastructure criteria N-1 ≥ 100% must be fulfilled.

The parameters used in the calculation are defined as follows:

D_{max} is the total daily gas demand (in mcm/d) in Denmark during a day with exceptionally high gas demand[17] occurring with a statistical probability of once in 20 years.

D_{eff} is the part (in mcm/d) of D_{max} that in case of a disruption of gas supply to Denmark can be sufficiently and timely covered with market-based demand-side measures.

EP_m is the technical capacity at entry points (in mcm/d), other than production, LNG and storage facilities covered by P_m, LNG_m and S_m, which means the sum of the technical capacity of all border entry points capable of supplying gas to Denmark.

P_m is the maximal technical production capability (in mcm/d) which means the sum of the maximal technical daily production capability of all gas production facilities which can be delivered to the Danish entry points.

S_m is the maximal technical storage deliverability (in mcm/d) which means the sum of the maximal technical daily withdrawal capacity of all storage facilities which can be delivered to the Danish entry points, considering their respective physical characteristics.

[17] A day with exceptionally high gas demand is defined at a day temperature at -13°C with a statistical probability of once in 20 years

LNG_m is the maximal technical LNG facility capacity (in mcm/d) which means the sum of the maximal technical daily send-out capacity at all LNG facilities in the Danish market, considering critical elements like offloading, ancillary services, temporary storage, and re-gasification of LNG as well as technical send-out capacity to the system

I_m is the technical capacity of the single largest gas infrastructure (in mcm/d) with the highest capacity to supply Denmark.

3.3 Calculation of the N-1 formula for Denmark

The calculations are made for two scenarios. These are excluding and including gas supply from Tyra, respectively. The parameters used in the N-1 calculation are given in Table 12 and Table 13.

Table 12 Parameters used in the N-1 calculation – with North Sea Entry as per 1. October 2022 (excl. Tyra)

Parameter	Capacity (mcm/d)	Description
D_{max}	17,2	The value covers the expected daily gas demand in Denmark
EP_m	58,3	The value covers the entry capacity on the Danish side of Ellund, Nybro (excl. Tyra) and Faxe
P_m	1,8	The value covers the expected Danish biomethane production in 2023
S_m	16,2	The value covers the total withdrawal capacities at the Danish gas storage facilities.
LNG_m	-	There are no LNG facilities in Denmark, thus LNG_m = 0
I_m	27,4	Technical capacity at North Sea Entry

Source: Energinet

Table 13 Parameters used in the N-1 calculation – with North Sea Entry as per ultimo 2023 (incl. Tyra)

Parameter	Capacity (mcm/d)	Description
D_{max}	17,2	The value covers the expected daily gas demand in Denmark
EP_m	66,5	The value covers the entry capacity on the Danish side of Ellund, Nybro (incl. Tyra) and Faxe
P_m	1,8	The value covers the expected Danish biomethane production in 2023
S_m	16,2	The value covers the total withdrawal capacities at the Danish gas storage facilities.
LNG_m	-	There are no LNG facilities in Denmark, thus LNG_m = 0
I_m	27,4	Technical capacity at North Sea Entry

Source: Energinet

The calculations of the N-1 shall be based on two different storage filling levels (100% and 30%, respectively). However, the Danish gas storage facilities can put restrictions on the injecting and withdrawal capacities on a year-on-year basis. Please see section 2.4.8.1 regarding global filling levels and restrictions regarding injection and withdrawal capacities in the Danish gas storage facilities. The withdrawal capacities given in Table 10 are not affected by the current filling levels restrictions imposed by the Danish storage facility company. The present emergency storage level ensures that the withdrawal capacity listed in Table 9 is available during the winter, meanwhile the injection capacities are reduced during the period when the storage level is high.
See Appendix section 6.1 for detailed assumptions.

3.3.1 Result for the N-1 scenario excl. Tyra

$$N-1[\%]_{excl.\ Tyra} = \frac{58.3 + 1.8 + 16.2 + 0 - 27.4}{17.2} \cdot 100 = \ 284\ \%$$

3.3.2 Result for the N-1 scenario incl. Tyra

$$N-1[\%]_{incl.\ Tyra} = \frac{66.5 + 1.8 + 16.2 + 0 - 27.4}{17.2} \cdot 100 = 332\ \%$$

3.3.3 Explanation of the main results from the N-1 calculation

The N-1 calculation for Denmark shows that N-1 equals 284% in the scenario with North Sea Entry in operation and excluding the full contribution from the Nybro Entry point (i.e., excluding Tyra). In the scenario where Tyra is back in operation during the winter 2023/2024, the N-1 equals 332%. This means the N-1 criteria is fulfilled in both scenarios.

The technical capacities used in the analysis have been checked by hydraulic simulations considering the system integrity and operational requirements of the transmission system.

Under normal conditions, a disruption of one entry point will not decrease the capacities of the remaining entry points. In a situation with a gas crisis in Europe, but without declared Emergency, the Danish balancing model will balance the Danish gas system. Thus, the technical capacities can be used for assessing the gas balance in a scenario of a disruption.

The conclusion is that the N-1 results show compliance to the infrastructure standard, without the need for further investment in further measures.

The hydraulic simulations show that gas consumers can be supplied according to the requirements of the security of supply regulation. In an Emergency situation with a disruption of the single largest infrastructure, the response time of the system operator and the facilities in the transmission system will be the limiting factors in order to timely accommodate for the situation.

3.3.4 N-1 formula using demand-side measures

To ensure a continuous supply of gas to the gas market, demand-side measures can compensate for a disruption of gas supply to ensure the remaining infrastructure has a technical capacity to satisfy the total gas demand. The infrastructure criteria N-1 ≥ 100% must be fulfilled.

The impact of a disruption of the single largest infrastructure on the security of supply, considering demand-side measures, is determined by the N-1 formula using demand-side measures:

$$N-1[\%]_{Demand-side\ measures} = \frac{EP_m + P_m + S_m + LNG_m - I_m}{D_{max} - D_{eff}} \cdot 100$$

The formula describes the technical capacity of the infrastructure to satisfy the total gas demand in the event of a disruption of the single largest infrastructure during a day with exceptionally high gas demand and with a statistical probability of once in 20 years considering demand-side measures.

The demand-side measure, Commercial Interruption, is a market-based tool which is currently not in use for the Danish gas market. Considering the N-1 results in section 3.3.1 and 3.3.2, further demand-side measures would not be considered economically feasible, as long as there is enough gas in the European gas market.

The EU member states agreed on July 26, 2022, to adopt a new regulation[18] on coordinated demand reduction measures for gas containing a 15% reduction target for gas for the winter and the option of declaring Union Alert. In 2022, the consumption in Denmark has fallen 10-20% as a reaction to the high gas prices. Consumption reached a level corresponding to the agreed consumption reduction already in the reference period 2021-2022 and a further decrease in consumption has been observed in 2022.

3.4 Bi-directional capacity

Bi-directional capacity is established between the Danish and the German gas systems in Ellund Entry/Exit, as well as between the Danish and the Polish gas systems at Faxe Entry/Exit. The maximum capacities of bi-directional flows are shown in Table 14.

Table 14 Maximum capacities of bi-directional flows (mcm/day)

	Entry	Exit
Ellund	See Table 4	See Table 4
Faxe	8,2	27

Source: Energinet

[18] COUNCIL REGULATION (EU) 2022/1369 of 5 August 2022 on coordinated demand-reduction measures for gas

4. Union-wide simulation of gas supply disruption scenario S-1

The union-wide simulation of supply disruption (S-1) is reported in ENTSOG's Winter Outlook 2022/23[19]. In the report the potential impact of the Russian supply routes disruption during Reference Winter and Cold Winter scenarios is investigated.

For a reference winter (normal demand for average winter temperatures) no demand curtailment is foreseen in Denmark as well as the rest of EU. However, without demand reduction most countries would be exposed to a significant risk of demand curtailment in case of a cold winter. In case of a 2-week cold spell the risk of demand curtailment is very much dependent on the level of storage gas in EU's gas storages. With an average storage level in EU on 30% of the total Work Gas Volume (WGV[20]) no demand curtailment is foreseen in case of a 2-week cold spell in February. In a case where the average storage level in EU is reduced to 20% of total WGV, the results show a risk of 8% demand curtailment of average winter demand.

The demand curtailment is a result of a supply deficient in the EU gas market and assumed to almost equally influence all national and regional markets in EU. Regions with high access to LNG (e.g., Portugal, Spain, Italy, Greece) will to a less extend experience lower demand curtailment than the rest of EU due to internal bottlenecks in the infrastructure. In case of a peak day disruption in February, the demand curtailment can be as high as 17% of peak day demand in case the WGV is reduced to 20% of total WGV. In case of a cold winter, the demand curtailment for Denmark on a peak day can be as high as 21% of peak day demand.

The EU demand curtailment can be mitigated with demand reduction response and/or additional LNG supply if no bottlenecks in the given conditions.

5. Identification of risks

A few risk scenarios for the Danish gas system have been identified and analyzed. There is a substantial list of threats to the energy supply in Denmark. As part of emergency planning, these threats are assessed to evaluate the ability to withstand or prevent threats from causing damage or supply failures.

19 SO0038-22 Winter Supply Outlook 2022-23_2 (entsog.eu)

20 In the total Working Gas Volume (WGV) national strategical storages are included (e.g., Danish Emergency Storage for protected customers).

5.1 Summary of main risks

The single largest infrastructure as per 1. October 2022 is identified as the North Sea Entry point. During the period, Tyra is still out for construction and is expected back in operation in the winter 2023/2024.

The identified main risks during the assessed period are:

Incidents that can affect the supply to Denmark. Geopolitics have a special focus within Europe due to the war in Ukraine as well as prior to the Russian invasion. The ultimate consequence of the war could be an EU Gas Supply Crisis.

Other mentionable risks which could potentially influence the security of supply could be IT related, especially seen in the light of an increased level of crime, espionage, activism, and terrorism as well as destructive cyberattacks in the aftermath from the Russian invasion of Ukraine and increased level of threats from China.

Energinet works closely with the Danish Centre for Cyber Security to accommodate relevant threats.

5.1.1 Incidents which could affect the supply to Denmark

The supply to Denmark could be affected by incidents which can affect the functioning of the gas system. Such incidents in relation to the gas supply in relation to N-1 e.g., can be offshore pipeline ruptures or failures at facilities in Norway which potentially could partially or fully preventing gas flow to Denmark.

Although pipeline ruptures occur at very low probabilities, and mitigation measures are well implemented and monitored in Denmark, such incidents would be critical for the security of supply via North Sea Entry. To minimize the negative effects from an offshore pipeline rupture, the market players are expected to balance the market by utilizing the alternative entry points or by withdrawal from the underground storages. Please see the results from the N-1 calculations in section 3 of this document.

Due to the war in Ukraine, the risk of supply shortage to Denmark could be due to a gas shortage in EU. An EU gas supply crisis could lead to reduced flow of gas via Ellund Entry, which could lead to an increased withdraw from the gas storages, elevating the risk of emptying the gas storages before the withdrawal season is over. To minimize the negative effects from an EU gas supply crisis, all member states must act in solidarity to ensure the security of supply to the most exposed customers. In addition, the member states may agree upon further measures such as the recent initiative "Save Gas for a Safe Winter". The EU has presented the "Safe Gas for a Safe Winter" initiative to mitigate the risk for supply shortage and to ensure that all member states are prepared for a longer period with reduced gas supplies. The initiative entails Regulation on coordinated measures for demand-reduction on gas with aims for voluntary reduction of gas use in Europe by at least 15% and mandatory demand-reduction in case of the declaration of Union Alert. Furthermore, the amending Regulation with regard to gas storage have secured a high filling level in the European storages. Other measures regarding the initiative entail acceleration on work on supply diversification, joint purchasing of gas to strengthen the EU´s possibility of sourcing alternative gas deliveries[21]

[21] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_4608

6. Appendix

6.1 N-1 Assumptions

Listed below is the firm entry and exit transport capacities to and from the Danish gas system for the coming year. The capacities are updated yearly and published at Energinets website. The unit is Mio. Nm^3 pr. day. The capacities are used in the N-1 calculations.

Table 15 Entry/Exit capacities – assumptions for the N-1 calculation

	Entry	Exit
Nybro	16,2	-
Ellund	14,7	14,7
North Sea	27,4	-
Faxe	8,2	26,6
Storages	16,2	7,2

Figure 2 Capacities are given in MNm^3/d Source: Energinet

Other: