# Gas in Denmark 2010

## Security of supply and development

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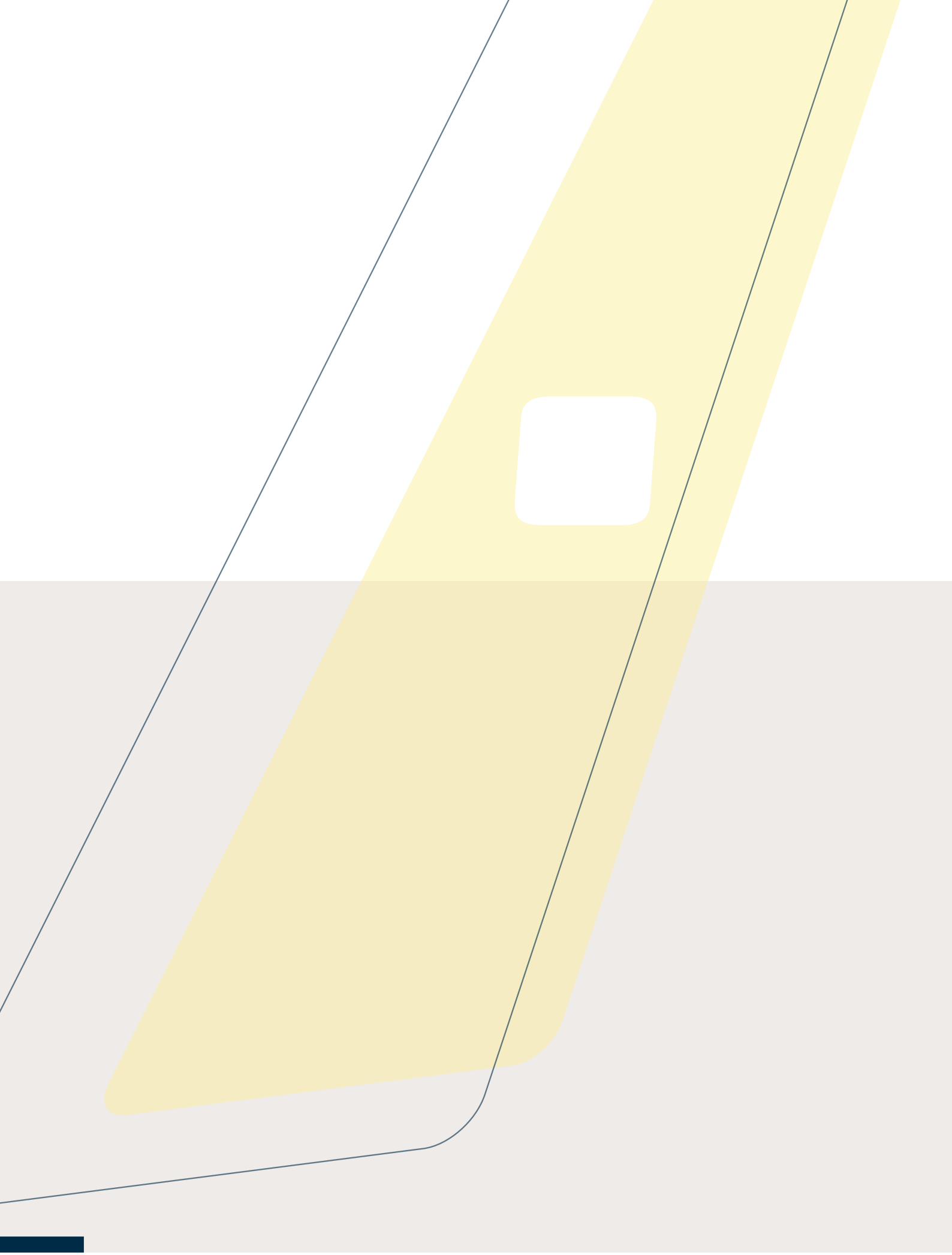

# Introduction to and summary of Gas in Denmark 2010

**Introduction**
Gas in Denmark 2010 is based on requirements set out in the Danish executive order on maintaining security of natural gas supply (*Bekendtgørelse om varetagelse af naturgasforsyningssikkerheden*) and the Danish executive order on the access to and use of the natural gas distribution network and plans for the future gas transmission capacity requirements (*Bekendtgørelse om anvendelse af naturgasforsyningsnettet og planer for det fremtidige behov for gastransmissionskapacitet*).

These executive orders set out requirements for annual reporting to the Danish Energy Agency. The reviews of security of supply and of the plans for expanding the transmission network are primarily contained in sections 2 to 7. Moreover, Energinet.dk wants to describe significant initiatives for the Danish gas market players and other stakeholders in the Danish gas system. These initiatives are described in the form of themes.

**Reading instructions**
The report begins with a number of themes describing major activities, which Energinet.dk has either launched or participated in. The majority of these activities tie in with Energinet.dk's overall strategy (see Strategy Plan 2010 and Strategy Plan 2008).

The description of the themes is followed by:
- A description of the gas system in section 2
- An overview of the past year in section 3
- Expectations for the coming year in section 4
- Expectations for the next decade in section 5
- Possibilities for development in the infrastructure in section 6[1]
- A description of the security of supply-related aspects in relation to the distribution companies in section 7.

**Energinet.dk's work to be influenced by increased international cooperation**
The international work plays an increasingly important role in Energinet.dk's daily tasks. Because of the implementation of the EU's third liberalisation package, a large part of the development of market terms in the gas area will take place at European level in the years to come. In future, much of the practical work to develop new rules and terms will be undertaken by ENTSOG (European Network of Transmission System Operators for Gas), and the international efforts are therefore a priority for Energinet.dk. The international cooperation affects both market development and the security of supply tasks. The international work itself is described in section 1.1, while the increased international focus is evident in the tasks described in the following sections.

**Market developments in 2010**
Energinet.dk continually cooperates with the transmission system operators (TSOs) in neighbouring countries. In 2010, Energinet.dk collaborated with the Dutch and German TSOs to set up a joint firm capacity initiative entitled Link4Hubs. This initiative made it possible for shippers to transport gas commercially and virtually across European borders using a joint IT platform. Trading via the service takes place on the day before the gas is to be transported physically, and the service is thus offered as a day-ahead service. Link4Hubs is described in further detail in section 1.2.

The second major change to the market model was the introduction of a so-called BNG entry point (BNG stands for bio natural gas). The entry point enables

[1] This section outlines the strategic opportunities for infrastructure development and has therefore been subjected to a strategic environmental assessment (SEA). The results of the SEA process are also described in this section.

shippers to trade and supply biogas produced in Denmark. Initially, the biogas will not be injected physically into the transmission network, but the system will be based on a certification scheme ensuring that the biogas can still be traded in all of Denmark and with neighbouring countries. Physically, the biogas remains in the distribution network. Biogas is described in further detail in section 1.7.

In the winter of 2009/2010, the gas exchange Nord Pool Gas succeeded in establishing a firm position in the Danish-Swedish gas market. The positive development started in October 2009 when around 100 trades were conducted on Nord Pool Gas. Since then, the number of trades has increased substantially, peaking at over 800 trades in March 2010. In terms of volume, almost 9% of Danish consumption in the period January 2010 to June 2010 was traded on Nord Pool Gas, which should be seen in light of the fact that only about 1% of Danish consumption was traded on Nord Pool Gas in the previous year.

Owing to more stable exports to Germany, 2010 has only seen a few days of congestion of German imports in Ellund and thus only a few transport disruptions. The increased physical exports allow for corresponding counterflow imports. In 2010, there were not as many disruptions as in 2009 and 2007. Read more in section 3.3.

**Security of supply in the coming years**
According to the Danish Energy Agency, the North Sea production will decline in the coming years and may be virtually phased out by 2040. These forecasts are, however, uncertain. So far, the North Sea has been the only way of physically supplying gas to Denmark and Sweden, and supply problems may therefore arise within a relatively few years. Energinet.dk has thus made a projection of Danish and Swedish gas consumption which shows that, if all the North Sea gas is supplied to Denmark and Sweden, the two countries would be self-sufficient in gas on an annual basis until 2017. In 2012/2013, the Danish production may, however, prove insufficient to cover Danish and Swedish requirements. Read more in section 5.

Consequently, Energinet.dk has decided to invest in new infrastructure, thus opening up for supplies to Denmark and Sweden from Germany from October 2013, and to conclude a pressure service agreement with Germany for the 2010-2013 period.

**Gas from Germany 2010-2013**
To cover the requirement in the 2010-2013 period, Energinet.dk has been working on the possibility of having gas supplied from Germany. This work takes the form of operational cooperation with the TSOs south of the Danish border regarding the physical import of gas from Germany and the conclusion of agreements with the DEUDAN partners on capacity and an increase in the pressure on the German side of the border. Energinet.dk is also collaborating with the Danish Safety Technology Authority to find ways of handling the somewhat different German gas quality in the Danish system. A capacity of up to 200,000 $m^3/h$ is expected, but owing to the relatively limited pressure supplied by the German system, the capacity will be interruptible. Read more in section 1.3.

**Emergency supply**
The Danish gas transmission system currently receives gas through the two offshore pipelines Tyra-Nybro and Syd Arne-Nybro. From October 2010, it also became possible to receive gas from the German market in most operating situations. In addition to these import sources, the two gas storage facilities in Denmark (Stenlille and Lille Torup) are an important part of the capacity reserves.

In pursuance of the Danish executive order on maintaining security of natural gas supply, Energinet.dk must ensure that consumers are supplied with gas in emergency situations. In case of major disruptions to gas supplies from Tyra, Energinet.dk has entered into a number of agreements to ensure, for example, supplies from the Danish gas storage facilities (reservation of storage volume), supplies from Tyra via Harald through the Syd Arne-Nybro pipeline (emergency supply agreement), interruption of the 35-40 largest natural gas consumers (ie interruptible emergency supply) and the use of linepack in land-based and submarine pipelines (physically). Moreover, since October 2010, a limited option of receiving emergency supplies from Germany has existed; a source of supply that is, however, not reliable in all operating situations.

The above measures ensure short-term security of supply in Denmark, and the agreements are analysed and adjusted annually. Read more in section 4.3.

**New emergency supply regulation**
In July 2009, the European Commission presented a draft regulation on security of gas supply which will come into force at the end of 2010. The primary purpose of the new regulation is to improve security of gas supply in the EU member states. This is to be achieved by 1) ensuring sufficient capacity in the systems (infrastructure standard) to handle extreme demand situations and major supply failures, 2) ensuring the supply to so-called 'protected consumers' even in the event of serious long-term supply failures (supply standard) and 3) ensuring that the member states cooperate and act together in emergency supply situations (regional cooperation).

The regulation introduces a minimum standard for handling the emergency supply task in the EU. The standard shares many similarities with the current Danish model, but certain adjustments are required, however, if Denmark is to comply with the regulation. In general, the EU countries must ensure increased use of market-based mechanisms. The changes will primarily relate to the fulfilment of the n-1 criterion at regional level[2], assessment and changes in relation to 'protected consumers', the preparation of risk assessments and plans for prevention and emergency supply, and a higher degree of coordination with neighbouring countries.

2 The n-1 criterion at regional level is the possibility of securing supplies for Denmark and Sweden if the largest source of supply – the Tyra-Nybro pipeline – cannot supply gas for a period of time.

Energinet.dk has joined forces with the Danish Energy Agency in launching a project aimed at mapping the extent of the changes that will have to be made in the way the emergency supply task is handled today as a result of the new regulation. The project will involve the market players and TSOs in the neighbouring countries in the process. Read more in section 1.4.

**Status of the Ellund-Egtved expansion**
Pursuant to the Danish Act on Energinet.dk (*Lov om Energinet.dk*), the Danish Minister for Climate and Energy has given the green light to establish installations for expanding the transport capacity from the Danish-German border to the town of Egtved. In letters of 29 January 2010 and 17 May 2010, the minister gave Energinet.dk permission to establish a compressor station and carry out a pipeline looping, respectively.

A compressor station is to be constructed in Egtved to ensure that the pressure is sufficiently high to transport gas from Germany through the Danish gas transmission system and out to Danish and Swedish consumers.

In addition to constructing a compressor station, it will also be necessary to lay a 94 km gas transmission pipeline from

the Danish-German border to Egtved. Today, there is a pipeline from Ellund/Frøslev to Egtved that currently exports gas from the North Sea to Germany. Capacity analyses have shown, however, that this pipeline does not facilitate gas imports in sufficient volumes. Consequently, the existing pipeline must be supplemented with a parallel pipeline.

In 2010, tenders were invited for the project planning and construction of the compressor station. Following the conclusion of a contract with a turnkey supplier, project planning for the plant will commence in 2011. The compressor station will be ready for commissioning in autumn 2013.

In 2010, an agreement will be concluded on the project planning of the pipeline. Preliminary archaeological studies will be conducted along the entire pipeline in 2011, and the final pipeline route will be determined. Actual pipeline construction will take place in spring 2012, and the pipeline is expected to be commissioned in autumn 2013. Read more in section 6.1.

**Gas quality**
Physically, the Danish North Sea gas is characterised by a very uniform composition and thus a very uniform quality. The gas imported from Germany is a mixture of gas supplied to the German market by many sources. As such, the Danish customers will receive natural gas of a different quality, and they will probably also experience greater variation in gas quality. In most situations, gas from Germany will be of a quality allowing it to be imported to Denmark, but in order to prevent gas quality from becoming an obstacle to importing gas, the Danish Gas Regulation (*Gasreglementet*) must be changed. Read more in sections 4.4 and 5.6.

**Possible energy savings in the North Sea**
In 2009-10, Energinet.dk conducted an analysis in cooperation with the Danish Energy Agency to determine whether it would be possible to lower the pressure of the gas supplied from Tyra Øst to Nybro in order to reduce energy consumption for compression. The results indicate that a solution involving reduced compression offshore and recompression onshore using energy-efficient electrically driven compressors in Nybro and Egtved creates energy savings. The potential realisation of these energy savings will require renegotiation of commercial contracts between the companies selling, buying and transporting gas from Tyra Øst as some of the costs will be allocated to other parties. Read more in section 6.2.

**Possibilities of supplying Norwegian gas direct to Denmark**
When the Danish Minister for Climate and Energy gave her seal of approval to the expansion of the gas transmission system to Germany, the consequences for the North Sea producers of looping the Ellund-Egtved pipeline were also analysed. The analysis showed, for example, that it may be necessary to establish an interconnection to Norway in the long term. Energinet.dk has therefore launched a number of initiatives to investigate the possibilities of establishing such an interconnection. The initiatives are coordinated with the Norwegian system operator for the offshore gas pipelines, Gassco, which in the autumn of 2010 investigated a number of potential connections between existing Norwegian and Danish infrastructure in the North Sea. Read more in section 6.3.

**More biogas in Denmark**
There is broad political consensus in Denmark for significantly increasing biogas production, one of the reasons being that biogas production reduces

emissions of the greenhouse gases methane and dinitrogen oxide. The biogas currently produced is chiefly used as fuel in the local CHP plants generating electricity and district heating. Upgrading and injecting biogas into the gas network may be one way of solving the problem of inflexible biogas production to the extent that it cannot be used locally. Consequently, Energinet.dk has developed a biogas market model in cooperation with the gas distribution companies, making it possible to trade biogas in the gas network. A working group has also been appointed to define the requirements for biogas quality. The requirements are expected to be implemented before the end of 2010.

A number of gas market players have requested a documentation scheme for biogas, and Energinet.dk is therefore working to supplement the biogas market model with such a scheme. The purpose of a documentation scheme is to create biogas traceability and in this way promote a reliable market for consumers who are willing to pay more for 'green energy' and who want to be able to document this. Read more in section 1.7.

**Strategic environmental assessment**
Energinet.dk believes that the issues *Norwegian gas direct to Denmark* and *biogas in the gas network* are of strategic importance to the future development of the gas system and may have major environmental impacts. These are described in sections 6.3 and 1.7.
A strategic environmental assessment (SEA) of Gas in Denmark 2010 has therefore been conducted, focusing particularly on these two sections.
The SEA was conducted in the summer and autumn of 2010, starting with a delimiting consultation aimed at determining whether Energinet.dk has focused on the right environmental issues in the environmental assessment.

Subsequently, a consultation was carried out on the strategic environmental assessment of the report. The strategic environmental assessment showed that the choice of location of the future installations could significantly reduce the potential environmental impact of a possible coming interconnection between Norway and Denmark. The responses received during the consultation process do not give rise to any changes in the plan. Read more in section 6.4.

**Tariffs**
The Danish gas market has developed significantly since its liberalisation in 2004. Integration with the northern European market has increased, and the nature of Danish and Swedish gas consumption has changed. Moreover, in the coming years, Denmark will go from being a net gas exporter to being a net gas importer, and the Ellund-Egtved expansion entails new investments which will have a major impact on the cost base.

In January 2010, Energinet.dk announced the principles of how to include the costs of the Ellund-Egtved expansion in the tariffs. In addition, a 'service check' of the current tariff model has been commenced with a view to adapting the methodology to the new market and supply terms. The analyses also assess the tariff model against the new EU regulation. Energinet.dk has therefore launched Tariff Project 2010 and will maintain close dialogue with the Danish Energy Regulatory Authority and the market players throughout the project. Read more in section 1.5.

**Optimising technical capacities in the transmission network**
Energinet.dk is working to further develop models for calculating and

optimising capacities in the Danish transmission system. The purpose of this is to maximise the capacity made available to the market without compromising security of supply. This work includes most of the elements mentioned above. Flow scenarios from either the North Sea or Germany, the market model, consumption patterns and gas quality thus all have an impact on the technical capacity of the gas system points. Read more in section 1.6.

**Non-fossil gas 2050**

In the short and medium term, the gas system has a unique potential to contribute gas as an efficient and environmentally friendly energy source and, in the long term, to contribute to the efficient and safe integration of large amounts of renewable energy (such as biogas and renewable energy gases) in an effective interaction with more fluctuating renewable energy sources such as wind, solar and wave power.

Gas constitutes a very large and flexible energy storage potential which can contribute effectively to wind power integration. From a socioeconomic perspective, gas is an efficient fuel for peak-load electricity generation, for process heating in the industrial and services sectors, and in the transport sector.

Moreover, gas may become a key fuel for the highly energy-efficient fuel cells of tomorrow. Denmark's strong positions within the biogas and hydrogen/fuel cell areas are crucial for achieving an energy supply that is independent of fossil fuels. Maintaining and strengthening the research and development efforts in a number of key areas such as the development of technologies which, by means of electricity, can convert hydrogen, water, synthesis gas and/or $CO_2$ into methane is thus important. This will make it possible to use the gas network as a 'storage facility' for cheap electricity. Read more in section 1.8.

# 1. Current themes in the Danish gas market

## 1.1 International cooperation

International cooperation is playing an increasingly important role in Energinet.dk's tasks. The third liberalisation package and the resulting binding cooperation between the TSOs and common European rules thus require Energinet.dk to intensify its international work. The launch of the work in ENTSOG in December 2010, new infrastructure projects and new products to improve cross-border trade are all examples of current international tasks.

### 1.1.1 The third liberalisation package

One of the most important EU initiatives in the field of energy in the last couple of years is the third liberalisation package adopted in July 2009. The package aims at harmonising the European electricity and gas markets by introducing a common set of rules and more integrated European cooperation with focus on five main elements:

- Ownership unbundling between transmission companies and production and trading (Energinet.dk already fully complies with the requirements)
- Strengthening of national regulatory authorities
- Establishment of a joint EU supervisory agency for national regulators (Agency for the Cooperation of Energy Regulators – ACER)
- Formalisation of the European TSO cooperation (European Network of Transmission System Operators – ENTSOE and ENTSOG for electricity and gas, respectively)
- Increased transparency in respect of cross-border trading and electricity and gas transmission.

**New work structure**

In the period until March 2011, ENTSOG, the European Commission and ACER will be fully engaged in implementing the new work structure set out in the third liberalisation package. Assisted by both regulators and TSOs, the European Commission has drawn up a prioritised list of the market regulations and technical regulations to be realised initially. The regulators will prepare the overall guidelines forming the framework for the initial regulations which will be developed by the TSOs under the auspices of ENTSOG. The regulations will be subject to a consultation procedure with all stakeholders. It will then be commented on and approved by the regulators and the European Commission, and finally be made binding in all member states.

**ACER**

It is the intention to considerably strengthen the role of the regulators by increasing national powers and establishing ACER. The period until March 2011, at which time ACER is to be fully operational, is a pilot phase during which the new cooperation structure will be tested by the national energy regulators. The rules developed in cooperation with the TSOs will not be binding, however, until the pilot phase is completed.

**ENTSOG**

A particularly important element for Energinet.dk in the third liberalisation package is the establishment of ENTSOG (European Network of Transmission System Operators for Gas). The main purpose of the new organisation is to improve cooperation between the European TSOs and to further develop the framework for common European development of the energy markets.

Through ENTSOG, the TSOs will be involved in the official EU cooperation in the energy area where a number of important tasks are to be solved:

- Development of market regulations and technical regulations for cross-border trading and transmission
- R&D activities

- Operational cooperation
- Investment planning in the form of ten-year network development plans.

ENTSOG's official work programme commenced on 1 December 2009. In 2010, ENTSOG established its head office in Brussels and appointed working groups with a secretariat within a number of fields of work, eg capacity allocation, handling of capacity limitations, balancing and investment. In addition, a ten-year network development plan, TYNDP[3], has been prepared for the period 2010-2020 along with a number of position papers in the gas area.

Under the auspices of ENTSOG, work continued in the autumn of 2010 on the first market regulation regarding capacity allocations, which, on the basis of the overall guidelines issued by the regulators, is to form the precedent for the regulations in the other fields of work. The work on the capacity allocation regulation is expected to be completed in mid-2012.

As the cooperation in ENTSOG is of high priority to the EU, and as the future network rules will be binding in Denmark, ENTSOG is an important cooperation forum for the development of European energy policy and for the operational cooperation across the EU. Energinet.dk has therefore decided to focus on the cooperation in ENTSOG, where Energinet.dk's Vice President, Gas Market, is a member of ENTSOG's Management Board, while employees from the entire Gas Division participate actively in working groups within capacity allocation, investment, interoperability, tariffs, etc.

[3] Ten Year Network Development Plan

### 1.1.2 Renewable energy directive and 20-20-20 targets

The adoption of the EU's climate and energy package in April 2009 was at the same time the formal adoption of the so-called 20-20-20 targets. The targets mean that the EU will have to reduce its greenhouse gas emissions by 20% by 2020, meet 20% of its total energy needs by renewable energy, and reduce its energy consumption by 20%. For Denmark, this will mean, according to the proposed burden-sharing principles, that renewable energy must account for 30% of final Danish energy consumption by 2020 compared with 17% of gross energy consumption in 2005.

Energinet.dk wants to contribute to fulfilling the national and European climate objectives, ensure security of supply, for example by supporting the use of biogas in Denmark, and ensure the possibility of striking the optimal balance between renewable energy sources such as biogas, natural gas and other more $CO_2$-emitting fossil fuels. Improving the utilisation of the flexible regulating power properties of gas in an increasingly more wind-based energy system may be an important element in ensuring security of supply.

### 1.1.3 Baltic Gas and West Baltic Task Force

In the period 2009-2012, Energinet.dk holds the chairmanship of Baltic Gas, which is a regional forum of gas companies and TSOs in the Baltic region. The organisation has particular focus on security of supply and gas market development, but has also conducted analyses regarding biogas development and gas in the transport sector in the Baltic region.

In 2010, Baltic Gas was charged with driving the work of West Baltic Task Force, a working group appointed by the European Commission with a view to assessing alternatives to the declining Danish gas production in the North Sea and strengthening security of supply in the region. A number of stakeholder meetings have therefore been held with participation of TSOs, gas companies,


Figure 1-1: Link4Hubs service between Energinet.dk, Gasunie Deutschland and Gasunie Netherlands.

energy authorities (government agencies and ministries), regulators and the European Commission. The meetings resulted in the publication of analyses regarding the status of and barriers to infrastructure projects in the region.

The purpose of the work is to develop a specific action plan, which is expected to be completed in December 2010. The action plan will involve the preliminary conclusions from the analyses and will have special focus on a Norwegian pipeline to the Baltic region as part of a holistic solution.

If the European Commission is satisfied with the work presented by Baltic Gas to the West Baltic Task Force, the analyses and conclusions related to this work are expected to have a considerable impact on the European Commission's regional plans.

### 1.1.4 Bilateral cooperation

At bilateral and multilateral level, the most important cooperation takes place with the neighbouring TSOs in Sweden, Germany, the Netherlands and Norway.

## 1.2 Link4Hubs

Link4Hubs is a new border point service offered in a cooperation between three TSOs – GTS in the Netherlands, Gasunie Deutschland in northern Germany and Energinet.dk in Denmark.

Link4Hubs is a firm, bundled service, offering shippers the possibility of transporting gas across several borders in Europe using a joint Link4Hubs platform. Trading via the service takes place on the day before the gas is to be transported physically – ie the service is offered as a day-ahead service.

The basic idea is that, by the click of a button on a joint platform, the shipper can move gas from a virtual Link4Hubs point in Denmark to a virtual Link4Hubs point in either northern Germany or the Netherlands without having to reserve capacity in pipelines in and out of the countries in question and that the gas is nominated automatically when the service is reserved. The service is offered in Denmark, northern Germany and the Netherlands, with the possibility of more TSOs or countries hooking up.

## 1.3 Gas from Germany 2010-2013

### 1.3.1 Harmonisation of products in Ellund

Energinet.dk is continuously working to improve the market situation for shippers at Ellund border point. In 2010, Energinet.dk launched Link4Hubs, see section 1.2. At the same time, Energinet.dk is working on harmonising interruptible capacity products at the border point in cooperation with neighbouring TSOs in Germany. Finally, the possibilities for a changed set-up at the border point are being analysed, taking into consideration that the European regulators want to harmonise capacity allocation and congestion management in Europe.

### 1.3.2 Operational cooperation

Energinet.dk is still looking into all the possibilities of having gas supplied physically from Germany when required. Energinet.dk has initiated operational cooperation with the TSOs south of the Danish-German border, and the first physical import of gas from Germany since 1984 took place on 13 July 2010.

On this day, Energinet.dk closed a valve in Egtved, thus isolating the south Jutland

system. Subsequently, gas was imported from Germany at a pressure slightly under 60 bar, which was sufficient to supply the south Jutland system.

### 1.3.3 Temporary pressure service agreement 2010-2013

Energinet.dk has concluded a pressure service agreement with the DEUDAN partners which has made it possible to increase pressure on the German side of Ellund, thus enabling the physical import of gas from Germany since 1 October 2010.

Since October 2010, the Germans have been able to obtain a pressure of 68-72 bar which has made it possible to physically import gas from Germany without closing the valve in Egtved. This means that German gas has also entered the system north of Egtved.

The pressure increase may result in imports of up to 200,000 $Nm^3/h$. Because of the uncertainty concerning gas quality and the restrictions in the Danish system in respect of its possibilities of receiving gas from Germany, for example when high pressure is needed in the system in order to supply the Swedish market and to inject gas into the storage facilities, the import capacity from Germany will be interruptible.

The pressure service agreement came into force on 1 October 2010, and since then gas has been imported from Germany in several situations when the demand for northbound capacity has exceeded the demand for southbound capacity.
In the 2012-2013 gas year, the need for gas from Germany may be critical with a view to maintaining the supply of gas to the Danish and Swedish markets. Energinet.dk will therefore seek to maximise the possibilities of physically importing gas from Germany.

### 1.3.4 Quality of German gas 2010-2013

The composition of the gas imported from Germany will vary depending on the current supply conditions, and the gas is typically a mixture of German, Norwegian, Dutch and Russian natural gas and, in the long term, some biogas. The gas from Germany is expected to have a considerably lower Wobbe index[4] and calorific value as well as greater variation in these parameters than experienced by Danish gas consumers to date. As for other gas quality parameters such as relative density, sulphur content and dew points, the quality of the German gas resembles that of Danish gas. The gas from Germany will only be received if it is within the limits set out in the Danish Gas Regulation and the Rules for Gas Transport.

The permitted interval laid down in the Danish Gas Regulation for the Wobbe index is 14.1-15.5 $kWh/Nm^3$. Historically, the variation in the German gas is 13.9-15.3 $kWh/Nm^3$, whereas the Danish variation is approximately 15.2-15.3 $kWh/Nm^3$. Energinet.dk is cooperating with the Danish Safety Technology Authority, the public authority within this area with responsibility for the Danish Gas Regulation, on expanding the interval of the Wobbe index to 13.9-15.5 $kWh/Nm^3$. Energinet.dk expects that the Danish Safety Technology Authority will announce this expansion in the beginning of 2011.

## 1.4 New emergency supply regulation

In July 2009, the European Commission presented a draft regulation on security of gas supply. The draft regulation was presented as a direct consequence of the gas crisis between Ukraine and Russia in the winter of 2008/2009. Following extensive negotiations between the European Commission and the member states, the Council of Ministers adopted

[4] Fire-technical parameter

a revised draft regulation at the end of June 2010. The regulation will enter into force in December 2010 and will subsequently have legal effect in the individual member states.

The new regulation will introduce changes and stricter requirements in a number of areas in relation to the current handling of the emergency supply task in the EU.

The primary purpose of the new regulation is thus to improve security of supply in the member states. This will be achieved by ensuring sufficient capacity in the systems (infrastructure standard) to handle extreme demand situations and major supply failures, by ensuring the supply to so-called 'protected customers' (see next section) even in the event of serious and long-term supply failures (supply standard) and by regional cooperation between the member states in emergency supply situations. The European Commission will play a central and controlling role in case of serious emergency supply situations comprising all or part of the EU.

Another important purpose of the new regulation is to ensure that the single gas trading market is also maintained in emergency supply situations to the widest possible extent. The regulation therefore requires increased use of market-based mechanisms, such as interruption and change of fuel at major consumption sites, commercial use of storage facilities and flexible import agreements, etc., as tools to counteract and reduce the impact of supply failures. Only in extreme emergencies will it be possible in the future to use non-market-based tools such as strategic storage (emergency storage today), etc.

The regulation introduces a minimum standard for handling the emergency supply task in the EU, which shares many similarities with the Danish model, but adjustments will be required in the Danish model as well, not least with a view to ensuring increased use of market-based mechanisms. The areas in which the Danish handling of the emergency supply task will be changed as a consequence of the new EU regulation are described in the following.

### 1.4.1 Changes in relation to existing emergency supply set-up

**Infrastructure standard**
A central element in the regulation is the n-1 criterion. The criterion means that if the supplies from the largest source of supply fail, the remaining available sources must be able to supply the entire market.

In future, the n-1 criterion must be met at regional level, and, as Sweden is completely dependent on supplies via Denmark, the infrastructure standard will generally have to be met for Denmark and Sweden. In practice, this does not deviate from the current situation where Energinet.dk in the event of a supply failure will be obliged to make the required transport capacity available to Sweden, but neither Energinet.dk nor other players are currently bound by any statutory emergency supply obligations towards the Swedish market. Today, if shippers/gas suppliers have gas available for the Swedish market, Energinet.dk will handle the transport if physically possible. With the regulation, it will be necessary to ensure the physical framework, and it may involve paying a fee to Energinet.dk for securing the necessary infrastructure and to Energinet.dk or other players for the required storage gas.

Currently, the Danish transmission system is based solely on supplies from the Danish part of the North Sea, but a high degree of security of supply is offered at the same time. This means that Energinet.dk guarantees gas deliveries in the event of supply failures resulting from damage to

the Tyra pipeline for up to 60 days. Supplies can be maintained by bringing gas ashore via the Syd Arne pipeline, by drawing on stored gas and by interrupting supplies to customers with interruptible supply.

**Situation from October 2013**
With the adopted expansion of the capacity to Germany, in the event of long-term supply failures from the North Sea, it is expected that, from the end of 2013, supplies to the Danish and Swedish markets can amply be covered via Germany, by drawing on stored gas and by interrupting supplies to customers with interruptible supply contracts, ie without supplies from the Syd Arne pipeline.

In 2014, the total capacity requirement of the Danish and Swedish markets is estimated to amount to max. 31 million $Nm^3$/day (Denmark 24 million $Nm^3$/day and Sweden 7 million $Nm^3$/day). The capacity requirement should be compared with the possible supplies.

Currently, agreements have been made with the storage facilities on the supply of the full withdrawal capacity from the storage facilities of up to 20 million $Nm^3$/day in emergency situations, but there is no guarantee that this capacity will also be available in 2014 as this depends on the storage volume.

Upon the establishment of a compressor station and pipeline looping, the capacity of the Danish system will amount to 17 million $Nm^3$/day (possibly less in the German system), following which Energinet.dk will be able to amply meet the n-1 criterion without interrupting supplies to customers. The increased capacity will open up for competition on the delivery of the emergency supply service as the capacity can be provided from several locations.

In the event of failures in the supply from Germany, the n-1 criterion will similarly be met through supplies from the North Sea, from storage facilities and possibly through customers with interruptible supply.

**Situation in 2020-2025**
The Danish Energy Agency expects supplies from the North Sea to continue to wane. In the long term, when gas from Germany is the largest source of supply, Energinet.dk assesses that there may be problems meeting the n-1 criterion. This problem could, for example, be solved by establishing an interconnection to Norway.

**Protected customers**
Basically, all Danish consumers are 'protected' against emergency supply situations today, but a number of large consumption sites have chosen to enter into an agreement with Energinet.dk on the interruption or reduction of gas consumption in emergency supply situations. These consumers, which are called interruptible consumers, account for just under 20% of Danish consumption.

In future, only some types of consumers will be guaranteed gas supplies in emergency supply situations. This concerns the following categories:

- Households
- Small business customers, industries, and consumers providing essential services to the general public (hospitals etc.), provided that they do not account for more than 20% of consumption
- Gas for district heat production at plants without alternative fuel.

All in all, these categories are deemed to make up approximately 60% of consumption in Denmark. Today, interruptible consumers account for around 80% of consumption.

Interruptions are therefore required at more consumption sites than is the case today.

**Risk assessment, plans and crisis management**
A risk assessment will be conducted in future, mapping the risk elements that may potentially impact security of supply in Denmark, and specific prevention and emergency supply plans will be prepared on the basis of this assessment. The purpose of the prevention plans is to describe how the risk elements identified in the risk assessment can be eliminated or reduced, while the emergency supply plans should describe how the effect of emergency situations is eliminated or reduced.

The prevention and emergency supply plans will thus demonstrate how increased use of market-based mechanisms can counteract emergency supply situations or reduce their negative impact.

**Regional cooperation**
The new EU regulation requires that all member states act in solidarity with the other EU member states in emergency supply situations, and particular requirements are made for increased regional cooperation. In practice, this means that a member state is not allowed to handle supply failure situations in such a way that supplies to protected consumers in neighbouring countries are threatened.

The increased requirement for regional cooperation means that, in future, Denmark must as a minimum coordinate the emergency supply preparedness and the prevention and emergency supply plans with Sweden, and Sweden must be incorporated in the plans on how to meet the infrastructure standard as supplies via Denmark constitute Sweden's sole import option. In addition, it will probably also be necessary to coordinate with Germany and the Netherlands whose systems are interconnected with the Danish gas system.

Situations might thus arise where Denmark is asked to send gas to Germany with a view to relieving supply failures there or in other parts of the region or the entire EU. Coordination with the adjacent systems is necessary in order to map the possible needs for this.

**Introduction of crisis levels**
Three crisis levels will be employed in the future: **'early warning'** (varsel), **'alert'** (skærpet drift) and **'emergency supply'** (nødforsyning).

In future, actual emergency supply situations can only be declared if supplies cannot be maintained through use of market-based mechanisms such as interruption of supply/change of fuel, commercial use of stored capacity, etc. In these situations, supplies to protected consumers must be maintained by using non-market-based tools such as strategic storage.

The 'emergency supply' crisis level is similar to the situations in which an emergency supply situation would have been declared in the existing model, but where the largest consumption sites are only interrupted in emergency supply situations today, this will have to take place already in alert state situations in the future. This is done to avoid emergency supply situations and thus maintain the single gas trading market.

## 1.4.2 Implementation

The regulation came into effect in December 2010. The risk analysis must be conducted and the prevention and emergency supply plans prepared by 1 October 2011 at the latest, and all of them must be approved by the EU. Coordination with neighbouring countries must be completed within six months thereafter.

This means that the plans for maintaining supplies to protected consumers and ensuring interruption of non-protected consumers must be drawn up before then.

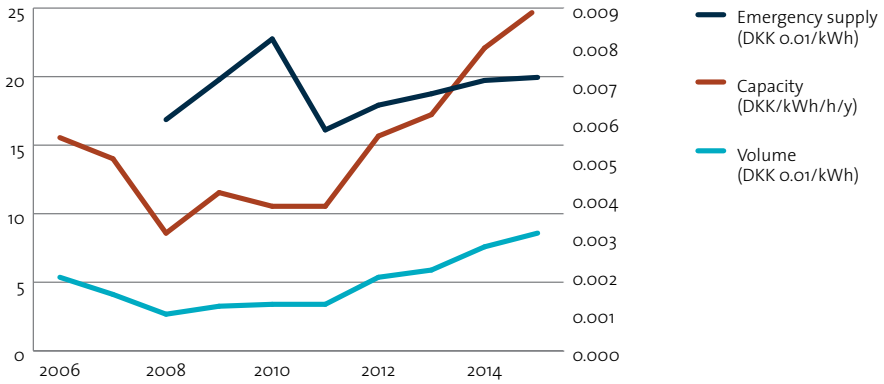


Figure 1-2: The figure shows the development in tariffs since 2006 and the expected development until 2014. The unit used on the left axis to show the capacity tariff is DKK/kWh/h/y. The unit used on the right axis to show the volume and emergency supply tariffs is DKK 0.01/kWh.

Energinet.dk has therefore decided to launch a project in cooperation with the Danish Energy Agency, which is to map the extent of the changes required in the handling of the emergency supply task. The project will involve the market players in the process.

## 1.5 Tariffs

### 1.5.1 Background

The tariff method currently used by Energinet.dk in the gas transmission field has existed since 2004 and is based on the following basic principles:

- Break-even principle – ie Energinet.dk does not earn a profit on the tariffs and therefore only seeks to have its total costs covered through tariffs
- Uniform tariffs – identical tariffs at each entry and exit point
- Uniform, straight-line depreciation within asset categories (pipes, meter and regulator stations, etc.)
- Main emphasis on capacity payment (75% capacity payment and 25% volume-dependent payment)
- Relatively higher price of short-term products (less than one year) than of long-term capacity products.

Since 2004, various adjustments have been made to the applicable method, impacting the level of the tariffs, while the basic principles have remained unchanged.

As can be seen from Figure 1-2, the capacity and volume tariff dropped significantly in 2008 due to a change in corporation tax, thereby generating significant excess revenue which Energinet.dk is still paying back to the customers. Tariffs are expected to increase in the coming years as the volumes which are transported through the system and to which the expenses must be allocated are falling. The emergency supply tariff fell markedly in 2010 due to lower expenses, but is also expected to rise in the coming years on account of dropping volumes.

The Danish gas market has developed significantly since the market liberalisation in 2004. Integration with the northern European market has increased, and the nature of gas consumption in Denmark and Sweden has changed. There may therefore be a need for a general update of the applicable method, which is made more pressing by the fact that the supply situation will be changing over the coming years. Denmark will go from being a net exporter of gas to being a net importer, and the Ellund-Egtved expansion will entail new investments which will have a major impact on the cost base.

The process behind the application for the Ellund-Egtved expansion required that a decision be made specifically on the uniform tariffs principle.

In January 2010, Energinet.dk thus announced the principles of how the costs of the Ellund-Egtved expansion will be included in the tariffs in the future. These principles entail a partial departure from uniform tariffs as differentiated tariffs will come to apply in the individual points based on a distribution of costs for new and future installations. The differentiation will not be realised until the expansion investment has been implemented and the plants have been commissioned, which is expected to take place in October 2013.

### 1.5.2 Tariff project 2010

The principles announced involve changing the existing tariff method, and Energinet.dk has therefore decided to conduct a general 'overhaul' of the existing tariff model with a view to adapting the method to the new market and supply terms.

The work is organised as an internal Energinet.dk project, Tariff Project 2010, but the project is being executed in close dialogue with the Danish Energy

Regulatory Authority and the market players. The following issues will be dealt with in the project:

- Implementation and specification of new principles concerning the allocation of costs related to new investments
- Handling of the existing cost base
- Depreciation – useful lives
- Distribution between capacity and volume-dependent payment
- Pricing of short-term products.

### 1.5.3 Assessment criteria

A possible change of method in respect of the issues selected will be based on the following criteria:

- The change must comply with the legislative framework or fall within a development in legislation expected to be implemented shortly
- The change must support/improve the socioeconomic objectives of efficiency:
  - Efficient capacity utilisation, including competitive tariffs compared with competing pipelines
  - Efficient market with low access barriers and minimal transaction costs
  - Overall climate and energy policies, including the promotion of renewable energy by supporting gas-fired electricity generation as regulating power
- The change must be in line with the practice followed by the neighbouring countries (and general development trends), in the EU in general and internationally.

## 1.6 Optimising technical capacities in the transmission system

This section describes the issues in relation to the further development of models for calculating and optimising capacities in the Danish transmission system. The description comprises both technical and commercial aspects. The purpose of the developed model is to be able to optimise and maximise the technical capacity in an interconnected system between Denmark, Sweden, northern Germany, and via Link4Hubs, the Netherlands.

### 1.6.1 Background

European regulators require non-discriminatory calculation of capacities at border points. In this context, central 'high-priority' capacity issues have been defined which the TSO must respect:

- Transparency – the TSO should make all capacity available
- Consistency – the capacities must be calculated in a consistent manner, both over time and in all parts of the network
- Capacity maximisation – the capacities must be calculated under all conditions in the system and using all available tools.

Calculating the capacities in the transmission network is a complex task as there are several limitations and uncertainties which are difficult to define. The maximum technical capacity varies in relation to both time and transport distance and as a result of fluctuations in consumption, storage operation factors, etc. A basic method for determining the technical capacity is the worst-case scenario, which provides a conservative assessment of the capacity.

Since the deregulation, Energinet.dk has had to extrapolate network loads depending on infrastructure and operating conditions due to limited knowledge of the shipper's decisions. The challenge for the shipper is to decide how much gas to take in from the various entry points, which access model to use, and how much gas to allocate to the different customer types. This challenge is called load dispatching. The gas flow in the network will depend on consump-

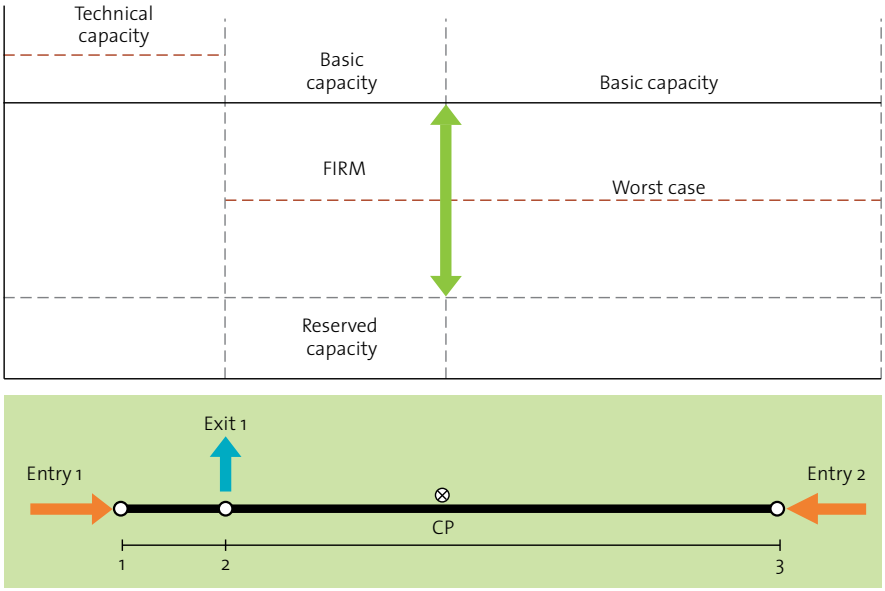


Figure 1-3: Graphic illustration of the segmentation method.

tion and price fluctuations, which leads to uncertainty when calculating capacities. The existence of long-term and spot markets further complicates this issue, as the price signals may have a large impact on where the gas in a specific situation comes from and to where it flows. Generally speaking, all commercial factors are difficult to forecast.

## 1.6.2 Screening of the new capacity optimisation methods

There are several methods and possibilities available for optimising capacities in the transmission network depending on the complexity of the model applied and the boundary conditions for the system such as size, number of operators in the system, the network access model used, etc. Energinet.dk is working on developing two different methods, one of which is a segmentation method and the other a more sophisticated mathematical forecasting model.

## 1.6.3 Segmentation method and capacity recalculation

The segmentation method opens up for optimised and consistent calculation of capacities in the system. The method is based on a breakdown of the transmission network into homogenous segments (subsystems) using a central point. This means that all existing offtake points are replaced by a central virtual point, 'CP'. In the next step, the basic capacities are calculated for each of the homogenous segments using hydraulic simulation. Capacity calculation in the modified system is simple, transparent and consistent. A further advantage of the segmentation method is enhanced maximum technical capacity compared with the worst-case method. The drawbacks of this method are that considerable efforts may be required to determine the operating parameters for a large number of segments and a risk of overrating the capacities.

The segmentation method is useful in connection with a recalculation of the capacities in the network in relation to time. Basic capacities are updated automatically after each order or at regular intervals. The solution involving regular updating can guarantee higher transparency, while the automated solution can lead to improved capacity optimisation.

Figure 1-3 illustrates the principle of this method. Based on the original asymmetric load, two different technical capacities are obtained (red dotted lines). To avoid capacity assessment on the basis of the worst-case method, the TSO can, by using the segmentation method, determine a virtual offtake point (CP) precisely in the middle between the two distribution points entry 1 and entry 2. As concerns the virtual point, two symmetric basic sections are obtained where capacity calculations are simple.

The topology for Energinet.dk's transmission system is well suited for the segmentation method, where the virtual central offtake point will be situated in Egtved. The hydraulic calculations are performed using Pipeline Studio or SIMONE. The method also requires development of a capacity management tool (in the form of an Excel spreadsheet, for example) to keep track of recalculations and capacity updating according to orders made.

**Forecasting model**

The gas market is not static and deterministic, but is determined by the uncertainties originating from typical stochastic parameters such as consumption and price fluctuations. A good forecasting tool therefore constitutes the key to maximising capacity in the transmission system. This model is based on the use of sophisticated mathematical tools for improving the

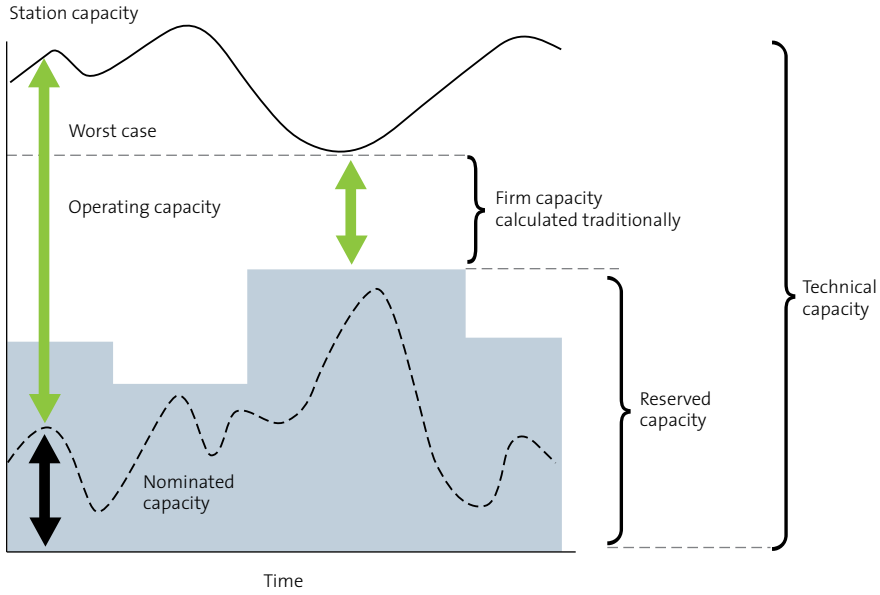


Figure 1-4: Definition of operating options.

forecasting of flow distribution in the gas network. Model development is based on operating options which oblige the shipper to guarantee a gas flow at a specified point, at a specified time, in a specified direction, at a specified rate and for a specified period of time.

In this solution, the TSO will follow the shipper's thinking, which is done by implementing the shipper's supply portfolio and the TSO's transport optimisation into a joint cost function. The result could be a forecast of the flow in the network which can be compared with the situation prior to gas market deregulation. The concept is thus based on a combination of the financial and hydraulic models:

- In the financial model, the shipper's supply challenge is solved, ie load dispatching
- In the hydraulic model, the physical flow in the network is optimised, and a hydraulic check of the shipper's orders is performed.

The model can calculate/optimise capacities in entry/exit systems at nomination level for a specific period of time. Figure 1-4 illustrates the capacities and the operation-dependent capacity forming the basis of the development of operating options. Operating capacity exceeds firm capacity and changes along with changes to nominated and technical capacity in a stochastic manner. The difference between operating capacity and firm capacity, determined on the basis of the worst-case scenario, forms the potential for capacity maximisation in the natural gas network.

The forecasting model is expected to always optimise the absolute maximum technical capacity at the given entry/exit station and for the given period of time under the current operating conditions.

In terms of development, a number of simplifications will be implemented initially in respect of gas price modelling, transport tariffs, consumer segments and gas storage facilities.

The tool for this will typically be an optimisation generator. A multiple-step stochastic program is proposed in respect of this issue, which the TSOs can use to forecast the shippers' potential flow scenarios in the long and short term. The model offers virtual integration of the overall planning tasks for the TSO and the shipper, by means of which the TSO seeks to predict the shippers' decisions. Technically, it is a flow forecast prepared on the basis of operating options.

## 1.7 More biogas in Denmark

### 1.7.1 About biogas

The production and use of biogas provides a number of climate and environmental benefits. An example of a very significant environmental benefit is the improved control of nutrients obtained when degassing liquid manure, which reduces the leaching of nitrate and phosphorus to the benefit of the aquatic environment. Degassing liquid manure also reduces odour nuisances, and the evaporation of ammonia is reduced considerably.

Both the production and consumption sides contribute to benefiting the climate. The production of biogas reduces the emission of the powerful greenhouse gases methane and dinitrogen oxide as they would otherwise be released to the atmosphere by organic degradation of untreated liquid manure in the fields. In itself, this benefits the climate considerably. The consumption of biogas further reduces emissions as biogas replaces fossil fuels elsewhere. Biogas provides, in other words, a number of climate and environmental benefits, and there is thus broad political consensus for significantly increasing the production of biogas in Denmark.

| | Farmyard manure | Meadow grass | Energy crops | Catch crops | Total |
|---|---|---|---|---|---|
| Capital Region of Denmark | 11,817 | 3,614 | 39,967 | 13,675 | 69,072 |
| Central Denmark Region | 179,290 | 22,990 | 317,461 | 108,622 | 628,363 |
| North Denmark Region | 120,193 | 21,410 | 190,467 | 65,170 | 397,239 |
| Region Zealand | 43,083 | 9,853 | 212,929 | 72,855 | 338,720 |
| Region Southern Denmark | 192,182 | 21,636 | 302,357 | 103,454 | 619,629 |
| **All of Denmark, 1,000 m³ of natural gas** | **546,564** | **79,503** | **1,063,182** | **363,775** | **2,053,024** |
| All of Denmark, PJ | 22 | 3 | 42 | 14 | 81 |

Table 1.1: Biogas potential from the agricultural sector in Denmark. The statement was prepared at municipality level.

**Biogas potential in Denmark**
Energinet.dk has had a calculation prepared of the potential for biogas production from the agricultural sector in Denmark. The calculation is distributed on the potential from farmyard manure, meadow grass from low-lying soils, catch crops and energy crops. The calculation is based on the assumption that it is possible to use 75% of farmyard manure and 15% of the areas under grain for energy production.

According to the most recent energy projection made by the Danish Energy Agency, biogas production in Denmark is expected to increase from the current level of just below 4 PJ (corresponding to approximately 100 million m³ of gas) to 17.8 PJ in 2020. This corresponds to around 10% of current natural gas consumption of around 4 billion m³. Gas consumption is, however, expected to see a decline in the coming years (see section 5.2), and biogas may thus end up accounting for a relatively larger share of gas consumption.

In Sweden, E.ON Sverige and the Swedish Gas Association estimate the potential to be 120-160 PJ (corresponding to 3-4 billion m³ of gas) around 2040-50. In comparison, Swedish gas consumption currently totals approximately 1.5 billion m³. In Sweden, biogas is produced mainly from sludge and waste, while most of the potential by far is based on expectations of thermal gasification of wood.

## 1.7.2 Use of biogas in Denmark

So far, focus in Denmark has been on biogas in CHP production, which has been subsidised by an exemption from duties on biogas-produced heat and a subsidy of approximately DKK 0.40 per kWh of electricity generated. The stipulation for both subsidies and the duty exemption is the direct infeed of biogas from the biogas producer for electricity generation in dedicated biogas pipes. Direct infeed of biogas is an advantage because it is not necessary to upgrade the biogas, ie remove $CO_2$ from the biogas, which is required when injecting biogas into the gas network. The energy consumption for upgrading corresponds to 2-5% of the energy content of the biogas, depending on the upgrading technology applied. An alternative to upgrading could be to downgrade selected parts of the distribution network to a gas quality similar to that of raw biogas. In 2008, the Danish Gas Technology Centre conducted a case study of this possible solution. The study pointed to a number of technological challenges related to the downgrading solution, which will have an adverse socioeconomic impact, the most important being that the capacity of the gas network will decrease by approximately 40%, and that all gas-consuming installations in the area must either be adjusted or replaced. Moreover, there are currently no commercially available biogas-fired single-family house boilers which comply with the requirements of the Danish Building Regulations.

Local electricity generation, for which biogas is consumed today, takes place chiefly in local CHP plants. Major Danish biogas plants typically sell the biogas through local biogas pipelines to a nearby local CHP plant generating electricity and district heating, to the extent that a local district heating infrastructure is in place. Small biogas plants are typically connected to an engine which generates electricity with no or limited exploitation of the waste heat.

In Denmark, biogas is mainly produced from liquid manure, and thus in particular in the western part of the country where livestock density is high. Energy consumption is concentrated in the densely populated areas in eastern Denmark, however, which means that there is a need to move the energy

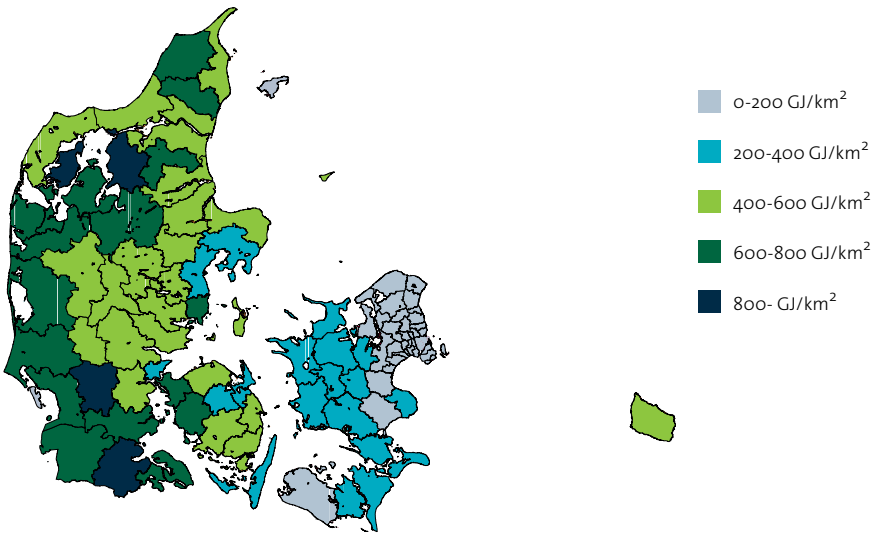


Figure 1-5: Biogas potential from farmyard manure per unit area by municipality.

eastwards. This currently takes place solely via local electricity generation and use of the electricity infrastructure. Biogas plants generally have a relatively steady production profile over the year, which means that the existing biogas plants, at most, produce 15-20% more in winter than in summer. It is possible to seasonally adjust production further, but for the sake of the operating economy, biogas plants will still maintain considerable production in summer. Seasonally adjusted biogas production also requires access to storage-stable biomasses. Energy crops have a major potential for storage-stable biomass, but is more expensive to purchase than the waste-based biomass types mainly used today.

Energy consumption at the local CHP plants – and thus the demand for biogas – is far higher in winter where there is a great need for district heating. As the local CHP plant is typically the only customer to which the biogas plant is connected, it should preferably be able to purchase the biogas produced irrespective of the demand for heating.

The relatively constant amount of biogas results in the CHP plants generating electricity and heating all year round, although they are often unable to sell the entire heating production in summer, thus resulting in lower biogas efficiency and a corresponding reduction in the value of the biogas for the local CHP plant. As appears from Figure 1-6, the heat loss increases along with an increase in the share of biogas at the local CHP plant. The fall in energy efficiency is attributable to the fact that the power stations which purchase the biogas also purchase it in summer even though the need for district heating is smaller, which means that heat must be cooled away.

The problem with lack of flexibility related to direct delivery of biogas will be exacerbated by the future, very strict requirements for the flexibility of the power system as a consequence of considerable wind power expansion. Increased biogas production resulting in increased inflexible power generation will thus become a drawback in the power system.

Seasonal adjustments and short-term storage facilities for biogas will increase flexibility between production and consumption of biogas. Full flexibility will only be achieved by upgrading and injecting the biogas into the gas network. The gas network has the possibility of carrying out seasonal adjustments via the two Danish gas storage facilities, which offer storage services on market terms. Physically, biogas can thus function as base load in the local gas network, while the natural gas is stored or sold to other segments. Commercially, biogas can be sold to any gas consumer connected to the European gas network. This allows the biogas producer to exploit the demand from the gas system, its storage flexibility and trading options and the free access to customer segments displaying the greatest willingness to pay for the biogas.

In the initial years of upgrading, the biogas is expected to physically enter the distribution network where it will also be consumed. By locally displacing natural gas and trading in biogas certificates, it will be possible to sell the biogas commercially on gas exchanges or directly to any gas consumer connected to the European gas system. Via certificates, it will thus be possible for biogas to obtain the best possible price signals from all parts of the gas system, which, depending on demand, may contribute to increasing biogas production.

Physical, cross-country transport in the transmission system may become necessary if the biogas production approaches the minimum gas consumption (consumption on a warm summer's day) in the local distribution networks. This may result in a need to inject

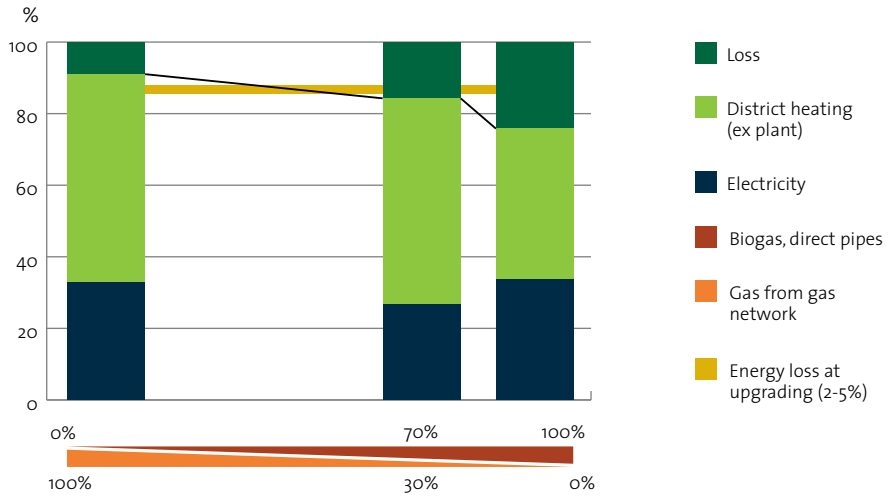


Figure 1-6: Statement of annual efficiency of biogas-fired local plants in Energiproducenttælling 2008 (*Energy Producer Count 2008*). The plants are sorted according to how large a share of their total fuel biogas accounts for. The reference in the left-hand column consists of natural gas-fired plants with an electrical capacity of 1 MW, corresponding to that of a typical biogas-fired local plant.

surplus biogas into the transmission system, which will entail additional costs for compression.

With the Green Growth (*Grøn Vækst*) agreement reached between the Danish Government and the Danish People's Party (*Dansk Folkeparti*), efforts are being made to ensure equal treatment of biogas in terms of subsidies, irrespective of whether this is used directly at the CHP plants or is purchased from the gas network.

### 1.7.3 Local use versus upgrading

In 2010, Energinet conducted a socioeconomic analysis of local use of biogas compared with upgrading and resale in the gas network.

As expected, the main conclusion is that it is most efficient to use biogas locally, where there is a large need for district heating compared with biogas production. From a socioeconomic point of view, it is, however, more profitable to upgrade the part of the biogas which cannot be used for CHP if the need for district heating is small in relation to biogas production.

Industrial demand for biogas locally will reduce the share which should be upgraded from a socioeconomic point of view, while a possible increased willingness to pay for biogas in the gas network and/or in the transport sector will increase the share of the biogas production which can be upgraded for socioeconomic benefit.

Local use for CHP generation will be reduced concurrently with increasing biogas production and a decreasing demand for heat. If a constantly growing share of the biogas potential in Denmark is exploited in the long term, the need for upgrading will increase.

### 1.7.4 Status of the market model

A large number of players in the Danish biogas sector today would like to be able to trade biogas via the gas network. So far, Energinet.dk's work, in cooperation with the gas distribution companies, has resulted in the development of a biogas market model which will make it possible for a biogas plant to sell upgraded biogas in the gas market.

### 1.7.5 Status of biogas quality

After upgrading (ie after removal of $CO_2$), the biogas consists of almost pure biomethane, which means that the properties are somewhat different to those of natural gas, which, in addition to methane, contains more heavier hydrocarbons. After having experienced a stable Danish gas quality for many years, authorities, gas infrastructure companies and other players are now cooperating on this technical challenge. Cooperation on more flexible gas specifications is also required as a result of the increasing European harmonisation and physical import of gas from Germany initiated in October 2010, see section 1.3. It is therefore expected that rules, measuring systems and settlement procedures, also without biogas, need to be adjusted in the coming years. The need for any addition of the propane present in natural gas produced in Denmark will also be assessed in this context. According to preliminary indications from the first Danish project involving biogas in the gas network in Fredericia, there will be no need to add propane here. The same applies to biogas injected into the gas network in Germany and Sweden.

Requirements for the gas quality of upgraded biogas are being prepared by the Danish Safety Technology Authority. Energinet.dk, the distribution companies and the Danish Gas Technology Centre have participated in a reference group with the Danish Safety Technology Au-

thority. Expectations are that the upgraded biogas will be required to comply with the Danish Gas Regulation as such and that additional requirements will be made for the content of ammonia, oxygen, etc., based on similar requirements in our neighbouring countries. The requirements are expected to be implemented by the end of 2010. The requirements for settlement of natural gas networks with biogas added are the same as for networks with natural gas only.

## 1.7.6 Status of biogas documentation scheme

The strong focus on renewable energy, $CO_2$ emission allowances and the environment is making biogas into a good commercial product, not only in Denmark but worldwide. Biogas producers and the consumer segments demanding biogas therefore have an interest in the possibility of tracking and trading biogas as a particularly environmentally and climate-friendly product in the gas system. In recent years, focus has therefore shifted increasingly towards a biogas documentation scheme.

A biogas documentation scheme will have no impact on the granting of funding for biogas; neither in the form of subsidies nor tax exemptions for producers, traders or consumers. The purpose of the documentation scheme is to provide the market players with the option of documenting the origin of the biogas in the commercial gas trade via certificates like those known from the electricity market. This will enable the biogas producer to transfer the green identity of the gas to the gas consumers, thus giving the biogas producer the chance to earn the added value that some consumers may be willing to pay extra for certified biogas.

Energinet.dk has set an objective of being able to issue biogas certificates in the course of 2011. In addition, Energinet.dk is cooperating with several European players which have either introduced or are contemplating introducing biogas certificates in their home countries. This cooperation aims to identify the possibility of setting up a European certificate system which, in the long term, will make it possible to trade biogas certificates between countries.

## 1.7.7 Biogas for shipping

The Danish Environmental Protection Agency is confident that gas for shipping[5] offers significant perspectives, and gas for land transport is already playing a considerable role in many neighbouring countries. It is thus expected that relatively large volumes of oil for, in particular, sea transport quickly and efficiently can be converted to energy gas[6].

Energinet.dk is a partner in a European project idea focusing on the use of LNG[7] for sea transport. The project, which stems from the EU's Baltic Sea strategy, is coordinated by the Danish Maritime Authority. LNG can also be based on biogas and is then called LBG. Switching from heavy fuel oil to energy gas will result in major reductions in sulphur and nitrogen emissions from shipping as well as a considerable $CO_2$ reduction. In addition, LNG plants will, potentially, be able to contribute to security of supply in the Danish gas network and may also increase competition in the Danish gas market. There may be synergies between gas for maritime traffic and gas for land transport. The project will examine this synergy in more detail.

[5] 'Natural gas for ship propulsion in Denmark', Danish Environmental Protection Agency, October 2010.

[6] The term 'energy gas' is used about methane irrespective of whether in liquefied or gaseous form and whether it is fossil (natural gas) or based on anaerobically digested organic matter (biogas) or thermally gasified biological material (gasification gas) or produced through electrolysis.

[7] LNG is natural gas which has been condensed into a liquid by cooling it to -163° C.

The technology for gas-based transport solutions exists in the market today. If the initial focus is on fleet vehicles, a major roll-out of new nationwide infrastructure will not be necessary.

## 1.8 Non-fossil gas in 2050

### 1.8.1 Background

Natural gas is the most environmentally-friendly fossil fuel today, offering lower $CO_2$ emissions than other fossil fuels and very clean combustion without particles and with limited sulphur emissions. Historically, natural gas has therefore had a 'green' image compared with other fossil fuels. Today, all gas supplies to Denmark come from the Danish part of the North Sea, but we are currently preparing for the next decades when an increasing share of gas supplies will be covered by gas from abroad.

In the long term, the Danish Government has a vision of Denmark being completely independent of fossil fuels. The Government therefore appointed the Danish Commission on Climate Change Policy, which, in September 2010, presented proposals on how to obtain an energy supply system without fossil fuels before 2050.

Energinet.dk is contributing actively in several areas with a number of analyses of the energy system of the future and has prepared four proposals for a future with a $CO_2$-neutral energy sector in 2050, see the report 'Energy 2050 – Development tracks for the energy system' (*Udviklingsspor for energisystemet frem til 2050*). The report describes two tracks offering fossil fuel independence where wind power and biomass, respectively, make up the bulk of the supplies. The report also describes two $CO_2$-neutral tracks where CCS (depositing $CO_2$ from flue gas) and the purchase of emission allowances from abroad create $CO_2$ neutrality.

The analysis of the four tracks shows that gas will still play an important role in the energy supply although it must be $CO_2$ neutral or independent of fossil fuels.

If the main focus is on $CO_2$-neutral energy supplies, natural gas may continue to play a role in our energy supply. If the main focus is on achieving fossil fuel independence, the role of gas may change significantly. In the wind power track and the biomass track, the role of the gas is to integrate renewable energy. In a future energy system independent of fossil fuels, there will be a large need for handling fluctuating electricity generation, and the gas system offers clear advantages in respect of this task.

In this context, gas means methane gas as we know it from the main component of natural gas, but also hydrogen and synthesis gas are comprised by the gas concept applied here, whether or not the origin is fossil or based on renewable energy. In addition to contributing to reducing $CO_2$ emissions and balancing the power system, increased production of renewable energy gas will also mean an increase in Danish self-sufficiency.

### 1.8.2 Role of gas in a future energy system independent of fossil fuels

**Value chain – from renewable energy resource to energy services**

The gas system can contribute to meeting the major challenge of integrating substantial amounts of renewable energy. Basically, this concerns the creation of a connecting link between renewable energy resources and consumer needs for energy services, see Figure 1-7, which, in highly simplified form, illustrates the value chain of the energy system.

Direct use of electricity from wind power at the time it is generated is the most

efficient in an energy system with large amounts of wind power, but energy consumption does not follow wind power generation. Wind power is not stable either, and the use of electricity is not expedient in connection with certain types of energy consumption. Finally, significant amounts of renewable energy resources are based on biomass, which is not supplied directly as electricity as is the case with wind power and photovoltaic cells.

Being able to utilise the other 'energy systems' with their specific strengths is therefore important. Electricity, gas and district heating can be seen as a trio of energy carriers which, with their highly different properties and strengths, together can rise to the significant challenge of creating an energy system independent of fossil fuels.

**From renewable energy resource to renewable energy gas**

In Denmark, the really heavy renewable resources are wind power and, to a lesser extent, biomass, waste, solar energy and geothermics. As a fuel, gas is an energy form into which most renewable energy resources can be converted. Biogas production is a well-known technology, and thermal gasification of biomass is also a known and existing technology. Electrolysis of electricity into hydrogen is a well-known process, and new processes for the production of synthesis gas using electrolysis are being developed and also tested in practice at some locations. Electrolysis involving new types of fuel cells (SOEC) where $CO_2$ is added to the water vapour enables the production of synthesis gas which can be converted into methane.

Despite the fact that many of the processes are well-known, they still need to be developed further and adapted in order to fit like building blocks in an overall future energy system independent of fossil fuels.

**Transport and storage of renewable energy gas**

As concerns transport and storage, gas is extremely efficient. As opposed to electricity and heat, gas is a fuel which, at relatively low cost, can be stored in very large amounts over a long period of time. This property is important if a large part of energy supplies are to be based on fluctuating wind power.

Energinet.dk has analysed the amounts of energy which can be stored in connection with different system solutions. Figure 1-8 illustrates the amounts of energy stored if there are 1 million electric vehicles, 0.3 million individual heat pumps, energy storage in the district heating system as we know it today and when using the existing gas storage facilities in Lille Torup and Stenlille. Finally, an example is shown of energy storage if the district heating system is expanded with a large seasonal heat storage facility so that 10% of annual consumption can be stored.

Electric vehicles and heat pumps are effective tools for creating flexibility for days and possibly weeks if the district heating system is expanded with dedicated heat storage facilities. Compared with the storage capacity of the existing gas storage facilities, however, the energy content is modest.

The cost of the storage part itself in an expanded heat storage facility is expected to remain significantly higher than the cost of the storage part of a gas storage facility[8]. Moreover, the heat from a heat storage facility cannot be effectively converted back into other forms of energy, but can in practice only be used for heating purposes.

[8] It typically costs DKK 3-5 per kWh to establish a heat storage facility, while the establishment of the storage part of a gas storage facility, excluding conversion, costs less than DKK 0.5 per kWh.

The transport and distribution of gas is competitive with other types of energy transport if an infrastructure has already been established, as is the case in Denmark. This means that large amounts of energy and capacity can be transported at low cost with limited losses of energy.

Natural gas consists almost of pure methane gas. In connection with a future use of the gas infrastructure, one of the key issues will be whether other types of gas can be handled (eg hydrogen and synthesis gas) in the gas network. It is technically feasible to convert hydrogen along with synthesis gas into methane, but the conversion involves loss of energy released in the form of heat. This heat may be used for district heating or process heating. As an alternative to upgrading to methane, hydrogen can be fed directly into the gas network.

Preliminary findings of analyses conducted by the Danish Gas Technology Centre show that up to 30% hydrogen can be added to the natural gas network without degrading the steel in the pipes in the transmission network, but seals and valves, etc., will probably need to be upgraded to some extent. At the same time, capacity in the transport system will drop significantly as the energy content of hydrogen is considerably lower than that of methane. Furthermore, separating hydrogen from the rest of the gas when it is to be used is energy consuming, and it will therefore be a demanding task to achieve efficient utilisation of the energy in the hydrogen. It is thus not likely that pursuing this solution is relevant.

The assessment of the pros and cons of upgrading gas to methane quality versus upgrading the gas network to handle hydrogen must take place over the coming years. There is no doubt, however, that the gas system offers a huge potential for constituting an effective storage for fluctuating renewable energy sources.

**From renewable energy gas to energy service**

In connection with end consumption, the energy product is converted into an energy service. As gas is a very clean and easy-to-handle fuel, it is particularly well suited for a number of purposes, including:

- **Peak-load power generation.** Concurrently with increasing wind power generation, there will be an increasing number of hours with very low electricity prices. Analyses of the power system towards 2050 show that electricity generation at base-load power stations as we know them today with 5,000-8,000 operating hours per year will not play as large a role in an energy system with large amounts of wind power. A wind power-based system will instead require a number of power stations which can supply electricity for the number of hours each year when there is insufficient wind power and other fluctuating renewable energy. In this context, gas is very competitive with other fuels as it can be used in gas turbine plants, etc., which are far cheaper to establish for peak-load generation than biomass power stations. In the long term, gas fuel cells are also expected to be competitive for peak-load power generation[9]. Fuel cells offer the further advantage that they can be placed in small units, eg in local CHP plants or possibly as mini/micro-CHP.
- **Supply of energy to direct fuel-based processes in the industrial and services sectors.** A number of processes in the industrial and services sectors requiring high process temperatures and an easy-to-handle, environmentally friendly fuel could, from a socioeconomic perspective, advantageously be based on renewable energy gas, par-

[9] Technology Data for Energy Plants. Danish Energy Agency and Energinet.dk, June 2010.

ticularly in those parts of the country which have an established gas infrastructure. Alternatives involving liquid biofuel will be relatively more costly with regard to conversion loss, generation and distribution.

- **Transport sector.** In a number of fields in the transport sector, gas will constitute a good alternative to, for example, battery supply (electric vehicles). From a socioeconomic viewpoint, gas will in many situations, particularly for long-distance transport and heavy transport, constitute the cheapest renewable energy alternative to gasoline and diesel, see the report 'Supplementary analyses, alternative propellants in the transport sector, Danish Energy Agency, 2010' (*Supplerende analyser, alternative drivmidler til transportsektoren,* ENS 2010). Gas can also be a competitive and environmentally friendly fuel for sea transport, including especially in relation to bunker fuel and regular short-distance traffic in sensitive areas such as, for example, internal Danish waters and the Baltic Sea. Gas is thus already being utilised in parts of the Norwegian domestic sea transport, and the Danish ferry company Mols-Linien and several other ferry companies operating routes in the Baltic states are looking into the possibilities of switching to gas.

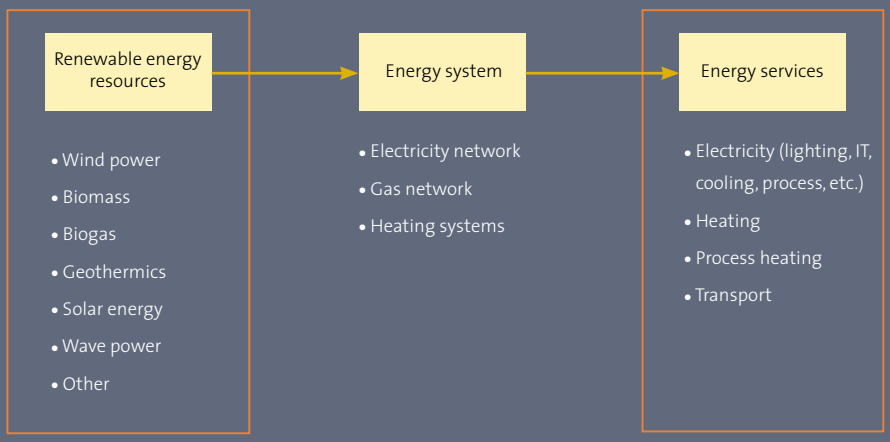


Figure 1-7: Value chain of an energy system based on renewable energy – from resource to energy service.

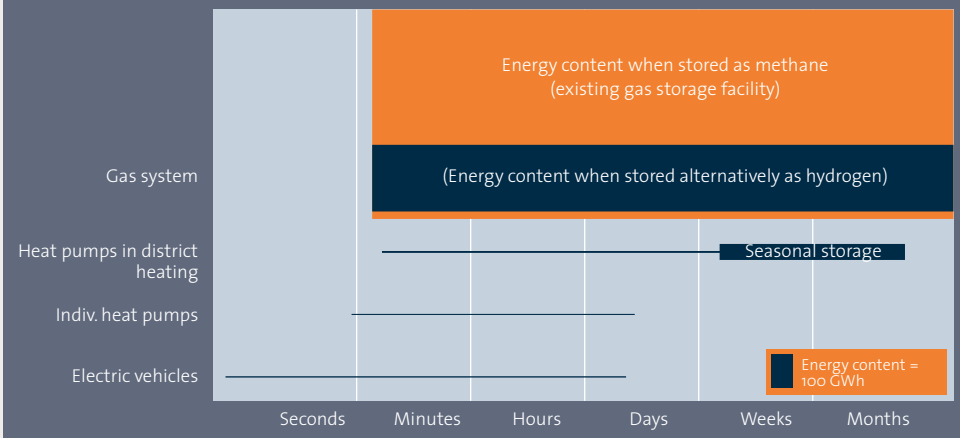


Figure 1-8: Energy content (electricity input) of different storage types in the energy system. The orange areas show the size of the potential energy storage. For gas, the small black box indicates the content if the gas is stored as hydrogen rather than methane.

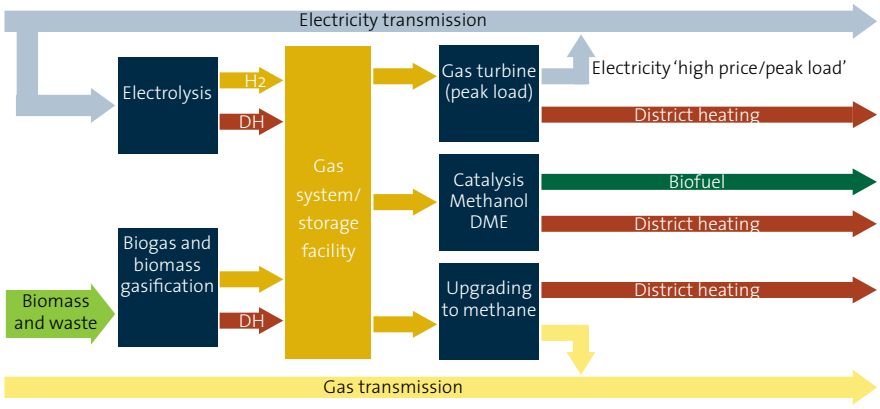


Figure 1-9: Principle diagram of gas infrastructure elements towards 2050.

- **Fuels for fuel cells in general.** It is assumed that the price of fuel cells will drop very markedly towards 2025, while such cells offer high energy efficiency. Fuel cells are expected to play a key role in the energy system of the future, both for stationary applications and in the transport sector. All types of fuel cells require a fuel with very high hydrogen content. Apart from pure hydrogen, methane gas is one of the most suitable fuels for fuel cells (HTPEM and SOFC). Alternatives involving methanol or DME are also extremely suitable for fuel cells. The production of fuel for these cells will typically take place using a form of gas as part of the process. Gas can thus ensure flexibility in the future supply of fuel cells, whether or not the fuel is methane, hydrogen, methanol, DME, etc.
- **Materials for the petrochemical industry.** Today, oil and natural gas are important resources as raw materials for the petrochemical industry, packaging, etc. In view of the increasing demand for raw materials based on renewable energy for this industry, renewable energy gas may prove an effective medium in the long term.

In addition to these end-uses, gas has a number of additional strengths in respect of establishing flexibility and security of supply in an energy system independent of fossil fuels. The supply of gas (as is the case with the power system) may be based on a combination of both imported gas, fossil-based production and renewable energy-based production.

Environmentally clean energy supplies are expected to receive increasing attention. Over the last few decades, increasing focus has been placed on local emissions of $SO_2$, $NO_x$, VOC[10] and particles and noise. Electricity and district heating do not give off local air emissions when used, but to the extent that a combustion process is required locally at the consumption site, gas is the fuel-based energy form which offers the cleanest combustion in connection with end-use. This applies in particular to the use of the gas in fuel cells.

## 1.8.3 Example of gas supply in 2050 in Energinet.dk's wind power track

Energinet.dk's wind power track in 2050 illustrates a scenario where gas consumption is adapted to the tasks within which gas has its long-term strong position in an energy system independent of fossil fuels. At the same time, gas production is gradually converted from natural gas supplies mainly produced in Denmark to the production of renewable energy gases in 2050.

In the wind power track, the Danish gas infrastructure is a part of the international gas infrastructure to ensure that an international market and a high level of security of supply are maintained. A principle diagram of the infrastructure and processes is shown in Figure 1-9.

Figure 1-9 shows central processes involved in renewable energy-based gas supply. Both the gas and electricity infrastructures remain part of an international energy system. The gas consumption and production process is outlined in Figure 1-10.

Figure 1-10 shows the consumption and production until 2050. In the period 2030-2050, there will be annual gas imports of up to 50 PJ (corresponding to approximately 1.3 billion $m^3$) until a fully developed renewable energy-based gas supply is available in 2050.

## 1.8.4 Roadmap and R&D

Developing an energy system so that the special strengths of the gas are reinforced in connection with a conver-

[10] Volatile Organic Components.

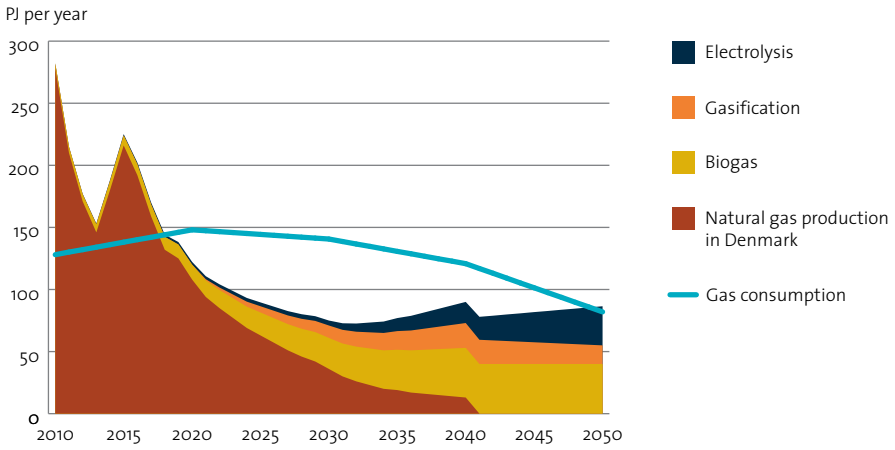


Figure 1-10: Production and consumption of gas until 2050 in Energinet.dk's development track (wind power track).

sion to fossil fuel independence requires a targeted focus on infrastructure and administrative frameworks as well as research and development.

The gas infrastructure was originally established to ensure efficient use of the Danish natural gas resources in the North Sea. Gas, however, is a socioeconomically cheap fuel and, even without Danish natural gas resources, the established gas infrastructure will still be able to contribute to Denmark saving DKK 2-5 billion per year compared with supplies from oil-based fuels. Natural gas can thus strengthen the socioeconomic aspects of the energy supply towards a future of fossil fuel independence.

It is important, however, to intensify efforts to reinforce the strengths of the gas in a future energy system with large amounts of wind power. Some of the central processes in the integration between renewable energy gas and the other parts of the energy system have (as was also the case for wind turbines) been known and used for more than a century, eg gasification, electrolysis and a number of catalytic gas reforming processes. However, there is a need to product develop and streamline the processes for large-scale use in order that they can continue fulfilling their role in the energy system of the future. Energinet.dk therefore recommends that the R&D efforts be maintained and strengthened. The same applies to the development of the frameworks in the following areas, among others:

- Strategic planning of the gas sector's role in an energy system independent of fossil fuels so that the long-term strengths of the gas are brought into play at national and international level
- Research and development in processes between the renewable energy resources, including both electrolysis, biogas processes and thermal gasification/pyrolysis
- Research, development and demonstration in respect of catalytic reforming of gases such as synthesis gas, hydrogen, methane and biofuel (methanol and DME) can be handled with minimal energy loss. Denmark is in a unique position in this field today, with Danish companies and research institutions playing a key role
- Development of fuel cells and fuel cell-based units for both stationary and mobile purposes. Danish companies and research institutions possess core competencies in the field
- Know-how on handling gases, both pure methane and other gas types (synthesis gas and hydrogen). The Danish Gas Technology Centre and others have technical core competencies within the field
- Development of frameworks for the gas infrastructure and the markets to ensure optimum interaction between the commercial activities and the TSO for the commercially operated plants supplying and consuming renewable energy gas.

In the short and medium term, the gas system offers a unique potential for contributing natural gas as an efficient and environmentally friendly energy source and, in the long term, for contributing to the efficient and safe integration of large amounts of renewable energy in effective interaction with more fluctuating renewable energy sources (wind power, solar energy and wave power). Read more in 'Perspectives on sustainable gas in Denmark, Energinet.dk 2010' (*Perspektiver omkring bæredygtig gas i Danmark*, Energinet.dk 2010).

## 1.9 Unconventional gas

New techniques such as horizontal drilling and hydraulic fracturing have made otherwise not very accessible unconventional gas resources from tight sands and from shale as well as coal-bed methane (CBM) accessible to energy companies at far lower costs than was

believed possible five years ago. In some cases, costs are now lower than in conventional projects.

In North America, unconventional gas is thus no longer unconventional, as almost 50% of US gas is produced from coal-bed methane, tight sands and shale.

The dramatic growth in unconventional gas production is driven by the declining production from traditional reservoirs and a desire to increase security of supply by producing gas from domestic sources. Other drivers include technological advances within drilling and completion.

Even though production from shale gas and CBM reservoirs in the USA and Canada accounts for a significant share of the North American market, no commercial breakthrough for similar projects in Europe has as yet been made. The International Energy Agency (IEA) estimates that Europe has reserves of unconventional gas for approximately 35 trillion $m^3$ of gas – enough to replace 40 years' gas imports at the existing level.

It is still early days for shale gas extraction in Europe, but several countries are examining the possibilities. Large international gas companies are already in the process of drilling for shale gas and have been granted a licence to explore for shale gas in Germany, Poland, Sweden and Denmark.

The Polish gas company PGNiG, for example, started collaborating with international companies in 2009 with a view to analysing the potential for unconventional gas in Poland. This analysis is still at a very early stage.

At present, it is thus very difficult to say anything about expected future volumes of unconventional resources and when they will be available to the market. Unconventional gas in Europe is currently surrounded by considerable uncertainty. When examining the shale gas possibilities, it is important to take account of the environmental impacts in the form of intensive water consumption and the risk of groundwater pollution.

A number of European countries, including the UK, Germany and Poland, exploit coal-bed methane. There is currently no reliable figures available for volumes, sources or the feasibility of the extraction potential.

The need for additional infrastructure depends to a large extent on the future development of the domestic production. It is unlikely that Europe will experience as rapid and comprehensive an introduction of unconventional gas as North America.

Gas consumers in Denmark can probably already today see the effect of the unconventional gas technology on the gas price. The strongly increased self-sufficiency in the USA has thus increased the global supply of LNG, which, due to the lack of the expected US demand, increases competition on the supply side in Europe and thus also in Denmark. Already now, unconventional gas seems to have contributed to the gas price being less and less linked to the oil price.

# 2. The Danish gas system

## 2.1 Infrastructure

The Danish gas transmission system consists of upstream pipelines in the Danish part of the North Sea and of onshore transmission pipelines.

The transmission pipelines go north-south (Aalborg-Ellund) and west-east (Nybro-Dragør), and the distribution pipelines are made up of a network of pipeline systems to the consumers. Moreover, the gas transmission system consists of a gas treatment plant (Nybro) and two underground gas storage facilities (Stenlille and Lille Torup), see Figure 2-1.

Natural gas from the Danish section of the North Sea is transported through two offshore pipelines from the Tyra and Syd Arne fields to the shore north of Esbjerg at a maximum pressure of 138 bar. In summer when less gas is consumed, the outlet pressure is reduced to minimise the energy consumption for compression. In winter, the pressure is increased to also ensure large volumes of linepack[11] (ie the gas volume stored in the actual gas pipelines) to be used in the event of supply disruptions and emergency situations.

On shore, the natural gas passes through a gas treatment plant in Nybro. Here, the quality of the gas is checked and measured, and pressure is reduced to the maximum pressure for land pipelines of 80 bar. The plant can also mix gas from the two offshore pipelines and reduce the content of impurities such as heavy hydrocarbons and hydrogen sulphide if necessary for the gas to comply with the agreed specifications. If the gas is to be cleaned, only reduced amounts can be supplied (about 50%).

From Nybro, the gas is sent to customers in Denmark and in other countries or for storage at one of two underground gas storage facilities. The storage facilities are typically filled up during the summer months when gas consumption is low. As the weather gets colder and consumption starts to exceed daily gas supplies from the North Sea, production is supplemented with gas from the storage facilities. In addition to making seasonal adjustments, trading in gas can influence exports and imports, and thus storage withdrawals and injections. In principle, the shippers' daily orders within the reserved capacity determine the hourly input/output from the system (the commercial system), while Energinet.dk is responsible for maintaining the physical system balance, for example by means of the storage facilities and linepack. Moreover, the storage facilities are used for emergency supply purposes.

Meter and regulator stations (M/R stations) have been established along the transmission pipelines for the purpose of supplying the local distribution networks. Their function is to filter and heat the gas to prevent it from becoming too cold during the next stage, reduce gas pressure to that of the distribution network, measure the gas flow through the station and add odorant to the gas. A total of 42 M/R stations and four specific metering stations have been established, all of which are owned by Energinet.dk.

From 2010, it became possible to physically import gas from Germany. In the spring of 2010, a number of changes were implemented to the German system south of the Danish-German border enabling a northbound flow. In principle, there are two different possibilities of a physical northbound flow in the Danish system, one of which is to reset the valves in Egtved so that

[11] At a given pressure, there is a certain volume of gas in the gas pipelines. If a lower pressure is acceptable, the gas volume in the pipelines must be smaller to maintain this pressure. The difference between the gas volume at the high and the low pressure is called linepack.

the section between Egtved and the Danish-German border is isolated in terms of pressure, as gas from Germany is supplied at a pressure of approximately 60 bar. This can be done without impacting the remaining Danish system. The offtake in southern Jutland is limited, however, and, in this situation, only limited volumes could be supplied from Germany to Denmark. The other alternative is to lower the pressure in the Danish system by up to approximately 10 bar to enable the German gas to pass through Egtved. This would open up for the supply of large volumes, but would only be possible at times when the pressure reduction in the Danish system is justifiable. The supplies would thus be on interruptible conditions.

## 2.2 Security of supply objective

Supplies to the Danish gas market are largely based on only one physical source of supply and one supply route (the Tyra-Nybro pipeline). If this source of supply is not available, Denmark will be faced with serious challenges in terms of contingency preparedness compared to many other countries that have several major sources of supply and routes. There is both a political desire and a wish from the TSO for security of supply. This also implies that, in practice, the emergency supply situations have dimensioned the entire transmission system and that it has been possible to supply all customers even in extremely cold weather.

As the entity responsible for security of supply, Energinet.dk must fulfil its emergency supply obligation in the Danish gas market. This means that Energinet.dk – in an emergency supply situation – will take over responsibility for supplying the Danish gas market from the market players. To this end, Energinet.dk purchases alternative transport capacity in the Syd Arne pipeline, reserves capacity in the storage facilities and enters into agreements on interruptibility with a number of major consumers. German and Swedish export customers can also receive gas in an emergency situation provided that they can make a similar volume of gas available from one of the storage facilities or in Nybro via Syd Arne.

Since the commissioning of the Danish gas system in 1984, there has been no serious damage to the transmission system, neither on the offshore pipelines nor the onshore facilities. However, on 8 November 2007, Energinet.dk activated its emergency supply preparedness and declared an emergency supply situation for storage customers and shippers as a consequence of the production stops caused by storms and unusually big waves at the North Sea fields. The emergency supply situation was called off after 28 hours.

Energinet.dk has two security of supply objectives for the Danish gas market which in combination dimension the reserve emergency preparedness level in emergency situations.

- One objective concerns short-term events with requirements being made as to how fast gas can be supplied from sources other than the North Sea. This objective places demand on, for example, the withdrawal capacity of the gas storage facilities
- The other objective concerns long-term events with requirements pertaining to the upkeep of physical supplies in case of longer-term interruptions of DONG Energy's Tyra-Nybro upstream pipeline in the North Sea. This objective involves requirements for the amount of gas that can be provided from alternative sources as well as for the amount of storage gas that must be available.

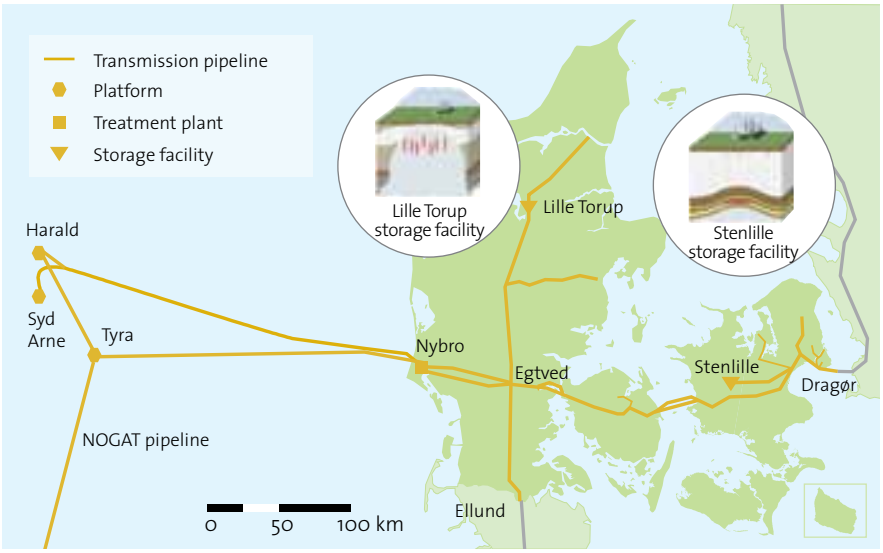


Figure 2-1: Main Danish gas infrastructure.

In March 2001, the overall security of supply objectives were reported to the Danish Energy Agency with the following dimensioning events for Energinet.dk's emergency supply preparedness:

- Short-term events: Under normal as well as abnormal supply conditions (complete interruption of supplies from the largest source of supply), Energinet.dk must have access to sufficient withdrawal capacity from the storage facilities to be able to maintain supplies to uninterruptible consumers in Denmark for three consecutive days at a daily mean temperature of down to -13° C (the 20-year event)
- Long-term events: Under abnormal supply conditions (complete interruption of supplies from the largest supplier), Energinet.dk must have sufficient volumes of gas to maintain supplies to consumers with uninterruptible supply in Denmark for up to approximately 60 days (corresponding to the expected repair time after the breakdown of an offshore pipeline) during a winter with 'normal' temperatures.

Energinet.dk's criteria for designing the transmission system also comprise winter situations with normal supply conditions without interruption of supplies. The security of supply objective for cold winter situations today is to have sufficient transmission capacity to handle the supply to all consumers in Denmark at a daily mean temperature of down to -13° C.

Energinet.dk's emergency supply concept is being reassessed in light of the expansion to Germany and the EU's planned emergency supply regulation, see section 1.4.

## 2.3 Security of supply nationally and locally

Security of gas supply generally includes the following factors, both in the short and in the long term:

1. Availability of gas, ie the availability of gas supplies (including gas from storage facilities) must be sufficient to meet Danish consumers' demand under normal as well as extreme weather conditions
2. Adequate network capacity, ie the gas network must have sufficient capacity to meet consumer demand under normal as well as extreme weather conditions
3. System integrity, ie the operational functionality of the system from production to consumer must be guaranteed.

The Danish Natural Gas Supply Act (*Lov om naturgasforsyning*) entrusts Energinet.dk, as TSO, with the responsibility for ensuring security of supply in the Danish gas market in parallel with its TSO responsibility.

As the only Danish TSO, Energinet.dk is responsible for the system integrity (3) of the Danish transmission system, ie the interaction between the 80-bar pipeline system and the adjacent systems.

Specifically, Energinet.dk is responsible for ensuring adequate network capacity in the gas transmission system (2), including transport capacity to and from the storage facilities and to the distribution systems via M/R stations.

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

Energinet.dk is not responsible for the availability of gas (1), except in emergency supply situations where Energinet.dk must ensure the availability of gas for the Danish market as necessary. The market players are responsible for the availability of gas, whereas Energinet.dk

is responsible for ensuring the required infrastructure to and from adjacent systems.

## 2.4 European and Danish gas markets

### 2.4.1 Europe

The market situation in Europe is still characterised by primarily national markets with national spot trading, but with significant and increasing cross-border trading binding these together and creating an often pronounced correlation between them. A proper and coherent spot market for gas in Europe is yet to be established. One reason for the lack of cross-border spot trading is general capacity shortages, especially at the border points, a lack of interoperability between the different national systems and as yet highly limited spot trading in several countries, including Denmark.

Most of the European countries are net importers of gas. Imports come primarily from Russia, Norway, Tunisia, Algeria and Morocco. A growing proportion of imports is LNG-based[12], but most of the gas reaches the European markets via pipelines. Domestic production is falling throughout Europe, while consumption and thus imports are on the rise and are expected to continue rising over the coming years. By 2030, the European Commission expects 80% of the EU's gas consumption to be covered by imports. Today, imports account for just over 50% of consumption, with approximately half of the gas imports coming from Russia and one-third from Norway. Biogas plays a small yet increasing role in quite a few EU member states, but has still to reach an extent which seriously affects security of supply.

The dependence on large supplies from one source through a number of countries gives rise to growing concerns that technical, commercial and political problems and disagreements will lead to situations with gas shortages in Europe and thus reduced security of supply.

The gas crisis in 2008 between Ukraine and Russia highlighted the risk of being dependent on Russian gas supplied via Ukraine, and it meant, among other things, that the European Commission accelerated the preparation of a security of supply regulation. See section 1.4.

A number of major infrastructure projects are currently being planned which are aimed at bringing more gas to Europe. New pipelines are thus being planned for example between northern Europe and Russia (North Stream) and between southern Europe and Russia/Caucasus (South Stream), the Middle East (Nabucco) and North Africa, respectively. Moreover, a number of LNG port facilities are being planned and designed in both southern and northern Europe.

At European level, work is taking place to strengthen compatibility between the systems in the individual countries. The aim is to increase the scope for exchanging gas between regional hubs and to solve the problems of cross-border interoperability. See section 1.1.

### 2.4.2 Denmark

The Danish gas market was fully liberalised in January 2004 to allow all consumers a free choice of gas supplier. Energinet.dk's role is to ensure an efficient and flexible gas market. This means, for instance, that Energinet.dk develops products and facilities that can be used by commercial players for gas trading. Gas market wholesalers (shippers) can:

- Conclude daily, weekly, monthly and annual contracts for transport capacity

12 Liquefied Natural Gas, cooled down to approximately -163° C and imported by ship.

- Trade gas on the gas exchange in Denmark, Nord Pool Gas. Here, shippers can trade anonymously as the gas exchange is the counterparty in all trades
- Conclude monthly balancing service agreements (right to imbalances between the within-day supplies and offtake)
- Order capacity and balancing services and keep abreast of own orders online via Energinet.dk's self-service portal
- Trade gas, capacity and balancing services bilaterally with each other via Energinet.dk's ownership transfer facilities: Gas Transfer Facility, Capacity Transfer Facility and Balance Transfer Facility. Shippers can meet and trade bilaterally via the electronic bulletin board.

In 2010, Energinet.dk introduced two major changes to the market model. The first major change was the introduction of the virtual cross-border point Link4Hubs, which is described in section 1.2.

The second major change was the introduction of a so-called BNG entry point. BNG, which is the abbreviation of bio natural gas, is described in further detail in section 1.7.

The market model for the Danish transmission system (the wholesale market) is designed as an entry-exit model, see Figure 2-2.

The market model consists of:
- Three entry points in Nybro, Ellund and Dragør where the gas enters Denmark commercially
- An exit zone where Danish consumers are supplied with gas by the gas suppliers via the distribution network. The exit zone is made up of four distribution areas, each with its own distribution company. The exit zone also has three large power stations (Avedøre 2, H.C. Ørsted Power Station and Skærbæk Power Station), which are directly connected to the transmission network. In addition, the distribution companies and Energinet.dk have designed the market model to also enable commercial biogas trading from the distribution systems to the transmission system when the first biogas producer is connected to one of the distribution systems
- Three transit exit points in Nybro, Ellund and Dragør, where natural gas can be exported from Denmark
- Two virtual gas trading points, the bilaterally agreement-based Gas Transfer Facility (GTF) and the multilateral gas exchange Nord Pool Gas Transfer Facility (NPTF) where shippers can trade natural gas with each other
- A virtual BNG entry point where (bio) gas is delivered virtually from the exit zone to the transmission network
- A virtual cross-border point – Link4Hubs
- Two physical storage points, ie the storage facilities in Stenlille and Lille Torup. Here, shippers that have purchased storage capacity can inject gas into and withdraw gas from the facilities.

A number of gas suppliers operate in the retail market from among which all gas consumers in Denmark have been able to choose freely since 1 January 2004. The number of changes of gas supplier is still not overwhelming, and it is in particular major gas consumers that have changed supplier, especially electricity and heating generators as well as major industrial consumers. In 2009, 3.2% of consumers with consumption corresponding to approximately 15% of the total volume thus changed gas supplier. In 2008, however, only approximately 0.5% of consumers changed supplier, but this represented a volume of around 17%. This may indicate that more small customers are changing supplier today than before.

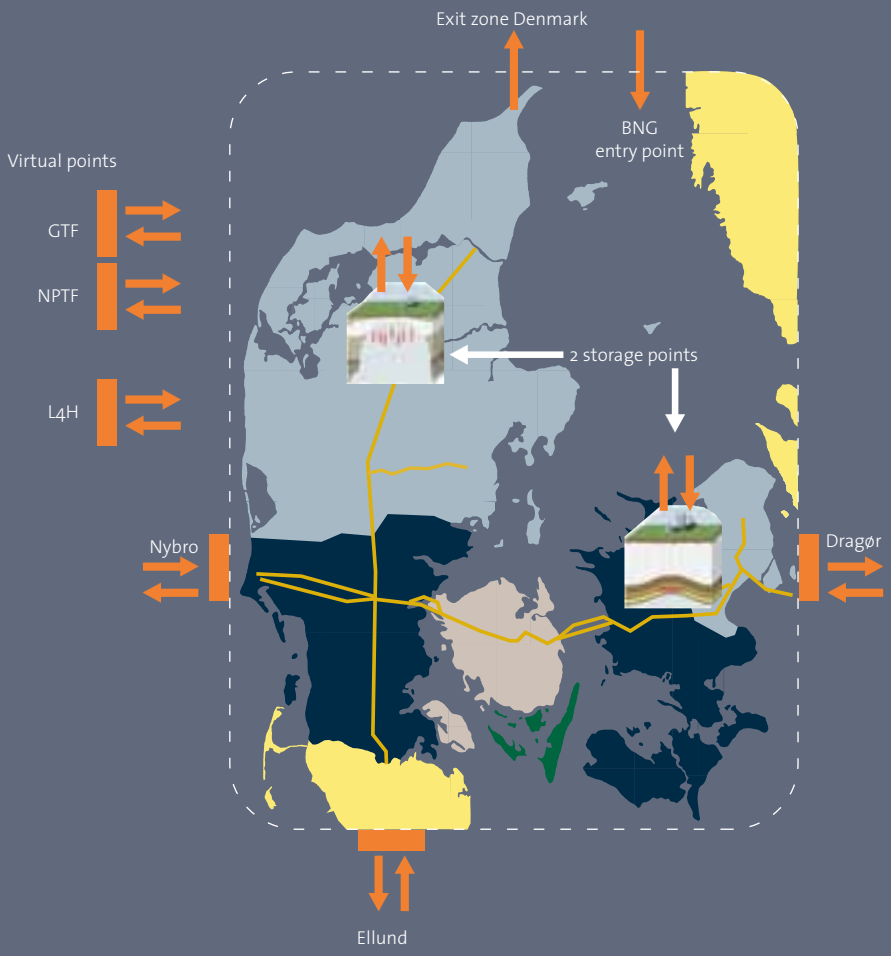


Figure 2-2: Market model for the transmission system.

# 3. Historical overview

## 3.1 General

This section provides a brief historical overview of important elements concerning security of supply, which are documented by data from the past years.

Figure 3-1 shows statements of the annual distribution of the Danish natural gas production (excluding own consumption in the North Sea) for the period 2001-2009. During the past six years, net production in the North Sea fields has outweighed supplies at Nybro since natural gas is exported to the Netherlands via the NOGAT pipeline. From 2005 to 2008, these exports constituted approximately 2 billion $Nm^3$/year; however, only 1.5 billion $Nm^3$/year in 2009.

## 3.2 Security of supply

### 3.2.1 Consumption

Over a number of years, gas consumption in Denmark has remained largely unchanged at approximately 4 billion $Nm^3$/year but has seen a slightly falling trend in recent years, see Figure 3-1. Generally, variations in gas consumption from one year to the next mainly depend on the average temperature in the winter months, the relationship between the price of electricity and the price of gas and the dispositions of a few large consumers (direct consumption sites). Moreover, consumption has generally decreased over the past years. Energinet.dk estimates consumption in 2010 at normal temperatures to be 3.6-3.7 billion $Nm^3$.

The dependence of consumption on the annual number of degree days and thus the average temperature is illustrated in Figure 3-2. A steadily declining number of degree days between 2005 and 2007 did not result in a proportionate fall in consumption. As can be seen, consumption in 2006 was higher than suggested by the number of degree days. The reason for this may be the existing market prices of electricity and gas and/or any special dispositions in relation to the operation of central power stations. The number of degree days was a little higher in 2008 and 2009 than in 2007, which is apparently not reflected in gas consumption. The Danish Energy Agency has observed a large drop in energy consumption in Denmark from 2008 to 2009. The Danish Energy Agency believes that the financial crisis is the cause of the decline as economic activity and the demand for energy services are closely related. Energinet.dk therefore assumes that the slightly higher number of degree days more than outweighs a decline in gas demand as a result of the financial crisis.

To illustrate the significance of the weather of the last few winters, Figure 3-3 compares annual duration curves for daily consumption during the period 1 July 2007-30 June 2010.

In 2005/2006, the number of degree days was about 5% below normal, while in 2006/2007 it was as much as 30% below normal and about 17% below normal in 2007/2008. In 2008/2009, the number of degree days was 13% below normal, and in 2009/2010 it was 12% below normal. In the winter of 2009/2010, there was a long period of cold weather; however, without very cold days. The rest of 2009 was below normal.

However, the peak day consumption of approximately 20 million $Nm^3$/day has almost been identical for the past three winters, with last winter being slightly higher (21.5 million $Nm^3$/day). This should be compared with expected peak day consumption of around 24 million $Nm^3$/day at -13° C.

### 3.2.2 Production

The natural gas transported via Energinet.dk's transmission network

comes physically from the North Sea fields. Denmark is a net exporter of gas. So far, only small volumes of gas have been imported to Denmark, but there are some commercial imports via Ellund.

Most of the gas from the Danish fields is sent to Denmark via the Tyra and Syd Arne pipelines where it is sold in exit zone Denmark or exported to Germany or Sweden. Also, quite a large amount of gas is exported to the Netherlands via the NOGAT pipeline, see Figure 3-1.

Approximately 20% of the natural gas production in 2009 was exported to the Netherlands, whereas around 15% and 14%, respectively, were exported to Sweden and Germany.

Production volumes shown in Figure 3-1 are net production (excluding own consumption) led onshore in Denmark or the Netherlands. In 2009, around 1.2 billion $m^3$ were used in the fields as fuel for injection or simply burnt (flaring). The share of natural gas used for injection in connection with oil extraction is expected to grow significantly in the coming years as it becomes increasingly difficult to extract the oil.

Maximum supplies at Nybro during the past winter were 23.1 million $Nm^3$/day.

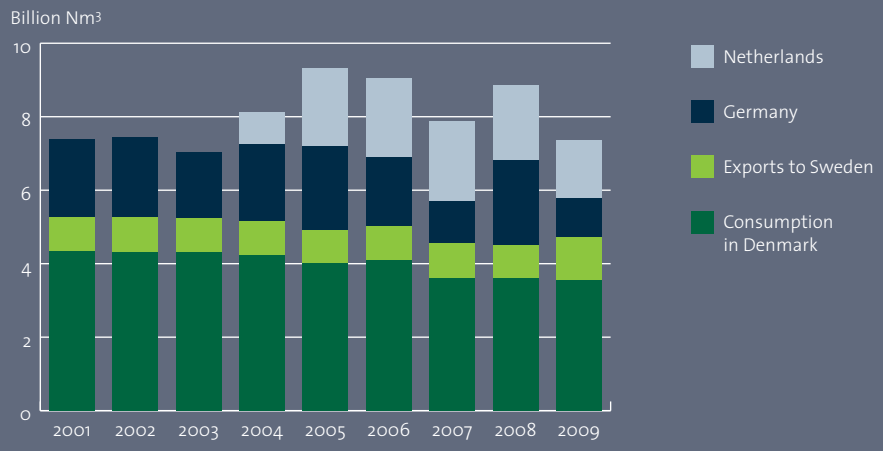


Figure 3-1: Danish natural gas production (excluding production for own consumption), by consumption in Denmark and exports to Sweden, Germany and the Netherlands in the period 2001-2009.

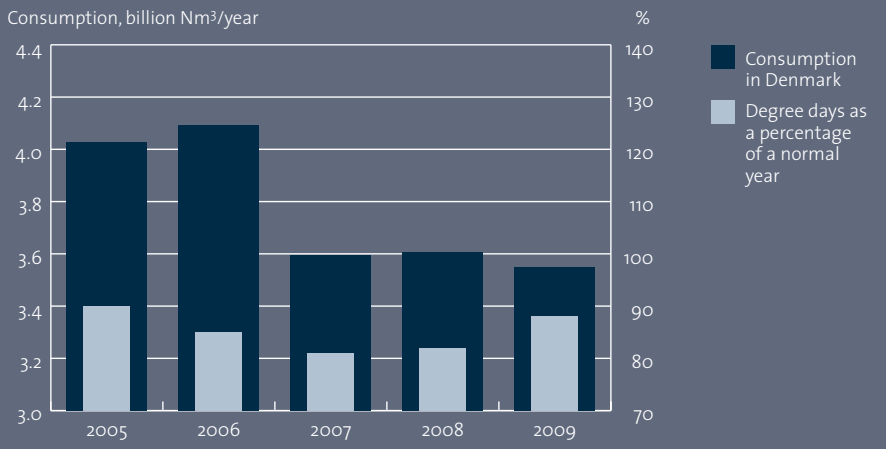


Figure 3-2: Annual consumption in 2005-2009 compared with the number of degree days as a percentage of the number of degree days in a normal year (3,385 degree days).

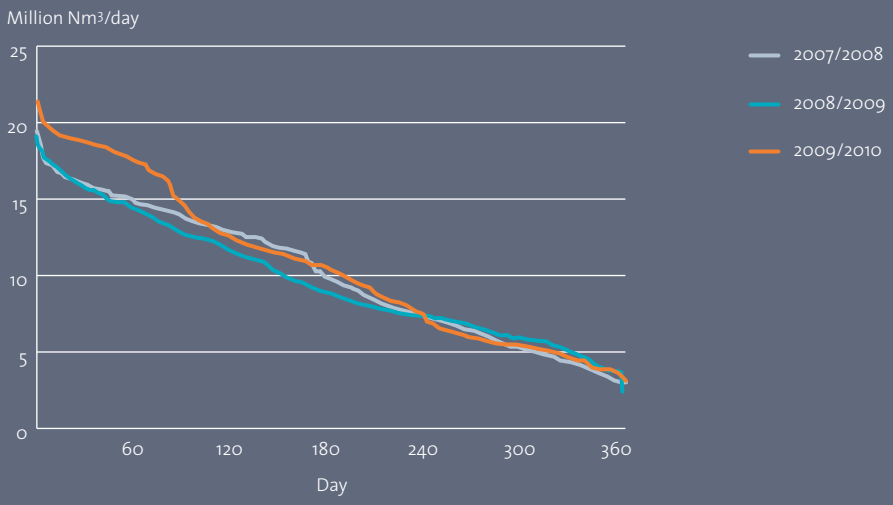


Figure 3-3: Duration curves for total natural gas consumption between 1 July 2007-30 June 2008, 1 July 2008-30 June 2009 and 1 July 2009-30 June 2010.

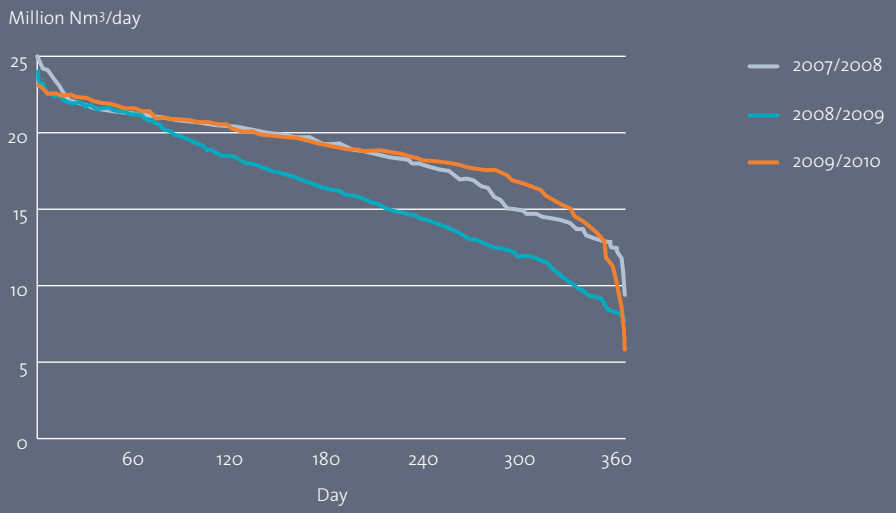


Figure 3-4: Duration curves for natural gas supplies at Nybro between 1 July 2007-30 June 2008, 1 July 2008-30 June 2009 and 1 July 2009-30 June 2010.

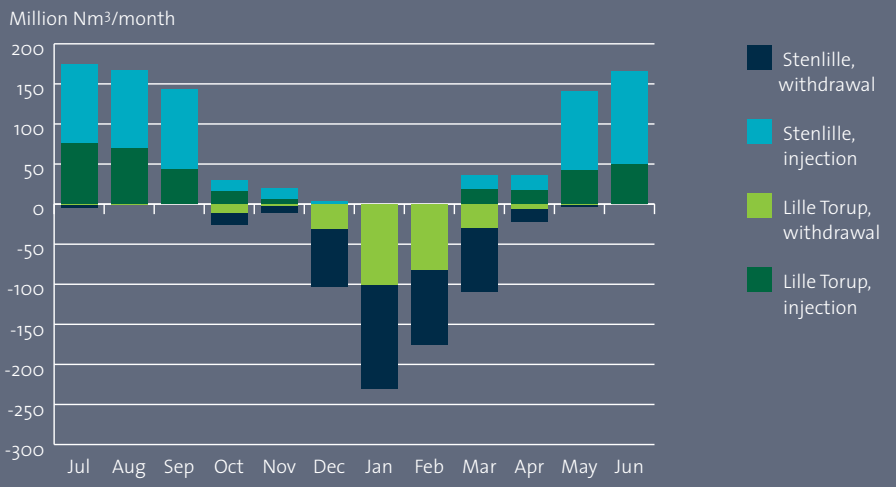


Figure 3-5: Use of the natural gas storage facilities in Lille Torup and Stenlille in the period 1 July 2008-30 June 2010.

Duration curves for the annual supplies from 1 July 2007 to 30 June 2010 can be seen in Figure 3-4.

In an emergency supply situation, Energinet.dk is charged with continuously assessing the supply situation and ensuring the supply of gas to the Danish consumers by applying a number of tools. Table 3.1 lists the events which have affected supplies at Nybro. Energinet.dk's intervention to maintain security of supply is also described in the table.

Energinet.dk has noted that the stability of the supplies from Tyra has been declining in recent years. More short-lived shutdowns are thus being seen. At the same time, it also takes longer for wells to reach production levels following a shutdown. It thus amounts to a general fall in stability from the DUC fields.

## 3.2.3 Storage use

Gas consumption varies much more during the day and during the year than supplies from the North Sea. The market players therefore have to use the two Danish gas storage facilities in Lille Torup and Stenlille.

Table 3.1: Events related to natural gas supplies at Nybro in 2007, 2008, 2009 and 2010.

| Year | Event | Action |
|---|---|---|
| 2007 | In 2007, supplies from the North Sea (Tyra Øst) suffered nine interruptions in total. Eight of these were handled by the general emergency preparedness without any consequences for the supply. One of the interruptions resulted in Energinet.dk having to declare a state of emergency supply: On 8 November 2007, Energinet.dk declared an emergency supply situation from 20:00 for storage customers and shippers as a consequence of the production stops caused by bad weather conditions in the North Sea fields. The emergency supply situation was called off on 9 November at 24:00. This meant that Energinet.dk's emergency supply preparedness was activated. The emergency supply preparedness is based on the activation of a number of tools which are continuously analysed and optimised. In the specific emergency supply situation on 8-9 November 2007, Energinet.dk's control centre immediately started filling the gas systems (ie Energinet.dk's transmission system, DONG Energy's submarine pipelines and adjacent systems) with extra gas from the storage facilities to withstand the challenges of the coming days as well as possible. Energinet.dk also chose to activate the consumers with interruptible (emergency) supply. | Energinet.dk also exercised its right of disposal of the withdrawal capacity at the two gas storage facilities. The part of the storage capacity not used for ensuring supplies to Danish consumers was made available to the commercial players for exports. Since Energinet.dk had taken over supplies to the Danish consumers, the commercial players were free to use surplus capacity in the storage facilities to supply Germany and Sweden. The players could maintain their transit through Denmark and continue trading among themselves via the national trading point. |
| 2008 | As usual, there were a number of short-lived interruptions of supplies to Nybro in 2008, none of which were critical to security of supply. | |
| 2009 | As in 2008 | |
| 2010 | As in 2009 | |

Figure 3-5 illustrates the monthly distribution of withdrawals from and injections into the storage facilities for the period 1 July 2009-30 June 2010. Surplus natural gas is injected during the summer, which is then withdrawn during the winter when supplies from the North Sea cannot reach the level of the consumption plus exports to Sweden and Germany.

In case of interruptions of supplies from the North Sea, the two natural gas storage facilities serve as emergency supply storage facilities.

## 3.2.4 Use of entry/exit capacity

Table 3.2 compares capacities at the entry-exit points of the transmission network with maximum actual daily volumes during the past three winters.

Capacity in the transmission network must be viewed together, ie total capacity depends on the relationship between entry and exit volumes and supplies from the storage facilities. Moreover, current volumes at specific points may affect capacity at other points. And viewed separately, the entry and exit points as well as the M/R stations have their own physical limitations.

The capacity in exit zone Denmark depends on the location of the consumption. Some parts of the transmission system are affected by capacity shortages and upper limits at the individual M/R stations. The capacity stated for exit zone Denmark is an estimate of the expected maximum offtake in the exit zone.

In Ellund, it has so far not been possible to nominate larger volumes as entry than as exit. The possibility of physical imports is now conditional on specific pressure conditions and the time constraints of reversing the physical flow. It is technically feasible to reverse the physical flow so compressor stations in northern Germany can supply gas to Denmark. However, the potential physical supplies from Germany to Denmark depend on load conditions in the north German transmission system and in the Danish transmission system. Since a pressure service agreement was concluded between Energinet.dk and the DEUDAN partners in October 2010, gas has been imported physically from Germany on several occasions.

The exit capacity stated for Ellund is the physical capacity. It is possible to nominate exit volumes that are larger than the physical capacity if the nomination does not exceed the physical capacity plus the volumes imported in the opposite direction.

2006 saw the expansion of the border station to Sweden, Dragør Border. The physical capacity of the actual border station was raised to 360,000 $Nm^3/h$ (8.6 million $Nm^3/d$). However, it should be pointed out that the Swedish system is not expected to be able to receive such large volumes at a pressure of 45 bar, which is the assumed minimum pressure in Dragør. Energinet.dk has therefore stated the firm capacity in Dragør at 250,000 $Nm^3/h$ (6 million $Nm^3/d$). Under most operating conditions, larger volumes can probably be received on the Swedish side under the existing load conditions in the Danish system, but these volumes are offered as interruptible capacity.

## 3.2.5 Use of the M/R stations' capacity

In 2009, some 5.8 billion $Nm^3$ of gas were transported through Energinet.dk's transmission network, of which approximately 3.5 billion $Nm^3$/year were earmarked for Danish consumers, approximately 1.2 billion $Nm^3$/year for exports to Sweden and approximately

1.1 billion Nm³/year (net) for exports to Germany, see Figure 3-1.

During the winter of 2009/2010, maximum net transports amounted to 31.5 million Nm³/day (26 January 2010). Exit zone Denmark accounted for 21.5 million Nm³/day. Exports to Sweden and Germany amounted to 6.8 million Nm³/day and 3.3 million Nm³/day, respectively, for this day and were thus lower than the maximum values. The maximum exports to Sweden and Germany amounted to 7.2 million Nm³/day (9 January 2010) and 7.1 million Nm³/day (12 June 2010), respectively.

Exports to Sweden normally depend on temperature, like Denmark's consumption, but exports to Germany depend on other factors and are therefore more evenly distributed over the year in general.

| Point | | Capacity Million Nm³/d | Max. flow 2007/2008 Million Nm³/d | Max. flow 2008/2009 Million Nm³/d | Max. flow 2009/2010 Million Nm³/d |
|---|---|---|---|---|---|
| Nybro | Entry | 32.4 [2] | 24.8 | 24.1 | 23.1 |
| Lille Torup storage facility | Withdrawal | 8.0 [3] | 5.5 | 4.0 | 4.5 |
| Stenlille storage facility | Withdrawal | 9.5 | 6.3 | 3.0 | 6.5 |
| Exit zone Denmark | Exit | 25.5 | 19.5 | 19.1 | 21.5 |
| Ellund | Entry/Exit | 4.8 [4]/8.3 | 0/8.3 | 0/8.3 | 0/7.1 |
| Dragør Border | Exit | 8.6 [1] | 5.6 | 5.0 | 7.2 |

Table 3.2: Capacity in normal situations compared with actual peak day volume during the past three winters.

1. The Swedish system, however, is not able to receive these volumes at the assumed minimum pressure in Dragør of 45 bar. The firm capacity is stated at 6 million Nm³/day.
2. Total capacity of the receiving terminals in Nybro. The potential supplies are today smaller as the Tyra-Nybro pipeline is subject to a capacity constraint of about 26 million Nm³/day, and large volumes cannot be supplied by the Syd Arne pipeline.
3. Assumes that supplies are pressure-controlled. The maximum supply is 7 million Nm³/day at constant flow.
4. Interruptible capacity.

The maximum realised transmission of gas for distribution at the individual M/R stations in the winters of 2008/2009 and 2009/2010 appears from Table 3.3, which lists the results of both peak day volume and maximum flow in one hour through the individual M/R station in the transmission system. The date and the hour of maximum flow may vary from one M/R station to the next.

## 3.3 Market

### 3.3.1 General market trend

In the first six months of 2010, Energinet.dk acquired three new shippers. With the new shippers, which are all foreign, the total number of shippers is now over 30.

At the same time, Energinet.dk has observed that several of the more recent shippers gain a better foothold in the Danish market with many transmission agreements and several different counterparty shippers in the system, and that a number of traders are registered and subsequently become active in the market.

In addition, some of the non-active customers have 'rediscovered' the Danish market and have signed up for

using Link4Hubs, which may mean that they will once again be active in the Danish market if the right opportunity presents itself.

The bilateral trading facility GTF remains an important trading hub for shippers, and approximately 50-60% of Danish consumption is still traded here. This should be seen in light of increased trading on Nord Pool Gas; in total, some 65% of Danish consumption is traded via the GTF and Nord Pool Gas, an increase of around 8-10% on the year before.

## 3.3.2 Gas exchange

In the autumn and winter of 2009/2010, Nord Pool Gas succeeded in establishing a firm position in the Danish gas market. The positive development started in October, when approximately 100 trades were conducted on Nord Pool Gas. Since then, the number of trades has increased substantially, peaking at more than 800 trades in March 2010, see Figure 3-6. In terms of volume, almost 9% of Danish consumption in the period January 2010 to June 2010 was traded on Nord Pool Gas, which should be seen in light of the fact that only about 1% of Danish consumption was traded on Nord Pool Gas in 2009.

| M/R station | Peak day in the period 01-04-2008 to 31-03-2009 | Peak hour in the period 01-04-2008 to 31-03-2009 | Peak day in the period 01-05-2009 to 30-04-2010 | Peak hour in the period 01-05-2009 to 30-04-2010 |
|---|---|---|---|---|
| | 1,000 Nm³/day | Nm³/h | 1,000 Nm³/day | Nm³/h |
| Amager Fælled | 47 | 6,664 | 50 | 3,815 |
| Billesbølle | 81 | 4,498 | 94 | 4,985 |
| Brande | 101 | 4,955 | 98 | 4,894 |
| Brøndby | 1,828 | 81,445 | 1,496 | 69,456 |
| Dragør | 185 | 9,026 | 203 | 9,803 |
| Egtved | 909 | 57,052 | 984 | 53,488 |
| Ellidshøj | 178 | 8,995 | 194 | 9,748 |
| Frøslev | 611 | 29,939 | 648 | 35,008 |
| Haverslev | 269 | 17,151 | 432 | 28,241 |
| Helle | 11 | 1,030 | 18 | 836 |
| Herning | 1,817 | 86,809 | 2,044 | 102,656 |
| Højby | 479 | 31,003 | 494 | 24,861 |
| Karlslunde | 673 | 35,004 | 697 | 37,666 |
| Karup | 269 | 12,535 | 277 | 13,055 |
| Koelbjerg | 418 | 28,666 | 497 | 35,613 |
| Køge | 446 | 23,387 | 707 | 34,312 |
| Lilballe | 49 | 2,295 | 53 | 2,461 |
| Lille Selskær | 423 | 22,176 | 429 | 22,064 |
| Lille Torup | 54 | 2,927 | 60 | 3,098 |
| Lynge | 1,534 | 73,492 | 1,470 | 71,216 |
| Middelfart | 58 | 2,864 | 60 | 3,097 |
| Måløv | 1,359 | 61,479 | 1,378 | 62,400 |
| Nyborg | 38 | 3,639 | 53 | 2,921 |
| Nybro | 49 | 3,152 | 58 | 2,683 |
| Nørskov | 331 | 17,744 | 287 | 16,492 |
| Pottehuse | 151 | 8,549 | 163 | 8,124 |
| Ringsted | 613 | 29,414 | 728 | 38,480 |
| Slagelse | 274 | 13,706 | 289 | 21,178 |
| Sorø | 347 | 19,303 | 574 | 26,792 |
| St. Andst | 539 | 26,202 | 370 | 22,752 |
| Stenlille | 367 | 18,499 | 583 | 29,280 |
| Sydhavnen | 23 | 1,535 | 16 | 1,326 |
| Taulov | 100 | 4,622 | 107 | 4,868 |
| Terkelsbøl | 319 | 16,756 | 323 | 22,720 |
| Torslunde | 203 | 11,430 | 332 | 15,688 |
| Ullerslev | 139 | 7,130 | 133 | 6,997 |
| Vallensbæk | 404 | 21,296 | 523 | 24,921 |
| Varde | 339 | 16,371 | 225 | 13,630 |
| Viborg | 1,435 | 70,705 | 1,588 | 76,096 |
| Aalborg | 1,402 | 73,804 | 1,376 | 70,992 |

Table 3.3: Registered peak day and peak hour consumption at individual M/R stations in the periods 1 April 2008-31 March 2009 and 1 May 2009-30 April 2010.

Another positive development is the fact that each day of 2010 has seen trades on Nord Pool Gas, a trend which began in November 2009.

In addition to the positive development in daily trades, Nord Pool Gas has also introduced two new products: A so-called balance-of-the-month product where customers trade gas for the rest of the days of the current month, and a swap product which makes it possible to swap gas in Germany with gas in Denmark with a counterparty having gas in Denmark or vice versa.

### 3.3.3 Ellund

In Q4 of 2009, commercial imports of gas from Germany were in high demand, which was also the case earlier in the year. This resulted in a number of days with interruptions as the volumes of gas exported were lower, see Figure 3-7.

During the quarter, exports rose again, allowing for an increase in imported volumes. Overall, imported commercial volumes have seen a dramatic increase in the past year. The level was previously approximately 1 million kWh/h and was relatively constant. At the end of 2009 and in 2010, we have witnessed a bottom level of approximately 2 million kWh/h with large upward fluctuations – up to almost 3 million kWh/h.

This means that large volumes of gas are also imported at Ellund in periods when gas prices in Denmark and in northern Europe do not differ significantly, which was the case last year.

2010 has only seen a few days with congestion and thus only a few transport disruptions. This is due to the fact that exports to Germany have been more stable and thus better able to safeguard imports than was the case in 2009 and 2007 when a gas surplus in Europe caused by warm winters resulted in exports being reduced to a minimum for several periods during the year. The fact that exports have been at a more normal level in 2010 is probably due to the cold winter.

## 3.4 Gas quality

The quality of the gas in Energinet.dk's transmission system, which is supplied either directly from the North Sea via the Nybro treatment plant or the gas storage facilities in Lille Torup and Stenlille, is checked at the metering stations in Nybro, Egtved, Dragør Border, Ellund, Lille Torup and Stenlille.

The gas must at all times comply with the quality specifications set out in Rules for Gas Transport. Gas distributed to Danish consumers must comply with the quality specifications set out in the Danish Gas Regulation, which are laid down by the Danish Safety Technology Authority. The Danish market is always supplied with gas complying with the requirements set out in Rules for Gas Transport and in the Danish Gas Regulation.

In the period 1 January 2009 to 1 January 2010, the Wobbe index for natural gas varied between 15.19 kWh/Nm$^3$ and 15.39 kWh/Nm$^3$ (54.70 MJ/Nm$^3$ and 55.42 MJ/Nm$^3$), averaging at 15.28 kWh/Nm$^3$. The relative density varied between 0.617 and 0.654, while the upper calorific value varied between 11.95 kWh/Nm$^3$ and 12.44 kWh/Nm$^3$, averaging at 12.12 kWh/Nm$^3$.

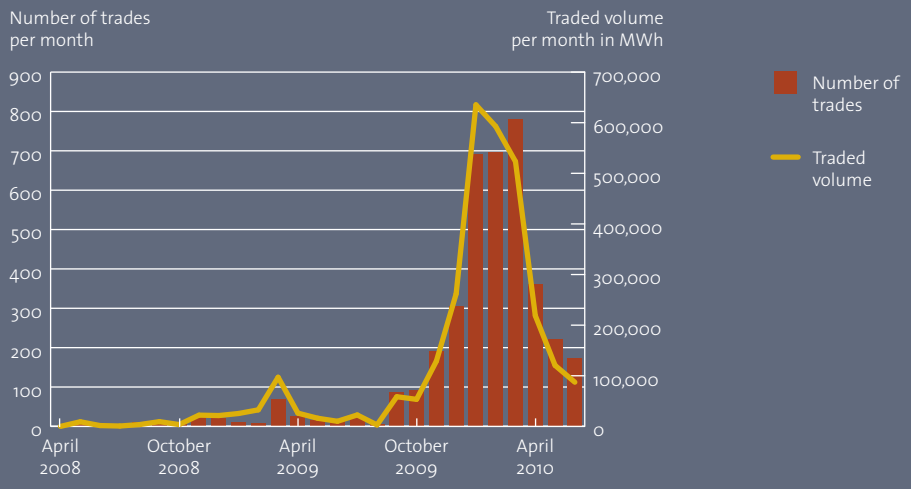


Figure 3-6: Number of trades and traded volumes per month on Nord Pool Gas.

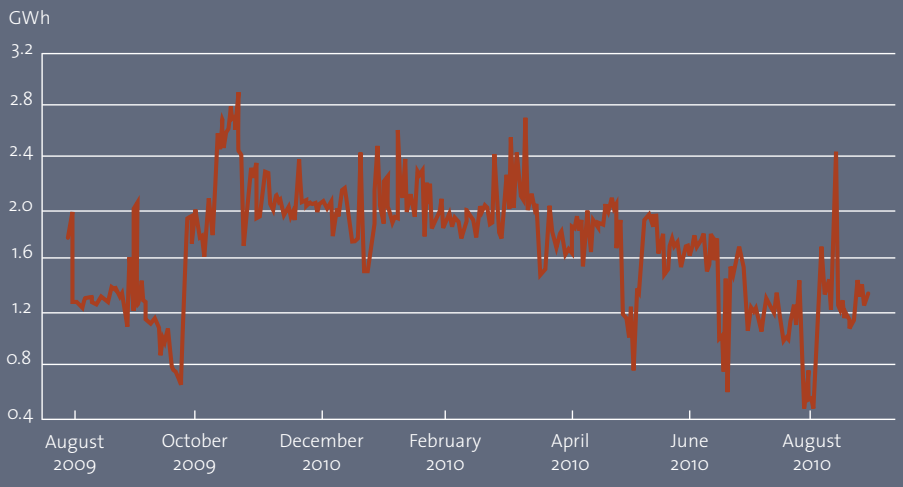


Figure 3-7: Commercial entry-flows at Ellund from August 2009 to August 2010.

# 4. Consumption and supply one year ahead (winter outlook)

## 4.1 Short-term security of supply

The M/R stations of the transmission system have the capacity necessary for handling the volumes taken off by the regional distribution companies. Energinet.dk makes annual assessments of the possible offtake by all stations, and any increases in consumption or pipeline configurations in the distribution networks, which may change the distribution of consumption at individual stations, will be coordinated with the distribution companies on an ongoing basis. The assessment for this year shows that the calculated capacities for the individual M/R stations meet the distribution companies' expectations for offtake under normal circumstances at a daily mean temperature of -13° C, which is the 20-year design temperature according to the Danish Meteorological Institute.

At the extreme ends at Lynge, Aalborg and Dragør, the M/R stations must be able to deliver the necessary volumes at an inlet pressure of 45 bar, which is the lowest assumed pressure in normal situations. At the extreme end of Ellund, the minimum pressure is 55 bar. In emergency situations, the pressure in the transmission system is assumed to be able to fall to 35 bar at the extreme ends, but the necessary supplies via the M/R stations will be reduced at the same time due to consumers being interrupted, including directly connected central power stations, which reduce the gas offtake according to their contracts.

### 4.1.1 Winter outlook

Below follows a brief description of the assumptions underlying the supply situation for the 2010/2011 winter at a temperature of -13° C, see Table 4.1 and Figure 4-1.

- Total net transports are estimated at 36.6 million Nm³/day, of which Danish consumption represents about 24 million Nm³/day. For exit zone Denmark, the offtake corresponds to Energinet.dk's expectations at a daily mean temperature of -13° C
- Total withdrawal of gas from the storage facilities is estimated at 17.6 million Nm³/day with 9.5 million Nm³/day coming from Stenlille and 8.1 million Nm³/day from Lille Torup. Optimised distribution of withdrawals is used to achieve the highest possible pressure in the network
- In Ellund, net transports were 5.4 million Nm³/day, or 225,000 Nm³/hour, and in Dragør, the figures were 7.2 million Nm³/day, or 300,000 Nm³/hour.

### 4.1.2 Capacity reserves in normal situations

Today, the Danish gas transmission system receives gas through two offshore pipelines with the following capacities:

- Tyra-Nybro pipeline, approximately 27 million Nm³/day
- Syd Arne-Nybro pipeline, approximately 13 million Nm³/day.

In normal situations, supplies amount to 0.5 million Nm³/day through the Syd Arne pipeline – the rest comes via the Tyra pipeline. The Syd Arne pipeline thus has ample capacity for use in emergency supply situations.

From October 2010, it will also be possible to supply gas to the Danish-Swedish market from Germany. The capacity depends on the pressure which the German TSOs are able to deliver and on the pressure required in the Danish transmission system in the specific situation. Under optimal conditions, a capacity of up to 200,000 Nm³/hour may be supplied, corresponding to approximately 4.8 million Nm³/day.

The storage facilities in Stenlille and Lille Torup constitute a significant part of the

capacity reserves, also under normal circumstances.

Energinet.dk must ensure that the individual storage facility owners can make optimum use of their available physical storage capacity without limiting the possibilities of the two storage facility owners of making use of their capacity or reducing Energinet.dk's possibilities of fulfilling its security of supply obligations.

This being the case, each year Energinet.dk and the storage companies fix the maximum commercial withdrawal capacities (possible withdrawal in normal situations) for the gas storage facilities in Lille Torup and Stenlille for the coming year.

Moreover, Energinet.dk has entered into a so-called swap agreement for the storage year, which ensures that Energinet.dk can determine the physical location of the gas at the two storage facilities to ensure maximum security of supply.

## 4.2 Capacity orders

**Dragør exit**

In 2010, Sweden (like Denmark) had a relatively cold winter, which was clearly

Table 4.1: Forecast for net transport at a daily mean temperature of -13° C in winter 2010/2011 (normal situation).

| | Entry Million Nm³/day | Exit Million Nm³/day |
|---|---|---|
| Exit zone Denmark | 0 | 24.0 |
| Dragør | 0 | 7.2 |
| Ellund, net | 0 | 5.4 |
| Nybro | 19.0 | 0 |
| Stenlille storage facility | 9.5 | 0 |
| Lille Torup storage facility | 8.1 | 0 |
| Total, net | 36.6 | 36.6 |


Figure 4-1: Forecast for a winter situation with a daily mean temperature of -13° C in 2010/2011 (normal situation).

reflected in the capacity orders in January and February. In this period, the sale of capacity was constantly above 3.8 million kWh/h, which is the limit between interruptible level 1 and level 2 capacity at Dragør. On the days with the highest capacity sale, the entire capacity was only 3,000 kWh/h from being sold out, which is the case when the maximum technical capacity at the border station of 4.4 million kWh/h has been sold. The capacity sale remained high right until May, with peaks reaching into interruptible level 2 capacity. After 1 October 2010, firm capacity was available again.

**Ellund entry**
Today, only interruptible capacity is sold at Ellund entry from Germany. From 1 October 2010, it will, however, be possible to obtain physical supplies from Germany to Denmark, but the capacity will still only be interruptible as the gas cannot be physically supplied at all times of the day.

2010 has seen the highest capacity sale ever at Ellund entry, with the lowest level being 2.2 million kWh/h and with long periods with capacity sales in excess of 3.5 million kWh/h. The highest sale was recorded at the beginning of July with a capacity sale of more than 4.4 million kWh/h, which is more than the firm capacity sold in the southbound direction. Level 1 capacity will not be available again before April 2011.

**Ellund exit**
For the past three years, both firm and interruptible level 1 capacity have been sold out at Ellund exit, which was also the case for the 2009/2010 gas year. This means that, for most of the gas year, capacity above level 2 has been sold (above 4.8 million kWh/h).

**Nybro entry**
In 2010, capacity orders at Nybro entry are at normal levels, ie about 11 million kWh/h.

**Exit zone**
In October and November 2009, the sale of capacity in the exit zone amounted to approximately 9.5 million kWh/h, which is relatively low compared to previous years when orders typically totalled up to 11 million kWh/h.

As a result of the cold winter, far more capacity was sold, however, from December to March, where shippers bought many short-term products. In this period, the sale of capacity was almost constantly above 10 million kWh/h, but on several days also ranged between 11 and 12 million kWh/h. The capacity limit in the exit zone is estimated at approximately 13 million kWh/h.

After 1 April, base orders in the exit zone again saw a decrease, this time to approximately 9 million kWh/h. This indicates that the shippers in the exit zone, to a larger extent than before, use short-term products to optimise their overall portfolio.

## 4.3 Emergency supply

Energinet.dk is responsible for security of supply in Denmark in keeping with the executive order on maintaining security of natural gas supply. This section describes the rules which will be applicable in winter 2010/2011. Section 1.4 specifies the changes resulting from the new emergency supply regulation.

Energinet.dk's emergency preparedness planning is designed to handle a number of supply failure situations and where the worst-case scenario is a failure in the supply from the Tyra-Nybro pipeline.

### 4.3.1 Tools

In case of serious disruptions, Energinet.dk can maintain the gas supply to Denmark using a series of tools which compensate

| 1 March | Million Nm³ |
|---|---|
| 60-day requirement in the exit zone before interruption | Approx. 900* |
| Expected interruption at interruptible consumption sites | Approx. 150 |
| 60-day requirement in the exit zone after interruption | Approx. 700 |
| Supplies from Syd Arne | Approx. 400 |
| Supplies from Germany | Approx. 50 |
| Emergency storage and filling requirements in the storage facilities | Approx. 300 |

Table 4.2: Emergency supply requirements for two months.
*Model estimate with uncertainty subtracted

for the failing supplies from the Tyra pipeline and reduce the need for gas:

- Supplies from the Danish gas storage facilities
- Emergency supply from the Tyra field via the Harald field through the Syd Arne-Nybro pipeline
- Interruption of the largest gas consumers – interruptible emergency supply
- Use of linepack in land-based pipelines and offshore pipelines.[13]

In addition, there is a limited option of supplies from Germany via the DEUDAN pipeline.

Energinet.dk establishes the required use of the above tools based on two dimensioning situations:

- 36-hour interruption of supplies at extreme temperatures (20-year winter)
- 60-day interruption of supplies at normal winter temperatures.

Each year, Energinet.dk calculates the expected consumption in the dimensioning situations and plans the use of the tools accordingly. For winter 2010/2011, emergency supply requirements and the contribution of the individual tools have been calculated as follows:

**Storage services**

Energinet.dk reserves a total storage volume, of which a small part is reserved for system balancing. For winter 2010/2011, Energinet.dk has reserved a total storage volume of about 250 million Nm³, of which 35 million m³ are reserved for system balancing. In addition, the majority of the volume capacity in Stenlille and Lille Torup has been sold subject to so-called filling requirements. This means that the storage customers commit themselves to maintaining a certain stock volume, so that Energinet.dk, in emergency supply situations, will have access to additional gas volumes in the storage facilities. The degree of required storage filling varies during the winter.

The reservation of storage volume is based on the requirements in the two dimensioning emergency supply situations related to the expected supplies from the Syd Arne pipeline, imports from Germany and interruption of the consumption sites with interruptible emergency supply.

For the purpose of handling short-term interruptions of supplies from the North Sea in extreme winter temperatures, Energinet.dk has reserved withdrawal capacity from the storage facilities to compensate for the lack of supply. Moreover, Energinet.dk can make use of the limited gas volumes which are stored in the actual gas pipelines – the so-called linepack.

The reserved withdrawal capacity at the two storage facilities is distributed differently over the year.

**Supplies from Syd Arne**

Energinet.dk has signed an emergency supply agreement which paves the way in emergency supply situations for supplies of 7 million Nm³/day from Tyra via Harald through the Syd Arne-Nybro pipeline for the Danish market.

Usually the gas flows via the Harald pipeline from the Harald field to the Tyra platform where it is processed before being sent ashore via the Tyra pipeline. In an emergency supply situation, gas would have to flow in the opposite direction in the Harald pipeline and be sent onshore via the Syd-Arne pipeline. In this situation, supplies from the Syd-Arne field and the Harald field are expected to stop since pipeline capacity

[13] At a given pressure, there is a volume of gas in the gas pipelines. If a lower pressure is acceptable, the gas volume in the pipelines must be smaller to maintain this pressure. The difference between the gas volume at the high and the low pressure is called the linepack.

| Category | Terms and conditions |
|---|---|
| Firm emergency supply | Firm (60 days') emergency supply<br>Full insurance |
| 36-hour interruptible emergency supply | In case of 36-hour interruptible emergency supply, the gas offtake at the consumption site must be reduced within 36 hours of an emergency supply situation being declared. Consumption must not be resumed until the emergency situation ends. |
| Hyper-interruptible emergency supply | In case of hyper-interruptible emergency supply, the gas offtake at the consumption site must be reduced within three hours of an emergency supply situation being declared and must not be resumed for 72 hours |

Table 4.3: Emergency supply categories in new emergency supply concept.

is limited and supplies from the Tyra platform will take up the capacity.

**Interruptible emergency supply (emergency supply concept)**
Energinet.dk's concept for interruptible emergency supply allows the largest consumption sites to opt out of the statutory emergency supply 'insurance'. In this context, the largest consumption sites are those with annual gas consumption exceeding 2 million $Nm^3$.

Under the emergency supply concept, Energinet.dk offers three categories of emergency supply as illustrated in Table 4.3. The three categories can be combined into partially interruptible emergency supply where the consumer must be able to reduce some of its consumption within three or 36 hours. This implies that part of the offtake is hyper-interruptible (interrupted within three hours), another part constitutes 36-hour interruptible emergency supply, while the rest is firm emergency supply.

By combining the three categories, the degree of 'insurance' may be composed to match the individual consumption site. This ensures flexibility in relation to the interruptibility of consumers.

In emergency supply situations, consumers that have entered into a contract on interruptible emergency supply with Energinet.dk are handled in cooperation between the distribution companies and Energinet.dk.

When Energinet.dk assesses that an emergency supply situation exists, Energinet.dk will issue an emergency supply statement to the interruptible consumers as well as to the TSOs in Sweden and Germany, the two storage companies and the upstream pipeline operator.

In the following hours, Energinet.dk will monitor the offtake of the interruptible consumers. If the offtake is not reduced, the interruptible consumers will be contacted with a view to interrupting supply.

Customers with hyper-interruptible supply as well as customers with 36-hour interruptible supply that fail to interrupt their offtake under the interruptibility agreements made will be interrupted physically by the distribution company at the request of Energinet.dk.

**Other tools, including supplies from Germany**
In addition to the alternative gas supplies available to Energinet.dk, Energinet.dk has made cooperation agreements with the neighbouring TSOs, thereby ensuring the required operational flexibility.

Initially, supplies from Germany via the DEUDAN pipeline will take place on a commercial basis if there is a physical flow towards Germany and thus the possibility of backhaul (or back flow). From October 2010, it will also be possible to physically supply up to 200,000 $Nm^3/h$ of gas from Germany to Denmark. In normal situations, this option will, in some periods, be limited by the pressure requirements of the Danish system, but in an emergency situation the pressure in the Danish system will, after a period of time, be so low that gas can flow from Germany to Denmark. Alternatively, physical flow from Germany is secured by closing the southbound valve in Egtved so that the south Jutland part of the Danish gas system is controlled from Germany, and gas with a German calorific value is restricted to this area. Energinet.dk cooperates with the German TSOs to identify options and ensure the necessary, commercial agreements on gas supplies to the Danish system. See section 1.3.

In an extreme scenario where an event or a combination of events causes a

more severe supply situation than the emergency preparedness is designed to handle, the provisions on force majeure in the Rules for Gas Transport will come into force. This implies, for instance, that general provisions regarding firm emergency supply will be inoperative and that Energinet.dk can make a prioritised interruption of consumers based on overall system requirements, taking account of the necessary consumption.

### 4.3.2 Prioritisation of means

The Rules for Gas Transport contain a number of conditions which ensure that, in certain situations, Energinet.dk can influence or make arrangements for the supply and consumption of gas to optimise security of supply and the gas system. This applies to interruptible consumers, reduced nomination, reduced capacity, emergency supply and force majeure.

Any decisions concerning the means by which Energinet.dk secures supplies are based on the premise that the effects of any technical problems on the market should be minimal. The specific supply and weather situation and the actual status of the gas system are important parameters for the timing and sequence of use of the various means, for which reason it is not possible to detail in advance when and how the individual means must be used.

In the event of major interruptions of supplies from the North Sea, a number of measures will be taken to ensure supplies to the Danish gas market. The means are described above.

In an emergency situation, Energinet.dk takes over all transport of gas in the system. Energinet.dk's emergency supply obligations apply only to the Danish gas market, but in so far as shippers ensure the availability of gas for transit at the entry points or from storage facilities, Energinet.dk will seek to make the necessary transport capacity available if the physical conditions so permit.

As described in the Rules for Gas Transport, Energinet.dk must, in the event of an emergency situation, distribute available gas volumes in the Danish gas market, giving due consideration to:

- Concluded agreements on emergency supply in accordance with the emergency supply concept, see section 4.3.1
- The consequences for consumers must be minimised to the greatest possible extent, preferably by not interrupting supplies to consumers sensitive to irregularities in the supply of gas.

In this context, it should be pointed out that shippers and storage customers must, if possible, continue supplying gas to the Danish gas system at the entry points and the storage facilities.

## 4.4 Gas quality

In 2011, the quality of the natural gas will be a combination of Danish North Sea gas and minor gas volumes from Germany imported via Ellund.

The Wobbe index of the Danish North Sea gas is expected to continue to vary between 15.0 kWh/Nm$^3$ and 15.5 kWh/Nm$^3$ (54.0 MJ/Nm$^3$ and 55.8 MJ/Nm$^3$). Gas imported from Germany is expected to have a lower Wobbe index than that of Danish North Sea gas. The average Wobbe index is expected to be 14.4 kWh/Nm$^3$ (51.8 MJ/Nm$^3$) varying from the lower limit specified in the Danish Gas Regulation, currently 14.1 kWh/Nm$^3$ (50.8 MJ/Nm$^3$), to 15.5 kWh/Nm$^3$ (55.0 MJ/Nm$^3$).

Historically, the variation in gas from northern Germany is between 13.9 and 15.3 kWh/Nm$^3$, which means that part of the gas does not comply with the Danish Gas Regulation. Energinet.dk is thus cooperating with the Danish Safety Technology Authority, the public

authority within this area with responsibility for the Danish Gas Regulation, to expand the interval of the Wobbe index to 13.9-15.5 kWh/Nm$^3$. Energinet.dk expects the Danish Safety Technology Authority to announce the changes at the beginning of 2011.

In connection with the work to expand the Danish Gas Regulation, Energinet.dk, the distribution companies and the Danish Gas Technology Centre have cooperated with the relevant authorities on identifying the consequences both for safe gas use, environmental impacts, efficiency and settlement with a view to ensuring that the right solutions are implemented.

# 5. Future consumption and supplies

## 5.1 Challenges in the coming years

Energinet.dk is obliged to ensure that the required gas transmission system is available to the commercial players and that it has the capacity necessary for commercial players to supply Danish gas consumers. In addition, the required capacity must be made available for transit on non-discriminatory conditions.

As a result of the large North Sea production, Denmark has been self-sufficient in gas since 1983, and the transmission system has been expanded based on supplies from the North Sea only. North Sea production peaked in 2006, see Figure 5-2.

According to the Danish Energy Agency, the North Sea production will decline significantly in the coming years and may be virtually phased out by 2040; however, the forecasts are very uncertain, see Figure 5-1.

As the uncertainty surrounding the gas volumes from technological contributions and exploration contributions is high, Energinet.dk has decided to only use the reserve contribution in the subsequent calculations. As the reserve contribution is also an uncertainty factor, and as Energinet.dk must ensure the necessary transmission capacity, a conservative assessment of the supply options has been chosen.

As the North Sea has so far represented the only physical possibility of supplying gas to Denmark and Sweden, supply problems may therefore arise within a relatively few years. Energinet.dk has therefore elected to invest in new infrastructure opening up for supplies to Denmark and Sweden from Germany from October 2013. At the same time, initiatives have been introduced which, by means of temporary technical solutions in the north German system, have enabled supplies from Germany from October 2010.

In 2010, the Danish Energy Agency made a projection of Denmark's gas consump-

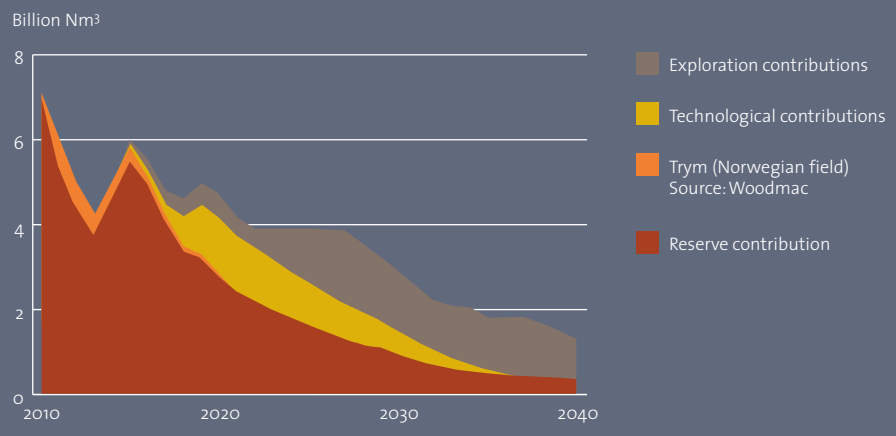


Figure 5-1: Production scenarios, Danish Energy Agency 2010. Trym is included as the gas is supplied via Danish platforms.

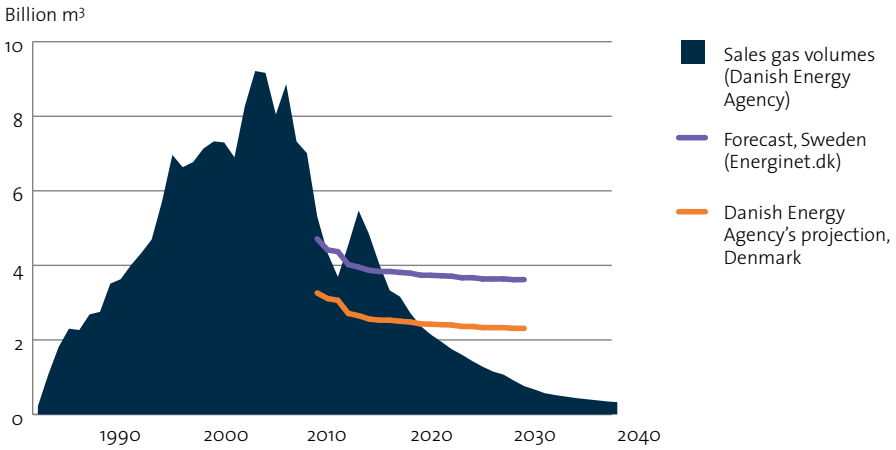


Figure 5-2: Gas consumption in Denmark and Sweden compared with supplies from the North Sea. Danish Energy Agency and Energinet.dk, 2010.

tion. The projection is shown in Figure 5-2 and is described in detail in section 5.2. According to the 2010 base projection, and with the expected gas reserves, Denmark and Sweden will, in theory (assuming that all gas available in the North Sea is supplied to the Danish and Swedish markets), be self-sufficient in gas until around 2017, but, as mentioned above, both consumption and production are surrounded by considerable uncertainty. As can be seen, problems may also arise in 2012/2013 as a result of a temporary production decline.

The 2010 projection covers the period until 2020. Energinet.dk's projection of gas consumption in the exit zone is approximately 0.5 billion $Nm^3$/year higher than the Danish Energy Agency's latest projection for the period until 2018, after which the difference becomes smaller.

With the expansion of the Danish transmission system to Germany in 2013, the capacity of the Danish transmission system will be more than sufficient to meet demand for many years, and the shippers will thus be able to choose between different supply routes. This makes it more complex for Energinet.dk to estimate future supplies, but it improves the market conditions. Figure 5-3 shows a possible transmission scenario where supplies to Denmark and Sweden primarily come from Germany, and where surplus gas is exported to the Netherlands via the NOGAT pipeline.

If the North Sea production with technological contributions and exploration contributions matches Figure 5-1, the supply situation will be materially different.

Overall, this makes the future supply situation very uncertain for Energinet.dk, but the investment in the expansion towards Germany ensures supplies to the Danish and Swedish markets, and the market players will have more flexibility and market opportunities.

### 5.1.1 Supply situation in 2011-2013

As supplies from the Danish part of the North Sea are declining, the supply situation is expected to be very tight in 2011-2013. Congested infrastructure and restrictions in the transmission system and/or in the storage facilities are expected to be the most critical elements.

Energinet.dk has attempted to create an overview of the expected development from 2011 to 2013. These expectations are summarised below to provide the market players with an optimal basis for making their own assessments and decisions, enabling them to take the necessary precautions to avoid critical supply situations on both a daily, monthly and annual basis.

The establishment of physical supplies of interruptible capacity from Germany, which became possible in October 2010, is expected to alleviate the short-term shortage in gas supplies to Denmark and Sweden which may occur until the permanent expansion of capacity between Denmark and Germany is commissioned at the end of 2013. The supply situation in 2012 and 2013 is, however, expected to be very strained, and consumers, suppliers, shippers and storage customers should thus carefully assess how to ensure sufficient flexibility and supply options in these years.

If all gas for the Danish and Swedish markets were still supplied from the Danish part of the North Sea, no congestion would occur in the Danish transmission system. The Danish Energy Agency's projection of the gas production in the Danish part of the North Sea does, however, show that it will probably be necessary, at least in 2013, to import gas from Germany to meet the demand of the Danish and Swedish markets.

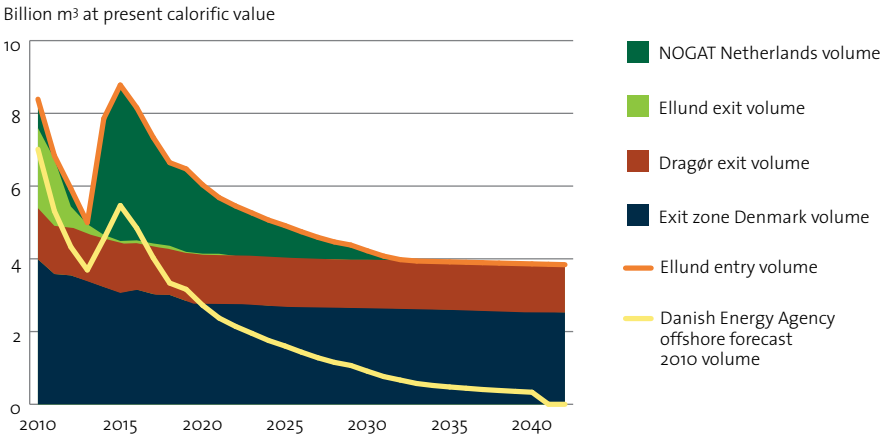


Figure 5-3: Possible supply scenario for 2010-2042.

The autumn of 2010 already saw physical imports of gas from Germany for several days in a row.

At Ellund entry, the gas is expected to be supplied at a pressure of between 68 (minimum) and 78 bar, whereas gas from Nybro is normally supplied at a pressure of between 74 and 78 bar. At the same time, the pressure drop between Nybro and Egtved is smaller than that between Ellund and Egtved because there are two 30" pipes between Nybro and Egtved whereas, between Ellund and Egtved, there is only one 24" pipe.

The daily supply situation depends to a large extent on whether gas is injected into or withdrawn from the storage facilities. On cold winter days, gas is typically withdrawn from both storage facilities. The storage facilities thus contribute to increasing the pressure at the extreme ends of the gas system (Aalborg, Lynge and Dragør). In the event of considerable physical imports from Germany (100,000-200,000 m³/h), the pressure will generally be low. If, at the same time, only small volumes are withdrawn from Stenlille storage facility, the pressure in Dragør will be low. In such situations, it may be impossible to supply large volumes of gas (more than the firm capacity of 250,000 m³/h) to Sweden, as the Swedish system is unable to receive large volumes at low pressure. Interruption of interruptible capacity in Dragør exit and/or Ellund entry may thus be required.

In summer, when large gas volumes are injected into the storage facilities, normal consumption (households, industry and power stations) is generally low, but in spring and autumn, when gas is also injected into the storage facilities, consumption in Denmark and Sweden can be relatively high. If, at the same time, large volumes (100,000-200,000 m³/h) are supplied from Germany in these situations, the pressure in the storage facilities will thus be relatively low. This will impact the injection capacity. It may, to a certain extent, become necessary to interrupt or reduce injection and/or interruptible capacity in Dragør exit or Ellund entry to maintain the required pressure in the transmission system.

For 2012 and 2013, large volumes of gas from Germany are expected, both on an annual and on a daily basis. Storage customers should therefore focus on ensuring stable injection over the entire injection season. It may be possible to inject maximum injection rates in June, July and August only, and the injection rates should preferably be kept at a moderate level in spring and autumn. Energinet.dk can use tools which minimise the consequences of occasional instances of 'random, unexpected and unusual behaviour' of gas customers, shippers and storage customers. Energinet.dk can, for example, choose to exercise the operation agreement concluded between the storage companies and swap gas between the two storage facilities. There is, however, no guarantee that these tools will be sufficient to prevent interruptions in any supply situation.

The following aspects are important to consider:

- **In 2011**, production from the Danish part of the North Sea is expected to be sufficient to meet Danish and Swedish demand. According to the reserve calculation, minor commercial export volumes to Germany via Ellund and/or supplies to the Netherlands via the NOGAT pipeline are possible. The surplus volumes are, however, not expected to exceed 0.3-0.5 billion m³. Depending on the existing contracts and the current market price, the gas from the Danish part of the North Sea will be supplied to the Netherlands or to Denmark (Danish, Swedish and German consumers)
- **In 2013**, the gas volumes from the Danish part of the North Sea are expected

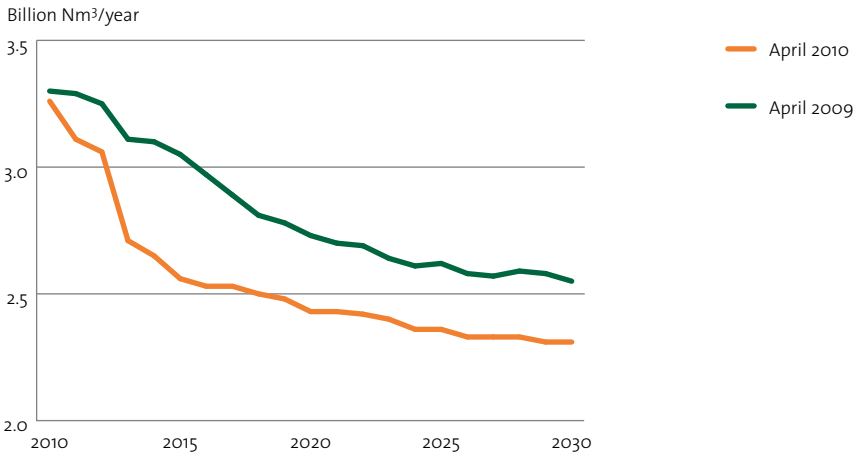


Figure 5-4: The Danish Energy Agency's projection of Danish natural gas consumption in exit zone Denmark from April 2009 and April 2010.

to be insufficient to meet Danish and Swedish market demand, even if no gas is supplied to the Netherlands. Physical net imports from Germany of around 1 billion m³ will be required

- **In 2012**, physical imports from Germany of 1 billion m³ are expected, but it is, at the same time, estimated that 0.5 billion m³ of gas will be supplied to the Netherlands. This means that total gas demand in the Danish and Swedish markets is expected to exceed production in the Danish part of the North Sea by 0.5 billion m³.

The compressor station in Egtved is scheduled for commissioning in October 2013. Due to the circumstances mentioned above, the possibility of bringing forward the establishment of one of the four compressors to October 2012 is being examined.

## 5.2 Development in consumption

Gas consumption in Denmark is still seeing a downward trend. From 2008 to 2009, natural gas consumption in the exit zone adjusted for climate variations showed a decrease of approximately 6%, primarily as a result of the economic situation following the financial crisis.

Total gas consumption for the existing consumer segments is also expected to fall, but at a lower rate.

The projections of natural gas consumption by consumer segment have been prepared by the Danish Energy Agency and Energinet.dk and are described in the following sections.

### 5.2.1 The Danish Energy Agency's projection

In April 2010, the Danish Energy Agency made a number of base projections of Denmark's energy consumption, among other things based on the energy agreement of 21 February 2008. The projections include natural gas consumption until 2030 based on current political energy agreements.

Based on the base projection, the Danish Energy Agency forecasts a fall in natural gas consumption, including offshore consumption, of 15% in the next five years and 20% in 2030 compared to 2010. The consumption of natural gas in the North Sea for oil and gas production is expected to rise so the anticipated reduction in natural gas consumption in exit zone Denmark will be 21% in 2015 and 29% in 2030 compared to 2010.

This expected annual consumption in exit zone Denmark is shown in Figure 5-4, where the base projection is compared with the previous base projection from April 2009. The lower natural gas consumption in the most recent projection is primarily attributable to the recession. The economic downturn results in reduced energy consumption and makes the projection very uncertain. Total consumption of fossil fuels, for example, saw a decline of more than 5% from 2008 to 2009, a period when the economic situation worsened significantly.

The relatively sharp decline from 2012 to 2013 in the latest projection, see Figure 5-4, is mainly the result of reduced central and local CHP generation based on natural gas. Unit 2 of Avedøre Power Station is expected to convert to coal firing, for example.

### 5.2.2 Energinet.dk's projection

Energinet.dk makes an annual projection of Danish gas consumption, which, this year, covers the period until 2020.

Energinet.dk's projection method involves the use of the SIVAEL model, which simulates the CHP sector for a selected year on an hourly basis. The

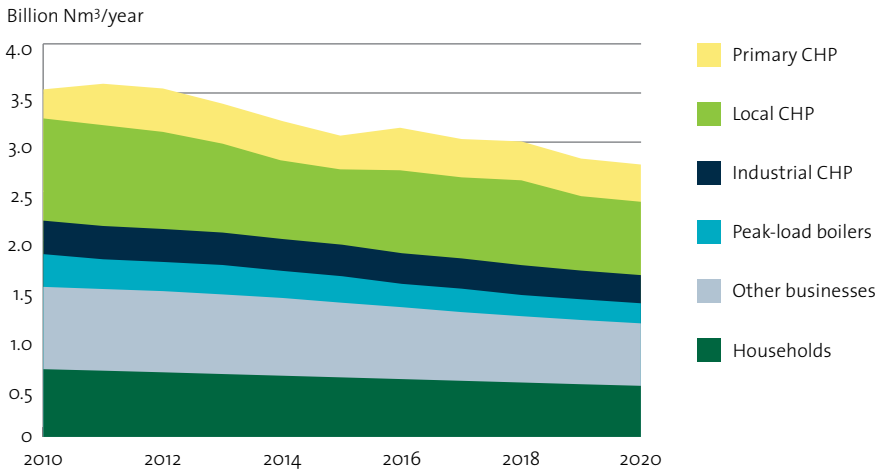


Figure 5-5: Energinet.dk's projection of natural gas consumption in exit zone Denmark by consumer segment.

model calculates the natural gas consumption of central, local and industrial CHP plants as well as peak-load boilers. The natural gas consumption of other businesses and households is not calculated. The projection of this year's consumption is based on the most recent projection from the Danish Energy Agency (April 2010).

Energinet.dk's projection takes its point of departure in the energy agreement of 21 February 2008 and a number of assumptions set out by the Danish Energy Agency and Energinet.dk's data coordination group. Energinet.dk's projection is based on data collected in connection with the preparation of Energinet.dk's Environmental Report 2010. The International Energy Agency's fuel price forecast from 2009 is used.

The SIVAEL simulations include means of integrating wind power in the form of electric vehicles, heat pumps in CHP areas and individual heat pumps which replace oil-fired boilers. The projection does not take into account that natural gas may be used in the transport sector within the time horizon analysed.

The simulation results appear from Figure 5-5, which shows the development in natural gas consumption by segment. In the first years, total consumption grows slightly or remains stable and then drops. The slight increase in consumption at central and local CHP plants in 2016 is a result of decreasing coal consumption. As can be seen, Energinet.dk expects continued use of gas at central CHP plants. DONG Energy, which owns Avedøre Power Station, has stated that they expect to keep open the option of firing natural gas at the power station.

Energinet.dk's projection of gas consumption in the exit zone is approximately 0.5 billion Nm³/year higher than the Danish Energy Agency's most recent projection for the period until 2018, when the difference becomes smaller. Energinet.dk and the Danish Energy Agency are currently investigating why their consumption projections differ. The difference may be explained in part by differences in the projection of consumption at central and local CHP plants, but there may be other differences as well. Figure 5-6 compares Energinet.dk's projection with the Danish Energy Agency's latest projection. Energinet.dk's and the Danish Energy Agency's projections show a decrease in gas consumption until 2020 of approximately 21% and approximately 26%, respectively, see Table 5.1.

### 5.2.3 Outlook for the development in Swedish gas consumption and supplies

Today, Sweden exclusively receives its supplies of natural gas from Denmark via Dragør. Following the shelving of the Skanled project, it is likely that Denmark will be Sweden's only source of supply for many years. One of the objectives of the Skanled project was to establish a supply route from Norway to the northern part of the Swedish system and to Denmark. Sweden and Norway are, however, still pursuing the idea of realising Skanled in one form or another.

In Sweden, many initiatives are in progress within biogas in the network and gas for the transport sector, but it is difficult to assess their effect on consumption and a possible local supply.

Consumption in Sweden rose sharply in 2009, among other things as a result of the commissioning of the new CHP plant in Malmö, and consumption in 2011 is expected to be around 1.3 billion Nm³/year. The projection of Swedish gas consumption is surrounded by considerable uncertainty as – according to statements from, amongst others,

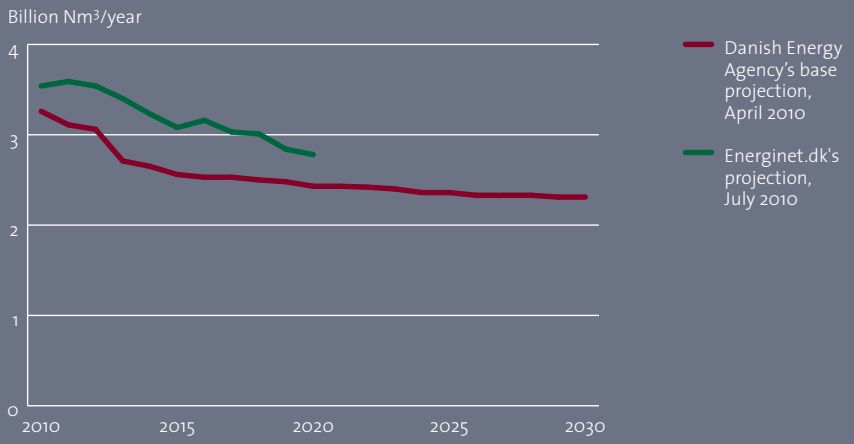


Figure 5-6: Energinet.dk's and the Danish Energy Agency's projections of natural gas consumption in exit zone Denmark.

| Billion Nm³/year | | 2015 | 2020 |
|---|---|---|---|
| Danish Energy Agency, April 2010 | Denmark | 2.6 | 2.4 |
| Energinet.dk, July 2010 | Denmark | 3.1 | 2.8 |
| Energinet.dk | Sweden | 1.3 | 1.3 |

Table 5.1: Forecast annual gas consumption in Denmark and Sweden (export via Dragør). Volumes correspond to Danish natural gas quality.

| Million Nm³/year | | Load factor | 2015 | 2020 |
|---|---|---|---|---|
| Energinet.dk | Denmark | 0.5 | 17.0 | 15.3 |
| | Sweden | 0.5 | 7.1 | 7.1 |

Table 5.2: Forecast peak day consumption in Denmark and Sweden (export via Dragør). Volumes correspond to Danish natural gas quality.

the Swedish Energy Agency[14] – the current consumption of approximately 1.3 billion m³/year is expected to increase, whereas in other forecasts it is expected to remain at the same level or fall. In the Open Season 2009[15] process, Energinet.dk did not receive any clear indications of the future market.

In the long term, Energinet.dk thus expects gas consumption in Sweden to remain unchanged and any increase in demand to be covered primarily by biogas.

## 5.2.4 Capacity requirements

In Energinet.dk's projection, total consumption in Denmark (exclusive of offshore consumption) is calculated at approximately 3.1 billion Nm³/year for 2015 and at 2.8 billion Nm³/year for 2020. Energinet.dk estimates gas consumption in Sweden at 1.3 billion Nm³/year for both 2015 and 2020.

During a normal winter, Energinet.dk assumes that peak day consumption in Denmark and Sweden is as shown in Table 5.2. For the peak day consumption,

[14] Corresponds to the Danish Energy Agency.

[15] In 2009, Energinet.dk conducted an Open Season process in which market players were given the opportunity to enter into binding contracts for future capacity.

the estimate uses daily load factors (the relationship between average and peak day consumption) of 0.5 for both Denmark and Sweden. Sweden receives its supplies from the Danish transmission system via Dragør.

## 5.3 Long-term security of supply

Long-term security of supply is related to the number and diversity of the supply sources. Compared to most of its neighbours, Denmark has been privileged to have its own abundant reserves. As such, the entire transport channel was within Danish territory and therefore shorter, in particular compared with those countries which mainly receive their supplies from Russia.

As production decreases, Denmark will become dependent on gas imported from Germany. The pipeline to the European gas network via Ellund ensures that the Danish gas market has access to gas reserves for many years to come. The gas in the north German system consists of Norwegian, Dutch, Russian and German gas as well as LNG. The Norwegian fields have reserves to cover the next 50 years or more, while Russia's reserves are assumed to be many times larger and sufficient to cover the next 100 years.

In the long term, there will be more Russian gas in the north German system, among other things because of the establishment of North Stream. DONG Energy has, for example, published agreements with Russian Gazprom on long-term supplies of gas to northern Germany, and DONG owns part of an LNG plant in Rotterdam in the Netherlands.

Energinet.dk's planned investments in import capacity are thus expected to have a large positive effect on long-term security of supply in relation to the decline in the North Sea production.

In May 2010, the Danish Energy Agency published the report 'Expansion of the infrastructure for transporting natural gas with a view to future imports to Denmark' (*Udbygning af infrastrukturen til transport af naturgas med henblik på fremtidig import til Danmark*). The purpose of the analysis was, among other things, to illustrate how the Danish installations and pipelines in the North Sea can best be used with the onshore infrastructure. The report was published at the same time as the Danish Minister for Climate and Energy approved Energinet.dk's expansion to Germany with the establishment of a compressor station and the looping of the Ellund-Egtved pipeline.

The report states that the expansion to Germany does not rule out a subsequent connection to the Norwegian gas infrastructure, either by using the existing Danish offshore infrastructure or by establishing a direct connection to the shore. This depends on whether there, at some point, is a market for this.

Gas imports from Norway may include volumes to supplement supplies to the Danish and Swedish markets and onward supplies to the northern European market, including the Baltic states. The report also states that, in connection with imports of Norwegian gas, the possibilities of using one or more of the Danish North Sea gas fields as a gas storage should be assessed. Through the Baltic Energy Market Interconnection Plan (BEMIP), for example, the European Commission supports initiatives for the diversification of gas supplies to northern Europe and the Baltic area and welcomes, in this context, an investigation of both a Norwegian-Danish and a Danish-Polish interconnection.

Against this background, Energinet.dk is examining the possibility of establishing an interconnection from Norway to Denmark, see section 6.3.

## 5.4 Gas storage capacity

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

The gas storage facilities in Stenlille and Lille Torup have a total storage volume of approximately 1,000 million $Nm^3$ and a total withdrawal capacity in normal situations and emergency situations of 17.5 million $Nm^3$/day and approximately 25 million $Nm^3$/day, respectively. Energinet.dk reserves capacity in the range of 200-250 million $Nm^3$ for emergency supplies, whereas the remaining volume of approximately 800 million $Nm^3$ can be sold to commercial players. For emergency supply situations, Energinet.dk has reserved capacity of around 20 million $Nm^3$ per day.

Future storage requirements will be determined by potential supplies to the Nybro and Ellund entry points, commercial aspects, the development in the Danish-Swedish offtake and the requirement for security of supply. The requirement for security of supply includes both the need for withdrawing capacity from storage facilities and the need for storage volume.

Energinet.dk has assessed the potential supply situation for the 2011-2030 period on the assumption of supplies from both Germany and the Danish part of the North Sea. Storage requirements will be determined by the supply situation, a number of market parameters and by Energinet.dk's choice of tools in the form of storage facility, alternative entry points as well as interruptible customers to cover the security of supply obligations in respect of the Danish market and the requirement for security of supply in respect of the Swedish market. The new EU security of supply regulation will require security of supply to be seen in a regional perspective. This means that security of supply in Sweden must also be included in the assessment

The general trend in Europe is that gas is supplied to entry points at a higher load factor than before, and the EU regulation makes the security of supply requirements stricter. On the face of it, both elements point towards an increased storage requirement. A falling market, if that proves to be the case, as is expected in Denmark, does, however, point in the opposite direction, and any connection from Norway to Denmark can change the assumptions considerably.

Energinet.dk has estimated the storage volume required in order to perform load balancing of the consumption in the Danish and Swedish markets. It is estimated that the volume required by commercial players for load balancing for the entire 2011-2030 period may vary between 200 and 800 million $m^3$, depending on the market parameters and the need for flexibility.

In 2013, and maybe already in 2012, when there is a risk of gas shortage due to falling North Sea production, the storage requirement is expected to amount to at least 500 million $m^3$. In these years, it is therefore important that shippers and storage customers carefully assess the need for flexibility, and Energinet.dk will attempt to provide the market with the best possible information about the expectations for transport and storage requirements.

The need for purchasing security of supply services is expected to fall in 2013 following the commencement of supplies from Germany. As yet, Energinet.dk has not assessed how to cover the reduced demand. It may, for example, be done by purchasing storage services or by using interruptible customers. If the storage volume purchased by Energinet.dk is no longer as large as before, it may have a significant impact on the commercial capacity in the storage facilities.

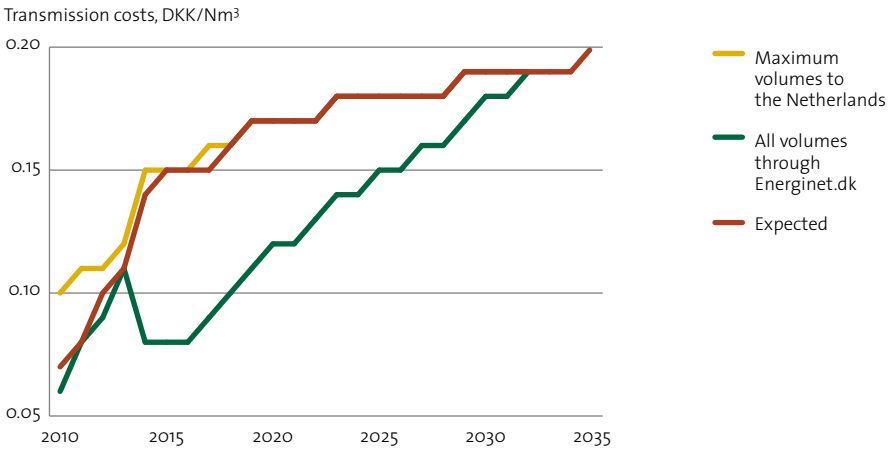


Figure 5-7: Effect of different distributions of transport volumes between Germany and the Netherlands 2009-2020.

In normal situations, the capacity requirement is similarly estimated to vary by up to 10 million Nm³/day, corresponding to the existing capacity of 18 million Nm³/day.

When supplies from the North Sea are phased out, the requirement for storage volume and capacity may increase.

If the gas system, in the long term, is to be used as reserve/peak load to ensure security of supply in a heavily expanded power system based on wind power, this may lead to additional storage requirements.

## 5.5 Transit to Germany

Energinet.dk has not yet sold any capacity for the 2011 gas year, ie from October 2011. Shippers are, however, expected to transport considerably less gas through Denmark next year as a result of the declining North Sea production.

Just under half of the gas production in the Danish part of the North Sea has for several years been exported to the Netherlands and Germany. The gas to the Netherlands is exported offshore through the NOGAT pipeline and thus not through Energinet.dk's transmission network, while the gas to Germany enters Denmark via Nybro and is sent through the transmission network to Germany via Ellund. Exports to Germany thus contribute to the economy in the Danish gas network through the payment of transmission tariffs. As North Sea production starts to fall, exports to Germany will decline. From October 2010, it became possible to physically import gas from Germany, and already before 2014, when the expansion towards Germany has been completed, Denmark is expected to become a net importer of gas from Germany on an annual basis.

As production falls in the coming years, the distribution of the falling export volumes between the Netherlands and Germany will thus considerably impact Energinet.dk's transmission income. Energinet.dk expects the exports to Germany to stop before those to the Netherlands. Exports to the Netherlands may, however, also stop first, which means that the gas will enter Denmark via Nybro. This depends on the commercial players' gas agreements and the transport prices in the Danish, German and Dutch transmission networks as well as the NOGAT pipeline.

The various alternatives for the coming years' exports have a direct influence on the Danish transmission tariffs. The effect can be measured using different distributions of the export volumes as shown in Figure 5-7. The figure shows that the average transport costs may increase steadily from approximately DKK 0.07/m³ in 2009 to approximately DKK 0.15/m³ in 2017.

The within-year difference in costs is large. Already in 2010, the difference between realised transport costs will be just under 50% (DKK 0.067 and DKK 0.10/m³, respectively). Over time, the cost curves will converge as production decreases.

**Note on volume assumptions:**

- Expected development: Exports to Germany stop before exports to the Netherlands
- High transmission costs: Danish North Sea production is exported directly to the Netherlands, bypassing the Danish transmission system
- Low transmission costs: North Sea production is sent through the Danish transmission system, and there is a considerable transit of gas to the German market concurrently with imports across the Ellund border point, which means that the transmission volume is considerably larger earlier in the period than consumption in the


Danish and Swedish markets. The sharp decline from 2013 to 2014 is a result of the production from the new Hejre field still not being increased.

## 5.6 Gas quality

For the past 25 years, the Danish gas market has received Danish North Sea gas only. Danish North Sea gas belongs to the second gas family, group H, and is characterised by a highly uniform composition and thus a very uniform quality. Danish natural gas has always had a high Wobbe index compared to the gas in surrounding systems. The explanation is that Danish gas has a relatively high content of ethane, propane and butane, which are not removed from the natural gas. Norway usually extracts these intermediate fractions, which are sold separately as, for example, LPG (Liquefied Petroleum Gas) or used as raw materials or fuel gas.

Over the past eight years, the Wobbe index of distributed Danish gas has been in the range of 15.0-15.5 kWh/Nm$^3$ (54.0-55.8 MJ/Nm$^3$). The gas rules allow the distribution of gas with a Wobbe index in the 14.1-15.5 kWh/Nm$^3$ range (50.8-55.8 MJ/Nm$^3$).

Natural gas will still belong to group H of the second gas family following the establishment of new supply routes. Customers will, however, receive gas of a different quality in Denmark. Similarly, they will probably also experience greater variation in gas quality. This applies whether or not future supplies will come from Norway, Germany, the Netherlands or Russia, as LNG or as a mixture from Germany. Following the decision to expand the infrastructure to Germany, the gas quality scenarios in the period from 2013 and onwards will be influenced by German supplies.

### 5.6.1 Gas from Germany via Ellund from 2013

Following the establishment of increased capacity at the Danish-German border in 2013, German gas imports are expected, which, in Egtved, will be mixed with natural gas from the Danish part of the North Sea. Supplies from the two entry points, and thus the mixing ratio between North Sea and German gas, will depend on commercial orders.

The composition of the gas from Germany will vary depending on the actual supply conditions and is typically a mixture of domestic German gas, Norwegian, Dutch and Russian gas as well as biogas. The German gas is expected to have a considerably lower Wobbe index and calorific value as well as greater variation in these parameters than experienced by Danish gas consumers to date. Historically, the variation in the German gas is from 13.9 to 15.3 kWh/Nm$^3$, which is also expected to be the variation range for future supplies from Germany to Denmark. The Danish Wobbe index specification is expected to be changed to allow for free imports of German gas in terms of gas quality already from 2011.

As for other gas quality parameters such as relative density, sulphur content and dew points, the imported gas will be within the limits set out in the gas rules and the Rules for Gas Transport.

# 6. Development in infrastructure

## 6.1 Status of the Ellund-Egtved expansion

Pursuant to the Danish Act on Energinet.dk, the Danish Minister for Climate and Energy has approved the establishment of installations to increase the transport capacity from the Danish-German border to Egtved. In letters of 29 January 2010 and 17 May 2010, the minister gave Energinet.dk permission to go ahead with both compressor station and pipeline looping.

A compressor station is to be constructed with the aim of increasing gas pressure from the level at which the gas is received from Germany to a pressure in the Danish gas transmission network which ensures that the required gas flow is maintained.

In addition to the compressor station, it is necessary to lay a 94 km gas transmission pipeline from the German border to Egtved. Today, there is a pipeline from Ellund/Frøslev to Egtved (24"), which is currently exporting gas from the North Sea to Germany. Capacity analyses have shown, however, that the existing pipeline does not facilitate gas imports in adequate volumes. It is therefore necessary to supplement the existing pipeline with a parallel connection (30").

The construction of the compressor station is decisive for the overall timetable. In 2010, tenders were invited for the project planning and construction of the compressor station. Following the conclusion of a contract with a turnkey supplier, the project planning for the plant will be commenced in 2011. The compressor station will be ready for commissioning in autumn 2013.

As is the case with the compressor station, an agreement on the project planning for the gas pipeline was also concluded in 2010. Preliminary archaeological studies will be conducted along the entire pipeline in 2011, and the final routing will be determined. Actual pipeline construction will be carried out in spring 2012, and the pipeline can be put into operation in autumn 2013.

Below follows a description of the two main infrastructure elements of the project, ie the gas transmission pipeline and the compressor station as well as the service facilities and valve arrangements intended to support operations and ensure a high safety level.

The gas transmission pipeline, the compressor station and all control equipment will be planned and constructed in accordance with the Danish executive order no. 414 of 8 July 1988 with subsequent amendments on safety provisions for natural gas systems pursuant to the Danish Working Environment Act (*Lov om arbejdsmiljø*). With certain limitations, this executive order recognises the detailed instructions set out in the US standard 'Guide for Transmission and Distribution Piping Systems, GPTC, 1998'. The GPTC guide is supplemented by additional provisions from the Danish Working Environment Authority set out in a guide (*AT-vejledning*) from July 2001. This guide refers to a number of standards for materials and construction.

The Directorate of the Danish Working Environment Authority will approve the construction of the systems, ensure that the requirements set out in the executive order are complied with and issue the commissioning permit.

### 6.1.1 Gas transmission pipeline

The preliminary line route for the gas transmission pipeline is planned to run closely in parallel with the existing gas pipeline, at the same time taking into account residents and users of the areas and local conditions such as crossings of watercourses, roads and other

| | |
|---|---|
| Total length (km) | 94 |
| Outer diameter (mm) | 762 |
| Length of individual pipes (m) | 11-18 |
| Depth below ground (m) | Minimum 1 |
| Material | Steel |
| Outer coating | Polyethylene (PE) |
| Inner coating | Epoxy |
| Design pressure (bar) | 80 |
| Design temperature (° C) | -25 to +50° C |

Table 6.1: General information about the gas transmission pipeline.

infrastructure elements, so that the construction work can be carried out with as little impact on the surroundings as possible.

In connection with the planning of the line route, it will be expedient for the new gas transmission pipeline to generally follow the existing gas pipeline at a distance of minimum 10 metres. This makes it possible to place the pipeline within the already established zone which, through compulsory acquisition, is subject to restrictions, and support facilities including valve stations along the section can be shared by the two pipelines. Considerable knowledge of local conditions was gained from the construction of the existing pipeline, which may be used when the new pipeline is to be constructed.

The detailed line route will be established taking into account safety requirements which ensure that minimum distances to existing built-up areas are maintained. In connection with the environmental impact assessment (EIA) procedure, natural, landscape and environmental conditions have been assessed in the test area to achieve the most appropriate location in relation to local conditions. The purpose has been to optimise the detailed line route in terms of environmental considerations, taking account of the technical and financial possibilities that dictate the placing of the gas transmission pipeline.

The actual gas pipeline will be made of steel pipes with an outer diameter of 30" (76.2 cm) which are welded on site and placed with a soil layer of at least 1 metre. The steel pipes are supplied with an external anti-corrosive coating. A coating has been applied to the inside of the pipes to reduce friction in the pipes.

Table 6.1 provides general information about the gas transmission pipeline.

The gas transmission pipeline will be laid in accordance with the provisions for safety distances to residential properties set out in the Danish supplementary provisions to the US GPTC standard and in accordance with Energinet.dk's own requirements. One implication of this is that densely populated areas should be avoided to the extent possible. In addition, minimum distances to buildings frequented by people are observed. The distances are calculated based on pipe dimensions, wall thickness and pressure. In the event that proximity to residential properties cannot be avoided, special test and construction requirements apply, including an increase of pipe wall thickness.

The archaeological preliminary study may have consequences for the line routing. In connection with the necessary compulsory acquisition, adjustments can be made following negotiations between landowners and Energinet.dk. These final negotiations are conducted by the committee responsible for the compulsory acquisition.

### 6.1.2 Compressor station in Egtved

Different locations for the compressor station have been investigated, and analyses show that the most appropriate location is on Energinet.dk's area in Egtved, where Energinet.dk already has an operations and maintenance centre as well as a control centre for the entire gas transmission system in Denmark. The compressor station in Egtved will be located in the intersection point between the west-easterly main transmission pipeline from Nybro (gas from the North Sea) to eastern Denmark and the north-southbound main transmission pipeline from Aalborg and the gas storage facility in Lille Torup to the Danish-German border, see Figure 6-1. This location provides, among other things, considerable flexibility in terms of gas transmission as the gas, as required, can be received and transported in all directions (north, south, east and west).


Figure 6-1: Main transmission pipelines in Denmark.

The compressor station in Egtved is to increase the pressure in the gas transmission system so that gas in sufficient volumes can be transported over long distances, thus contributing to ensuring the necessary gas flow in a future supply situation. The Egtved location opens up for a large number of supply scenarios, eg supplies via the existing gas pipeline and the new pipeline from Germany. In addition, there are already two 30" pipelines today from Nybro and a 20" pipeline from Lille Torup gas storage facility.

This requires an expansion of the existing valve arrangements in the intersection point between the gas transmission pipelines. These valve arrangements will be established on the area in Egtved north of the future compressor station where there are valves already.

A conceptual design for the compressor station has been prepared in the planning phase. In the detail planning phase, all details will be determined, but the overall concept for station construction will follow the guidelines from the preliminary design.

The compressor station is expected to consist of four separate electrically driven compressor units of identical dimensions. By combining several small

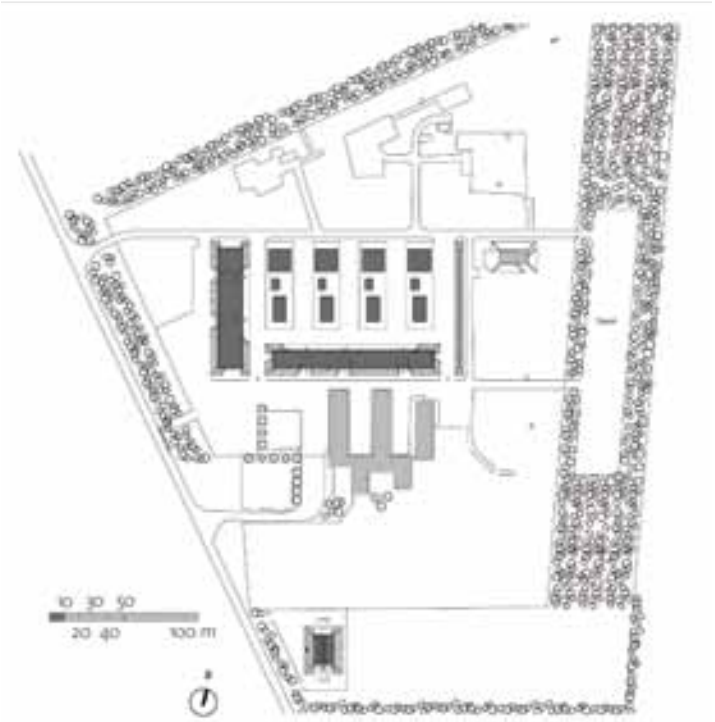


Figure 6-2: Preliminary layout plan showing the location of the compressor units and the planned service buildings on Energinet.dk's area in Egtved and the possible transformer location. Copyright Arkitektfirmaet C.F. Møller.

compressor station units, the necessary operational flexibility is ensured, taking account of the gas offtake. At the same time, a reserve capacity is maintained to meet the requirement for security of supply.

Each compressor unit has a filter which removes impurities from the gas, followed by a compressor with an electric motor and, finally, a cooling unit to cool the gas. These three part components and the compressor units will be interconnected via pipes which, if possible, will be routed close to or below ground level. Each compressor will be located in a noise-reducing building, each designed as industrial buildings, whereas filters and cooling units will be placed as stand-alone shielded machine components on the area. Each compressor building will cover 50-100 $m^2$ and will be 6-9 metres tall, and the filter and cooling units will be 6-8 metres tall. For safety reasons, the compressor units will be connected to blow-off pipes from which gas can be ventilated in an emergency situation and in connection with planned service of the plant. The blow-off pipes will be made of steel with a preliminarily calculated height of 15 metres. Blow-off is expected to take place once annually on average for each compressor unit.

The compressor station will be designed for a total capacity of 20 MW. This ensures that the pressure can be increased from 52 to 78 bar at a gas flow of 700,000 $Nm^3$ per hour from Germany, corresponding to the total capacity for both gas pipelines on the Ellund-Egtved section. There will always be a backup compressor unit. Each compressor unit will have a capacity of approximately 5 MW, which provides the desired flexibility in terms of pressure increase and flow capacity. The cooling systems on the compressor units will be prepared for subsequent heat recovery by means of heat pumps, for example. The design pressure for the compressor station has been fixed at 80 bar, and the design temperature is -28 to +50° C.

In addition to the compressor buildings with components, a service building will be constructed to house, among other things, control systems, electricity supply, emergency generator, spare parts and workshops. For service purposes, the valve arrangement for controlling the gas flow will be installed above ground level. The valves can be controlled and monitored from the control centre, but can also be remote controlled and monitored from the compressor station. If necessary, all valves can also be operated manually.

To the extent this is technically feasible, surplus heat from the compressors will be recovered. The heat will be used to heat buildings and water in the entire complex of buildings in Egtved, which comprises both the existing control and monitoring centre and buildings connected to the compressor station. As backup for the heat recovery plant, a new boiler house will be constructed in connection with the service building between the compressor station and the control centre.

Energinet.dk has contacted a recognised firm of architects which, in collaboration with the projecting engineers, will ensure the best possible location of the plant in the landscape.

As regards the appearance of the plant in the landscape, it should be mentioned that plantation has already today been established around Energinet.dk's entire area in Egtved, which surrounds and shields the view of the entire plant.

### 6.1.3 Line valve stations

In addition to the construction of the gas transmission pipeline itself, small plant elements need to be established on the section Ellund/Frøslev-Egtved which are to be connected to the pipeline.

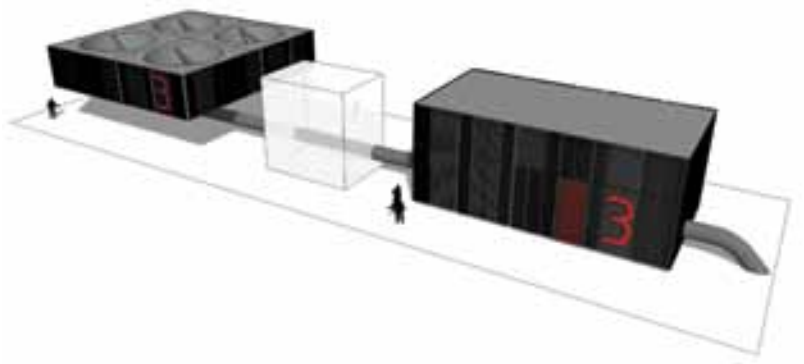

Figure 6-3: Drawing of a compressor unit. From left: Cooling unit, filter unit, compressor. Copyright Arkitektfirmaet C.F. Møller.

Figure 6-4: Preliminary drawing of plant design. Compressor units and new service buildings. Copyright Arkitektfirmaet C.F. Møller.

These elements are line valve stations which will be placed with a spacing that complies with the rules set out in the GPTC guide[16]. The spacing between the line valves currently varies from 7 to 26 km. The existing line valve stations connected to the existing gas pipeline are utilised by connecting the new pipeline to the stations. The line valve stations can be used to sectionally close off the gas in the pipeline in the event of repair work, and they include a valve arrangement and a blow-off stack which, together with pipes and flanges, constitute the visual above-ground part of the station. A line valve station typically covers an area of approximately 1,500 m$^2$. All valve stations are surrounded by border plantation shielding the view of the technical plant.

The new gas transmission pipeline will be connected to line valve stations at each end of the pipeline (Frøslev and Egtved) and to three connection points on the section (Vollerup, Rangstrup and Farris). The new gas pipeline does not give rise to the construction of new valve stations.

Upon connection of the new gas transmission pipeline, minor renovations and

[16] The guide concerns population density within a distance of 200 metres to each side of the pipeline.

Figure 6-5: M/R station, here combined with a line valve station shown at the front.

expansions of existing valve stations will be required. At some stations, expansion of existing areas is to be expected. If parts of the plantation are removed during this work, it will be reestablished upon completion of the work.

**Authority approval**
The establishment of the plants requires a number of permits in accordance with applicable legislation. So far, focus has been on obtaining permits under the Danish Spatial Planning Act (*Planloven*) and the Danish Environmental Protection Act (*Miljøloven*). An EIA has thus been prepared and was submitted for public consultation in June 2010. The EIA procedures aim at obtaining comments from the public on the expected environmental impacts of the project. An EIA permit for the establishment of the entire plant is expected to be obtained before the end of 2010.

The environmental impact assessment comprises the pipeline from the Ellund/Frøslev border point to Egtved and the compressor station. It is proposed that the pipeline be constructed in parallel with the existing gas pipeline, locally, however, with line route alternatives.

For the compressor station in Egtved, an EIA permit from 8 April 2008 exists. This permit was granted by the environmental centre in Odense based on a project involving transport of additional gas volumes on the Egtved-Dragør section. It has been decided to conduct a new overall environmental assessment of the Ellund-Egtved pipeline and the compressor station which are to both ensure supplies from Germany as well as west-east transport.

The construction of the compressor stations also requires the preparation of a local development plan in the Municipality of Vejle. A draft local development plan is being prepared and is expected to be submitted for public consultation in 2010. The local development plan is expected to be finally adopted in the first half of 2011.

## 6.2 Potential reduction of energy consumption for compression of gas from Tyra Øst to Denmark

### 6.2.1 Background

In 2009-2010, Energinet.dk conducted an analysis in cooperation with the Danish Energy Agency to determine whether it is possible to lower the pressure of the export gas from Tyra Øst to Denmark in order to reduce energy consumption for compression. The analysis has been made because very high gas consumption for compression in the North Sea has been observed, amounting to around half of total fuel consumption.

### 6.2.2 Analysis

Energinet.dk was responsible for conducting the technical analyses of the possibilities of reducing energy consumption for the transport of natural gas from Tyra Øst to Nybro. The analysis was based on the Danish Energy Agency's forecast scenarios for gas production and Energinet.dk's assessment of potential gas exports to Denmark from Tyra Øst until 2025. In addition to an expected scenario, a low scenario and a high scenario were also drawn up. In this context, gas quality and the load factor on supplies from Tyra Øst were taken into account.

A number of calculation scenarios with different outlet pressures ex Nybro have been drawn up. The analysis thus deals with the possibility of lowering the pressure ex Nybro from the existing 78 barg to 70 barg, 60 barg and 50 barg and includes a calculation of the potential

| Scenario | Medium | High | Low |
|---|---|---|---|
| | Million Nm³ | | |
| 1. Reference scenario with 78 barg ex Nybro | 575 | 735 | 325 |
| 2. Tyra compressor plus gas-driven compressor in Nybro, with waste heat | 545 | 705 | 308 |
| 3. Tyra compressor plus gas-driven compressor in Nybro, without waste heat | 594 | 773 | 325 |
| 4. Tyra compressor plus electrically driven compressor in Nybro | 492 | 640 | 295 |
| 5. Tyra compressor plus electrically driven compressor in Egtved | 495 | 645 | 299 |

Table 6.2: Accumulated energy consumption for the period 2009-2025.

energy savings as a consequence of the resulting pressure reduction. In order to be able to maintain the pressure in the transmission network at 78 barg, two solutions involving renewed compression onshore, either in Nybro or in Egtved, were also analysed. Both gas and electrically driven compressors and the possibility of utilising surplus heat were analysed. As regards the new compressor in Egtved, the same inlet pressure and the same flow profile were used as for the compressor in Nybro, which means that future supplies from Germany will have no bearing on the results of this analysis. All scenarios were compared to a reference situation, which is the supply so far with an outlet pressure ex Nybro of 78 barg.

The energy consumption calculations will form the basis of the further economic evaluation to be carried out by the Danish Energy Agency.

### 6.2.3 Results

Table 6.2 shows the accumulated fuel consumption translated into million Nm³ gas for the entire period[17] from 2009 to 2025 and in relation to the different scenarios mentioned above. The results indicate that it is the two solutions involving limited compression offshore and recompression onshore using energy-efficient electrically driven compressors in Nybro or Egtved (4 and 5) which will yield the largest possible energy savings. The differences shown are, however, marginal and very sensitive to the calculation assumptions, particularly in the low scenario, which is probably the most likely.

A solution combining a compressor in Tyra and an electrically driven compressor in Nybro or Egtved yields the lowest energy consumption.

Establishing Energinet.dk's compressor station in Egtved, see section 6.1, opens up for attempting to realise the energy savings achieved on energy consumption. A realisation of the energy savings will require renegotiation of commercial agreements between the companies selling, buying and transporting gas from Tyra Øst.

[17] Consumption on the new compressors in Nybro and Egtved has been accumulated from 2014 as an onshore compressor station will not be operational until 2014 at the earliest.

## 6.3 Potential transmission system expansions in the long term – the Norway project

### 6.3.1 Background and overview

In the autumn of 2009 when, on the basis of the Open Season process conducted, Energinet.dk applied to the Danish Ministry of Climate and Energy for permission to construct a compressor station in Egtved and to loop the pipeline between Egtved and Ellund, it was decided that the looping required further studies.

The Danish Ministry of Climate and Energy therefore appointed a working group tasked with analysing the consequences for the North Sea producers of looping the Ellund-Egtved pipeline and how the use of the North Sea infrastructure can be optimised in future. The working group completed its work in May 2010, and the conclusion was that looping the pipeline between Ellund and Egtved was the optimum solution to ensure supplies.

According to the ministry, the analysis shows that, in addition to the capacity increase resulting from looping the

Ellund-Egtved pipeline, there may be a need to open up for additional imports of gas from Norway in order to secure supplies to the Danish and Swedish markets and with a view to onward supply to the northern European market, including the Baltic states. On this basis, it is recommended that, in addition to establishing a compressor station and pipeline looping, work be continued to find potential solutions for importing Norwegian gas either via existing Danish infrastructure or direct to the shore, and that the possibilities of utilising one or more of the Danish North Sea gas fields for gas storage be assessed.[18]

Against this background, Energinet.dk has launched a number of initiatives aimed at investigating the physical and commercial possibilities for a Danish-Norwegian interconnection. A dialogue has thus been conducted with all relevant players on the Norwegian and Danish sides, including close cooperation with the Norwegian offshore system operator Gassco and the Danish authorities.

[18] Source: 'Expansion of the infrastructure for transporting natural gas with a view to future imports to Denmark' (*Udbygning af infrastrukturen til transport af naturgas med henblik på fremtidig import til Danmark*), Danish Energy Agency, 2010.

Energinet.dk thus held a seminar for the entire sector in September 2010 which many players participated in and which paved the way for the further process.

At the beginning of 2011, a clarification of which interconnections it will be technically feasible to establish in the short term is expected. This work, which is headed by Gassco, involves offshore infrastructure owners. Concurrently with this work, the market basis for a positive business case is being investigated by the commercial players. Energinet.dk is aiming towards a final investment decision being made before the end of 2011.

**Overview of alternatives**

There are various physically realisable possibilities for importing gas from Norway to Denmark and for transmitting gas from Norway through Denmark and onwards to Poland and the northern European gas market. Some of the alternatives described are of a scope which only makes distribution to the Danish and Swedish markets relevant, whereas others are of such magnitude so as to enable further distribution to the northern European market. Some alternatives utilise the existing Danish offshore infrastructure, while others imply new pipelines for the onshore system in Denmark. Similarly, some of the alternatives primarily utilise existing onshore infrastructure, while others entail new onshore pipelines.

The alternatives involving interconnections to Poland and the northern European gas market also comprise a new pipeline between Denmark and Poland called Baltic Pipe. The Baltic Pipe project has been analysed a number of times over the last decade, and an EIA permit has been granted for the onshore parts of the project in Denmark. In light of the new capacity between Germany and Denmark and the new analyses of interconnections to Norway, it should be considered whether the technical solution forming the basis of the EIA permit should be subjected to a renewed EIA process.

Energinet.dk has described three different solutions for transporting Norwegian gas to Denmark and Sweden and for further distribution to the northern European gas market. As shown in Figure 6-6, these solutions are called 1, 2.1 and 2.2.

At present, no decisions have been made as to optimum routes. The alternatives shown should be seen as general technical descriptions of possible future interconnections. Alternative 1 is

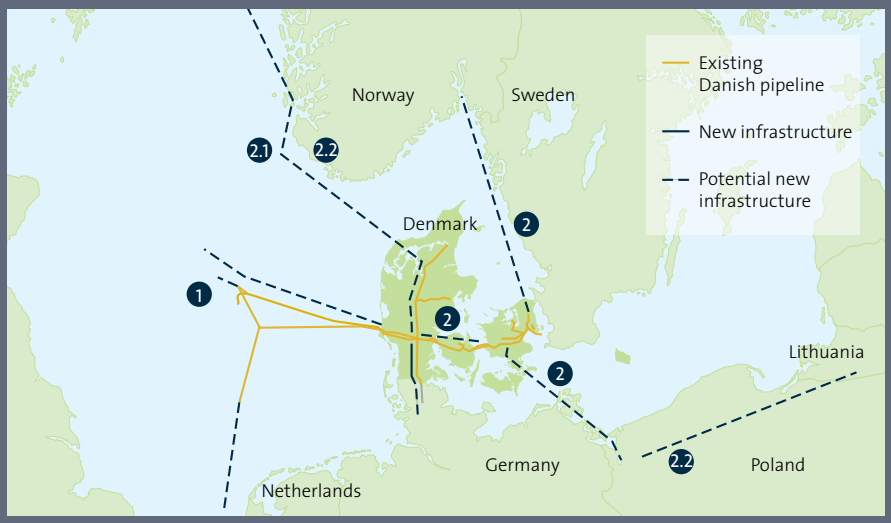


Figure 6-6: Existing gas transmission network with potential expansions from Norway to the Netherlands, Denmark, Sweden, Poland and further eastwards.

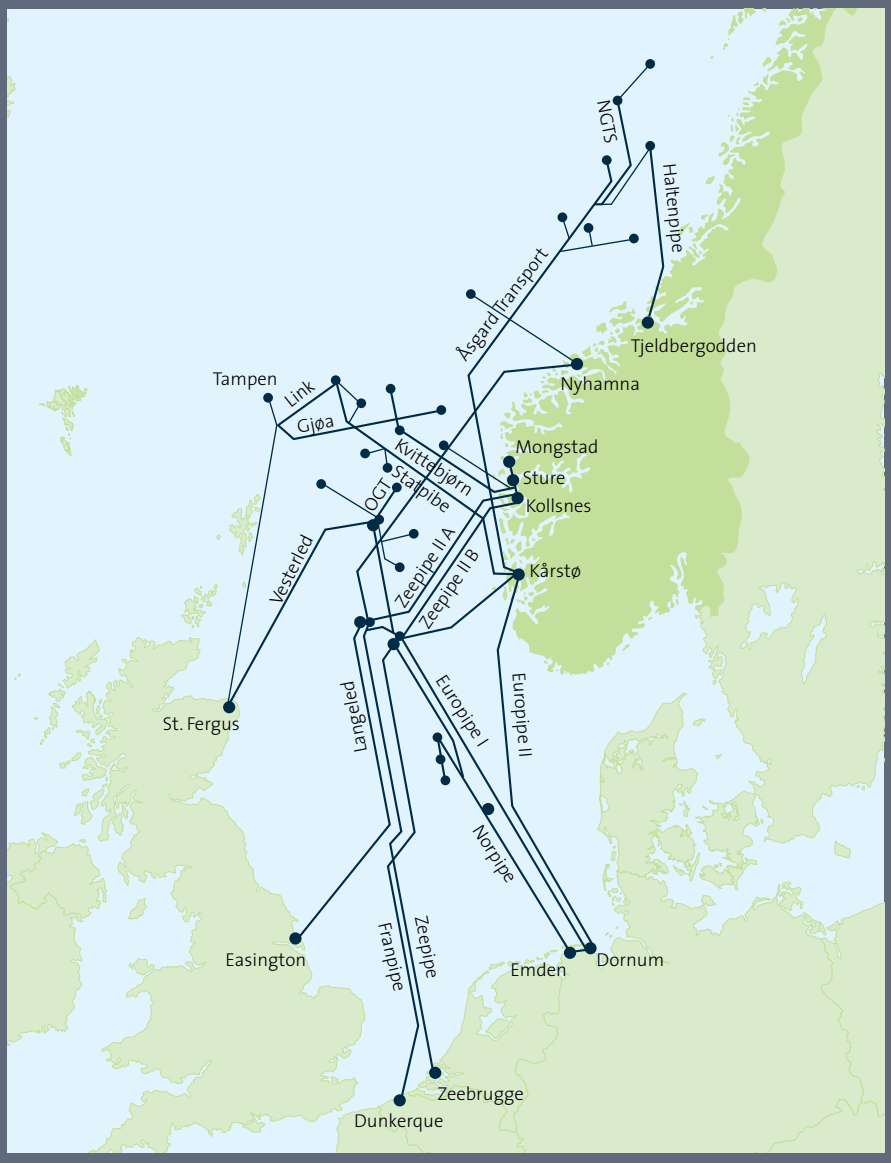


Figure 6-7: Norwegian offshore gas system.

currently being analysed in greater detail than the other alternatives, which are more uncertain at present.

Alternative 1 is an interconnection between the existing Norwegian offshore pipelines and the Danish offshore system. This can be achieved in a number of different ways with different possible capacities. Because of limitations in the Norwegian system, the capacity of the potential alternatives will be approximately 1-3 billion $Nm^3$/year. This means that only supplies to the Danish and Swedish markets and a possible continuation of the supplies to the Netherlands via NOGAT will be relevant.

Alternative 2.1 is an interconnection from further up in the Norwegian gas system to the Danish onshore system. This might be in the form of an interconnection from existing Norwegian offshore pipelines to Nybro in Denmark. The capacity of such an alternative is approximately 7 billion $Nm^3$/year, which would be sufficient to ensure a certain degree of transit of gas to Germany and/or Poland.

Alternative 2.2 is a new Norwegian pipeline to the Continent; this time to Denmark instead of to Germany or Belgium. This could be an interconnection from a collection point/hub in the Norwegian

offshore system to, for example, northern Jutland in Denmark. The pipeline should start in a collection point in the Norwegian system where gas is available. The potential capacity (10-25 billion Nm³/year) of this type of pipeline could be sufficiently large to enable significant transit volumes to Poland, Germany or other northern European countries.

The various possible solutions are described in the next section.

## 6.3.2 From Norway to Denmark

**Alternative 1**
Some of the Norwegian offshore gas pipelines to the Continent run through the Danish economic zone and close to the existing Danish offshore system. This is the case with Europipe I, Europipe II and Norpipe. These gas pipelines might offer natural connection options to the Danish offshore system.

**Gassco's Open Season 2010**
Gassco, the Norwegian offshore gas system operator, conducted two parallel Open Season processes in 2010. One of the processes, NSGI[19], focuses on pipelines to new fields and therefore on increasing transport capacity north of the existing collection points in the Gassled system[20]. Focus is on increasing transport capacity in the area northeast of Nyhamna in Norway.

The other Open Season process called 'GIR' (Gas Infrastructure Reinforcement), which focuses on increasing the possibilities of supplying gas from the collection points in the Norwegian system and down to the markets in the UK, Belgium, the Netherlands, Germany and possibly Denmark, is the most interesting option in relation to identifying the future possibilities of transporting Norwegian gas to Denmark. The alternatives included in this Open Season process constitute the most realistic possibilities of bringing Norwegian gas to Denmark.

At present, the most likely solution is the supply of gas to Denmark through Europipe I, which, according to Gassco, could reach around 8-9 million Nm³/day (corresponding to approximately 3 billion Nm³/year). This could, however, result in the capacity to Germany being reduced by 3-4 million Nm³/day.

Establishing an interconnection from Europipe II to the Danish system is also possible, but although this would marginally increase the total capacity of Europipe II, it would lead to a reduction in the capacity to Dornum in Germany. On Norpipe, the B11 platform will be decommissioned, which will result in a reduction in pipeline capacity. This leaves no room for supplies to Denmark, and new capacity from Norpipe is not included in the 'GIR' Open Season process.

Various possibilities of connecting Europipe I to the Danish platforms, the offshore pipelines and the onshore system are being investigated in GIR. Similarly, the possibilities of establishing an interconnection from Europipe II to offshore pipelines or the onshore system are being analysed.

The interconnections being analysed comprise pipes with a diameter of 20-24", a capacity of approximately 8-9 million Nm³/day (3 billion Nm³/year) and a pressure of 140 bar.

## 6.3.3 Danish analyses of potential connections

**Alternative 1**
The analyses conducted by the working group investigating the consequences for the North Sea producers of looping the Ellund-Egtved pipeline show that a

[19] Norwegian Sea Gas Infrastructure.

[20] Gassled comprises the Norwegian offshore pipeline systems.

pipeline from Europipe I can be connected to either the Tyra complex or the Harald platform in the Danish system.

An interconnection via Tyra could achieve a capacity of around 9 million m³/day (3 billion Nm³/year) and will require an approximately 24 km long pipeline of approximately 30".

An interconnection via Harald, but without additional compression at Harald, could achieve a capacity of around 9 million m³/day (3 billion Nm³/year) and will require an approximately 35 km long pipeline of approximately 24". If compression is performed at Harald, capacity can be increased to around 16 million m³/day (6 billion Nm³/year).

Alternative 1.1 offers the possibility of using the Danish fields as storage facilities as the new gas volumes will pass closely by the fields.

**Alternative 2.1**
An interconnection from the existing Norwegian offshore system to the Danish onshore system can be established by connecting, for example, Europipe I or Europipe II with Nybro when capacity is available. The capacity of such an interconnection could be approximately 7 billion Nm³/year.

Europipe II runs closer to the Danish shore, and it will therefore be cheaper to invest in a pipeline to Europipe II than to Europipe I. On the other hand, there are many indications that the possibilities of transporting gas through Europipe I are better. Both alternatives will therefore be analysed in greater detail.

**Alternative 2.2**
The largest alternative is the establishment of a new transmission pipeline from the Norwegian continental shelf to the Danish onshore system, which would ensure that the capacity is not limited by existing pipelines and platforms. The capacity could be 10-25 billion Nm³/year through the establishment of a 30-40" pipeline. On the Norwegian continental shelf, such a pipeline should be connected to a collection point which is expected to have ample volumes of gas in the coming years.

## 6.3.4 From Denmark to Poland

The largest alternatives (2.1 and 2.2) entail a possibility for the transit of gas to Poland.

Alternative 2.1 entails a transit option. This could, for example, be to Germany, but it could also be via Baltic Pipe to Poland. Exports to Germany can take place via the existing transmission system (incl. looping of the pipeline between Egtved and Ellund and the establishment of a compressor in Egtved). Export to Poland requires investments in Baltic Pipe.

The volumes of gas available in this alternative can be transported in the existing transmission system if the system is reinforced west-east and a compressor is established at the Baltic Pipe landing point. In this alternative where the volumes for export to Poland are limited, the export compressor for Baltic Pipe could probably be located in the area in Avedøre designated in the existing EIA permit.

If the capacity of Baltic Pipe is to be increased from approximately 3 billion Nm³/year to approximately 5 billion Nm³/year, it will be necessary to supplement the export compressor with a reinforcement of the pipeline between Torslunde and Avedøre. Such reinforcement may be very difficult to achieve both from a technical point of view and in respect of obtaining approval from the planning authorities as it will have to be established in a densely built-up urban area.

An alternative to reinforcing the pipeline between Torslunde and Avedøre could


Figure 6-8: Potential alternative expansions of the gas transmission network to Denmark, onshore in Denmark, and between Denmark and Poland.

be to move the Baltic Pipe landing point from Avedøre to Stevns. In this case, the capacity of Baltic Pipe could be increased to 8 billion Nm³/year.

If focus is placed on alternative 2.2, the Stevns location is probably the most relevant. In this case, Baltic Pipe will presumably be supplemented with increased consumption in Sweden and possibly an interconnection from Sweden to Norway.

## 6.3.5 Through Denmark

The largest alternative (2.2) will also require investments in the Danish onshore system in order to obtain sufficient west-to-east transport capacity. If the interconnection from Norway is brought ashore in northern Jutland, this will require looping of the pipeline between Lille Torup gas storage facility and the central collection point in Egtved as well as the establishment of a pipeline from the landing point to Lille Torup.

However, the large alternative will also necessitate reinforcement of the transmission system across the country from west to east. The construction of an extra pipeline under the Little Belt or alternatively further south will be necessary, possibly along with the establishment of additional compressor capacity in Egtved.

**Positive effects of transit**

The transit of gas through Denmark will have a positive market impact. Alternative 2.2, which involves large interconnections to Norway and Poland, will place Denmark right between the two major suppliers of gas to the northern European market (Russia and Norway), which will open up for creating a flexible spot market with good price signals, financial products and high liquidity.

Denmark will also be in a good position to become a hub between the different options for transporting gas in northern Europe, which will lead to improved security of supply as supplies are diversified in terms of sources as well as routes.

The impact on the tariffs for Danish and Swedish consumers will also be positive as the costs will be distributed on more volumes. Naturally, this is only the case if the transit capacity is used. If not, it will result in increased unit costs per m³ as all investments must then be paid by the customers using the system.

**Possibilities of using the Danish fields as storage facilities**

Gas fields which are no longer able to produce gas can generally be used as storage facilities. This is done in many parts of the world. One advantage of this is that the cushion gas[21] which normally needs to be pumped down into

[21] Cushion gas is the volume of gas which must be pumped down into a gas storage facility in order to make it possible to pump the working gas in and out of the facility. Cushion gas cannot normally be re-extracted from the storage facility.

a storage facility before the facility can be used is already there and need not be bought.

Compared with the Norwegian gas fields, the Danish fields might offer an advantage as storage facilities in relation to the alternatives with gas from Norway to Denmark as the Danish fields are situated closer to the consumers. This is particularly true of the Norwegian fields in the Norwegian Sea which hold gas for many years of supply. An offshore storage facility will improve the flexibility and could offer a higher load factor on the pipelines from the production sites.

The Danish fields – especially Tyra – were previously used as swing storage with approximately 3 bcm being injected on an annual basis. The reinjected gas comes from either the Tyra field itself or from the neighbouring fields.

## 6.4 Strategic environmental assessment

Energinet.dk has assessed that certain sections of Gas in Denmark 2010 contain considerations in respect of new infrastructure which should be subjected to a strategic environmental assessment (SEA). This concerns the plans for the new potential interconnections to Norway described in section 6, primarily in subsection 6.3 on a potential connection to Norway in the long term, and the possibilities of developing biogas in Denmark described in theme section 1.7 on biogas.

In July/August 2010, a brief delimiting consultation was conducted with a view to determining which environmental parameters the strategic environmental assessment is to comprise. The responses primarily concerned issues relating to an EIA phase or issues relating to overall energy policy, which fall outside the scope of Energinet.dk's area of responsibility.

Energinet.dk has had a strategic environmental assessment prepared. This shows that most of the major environmental impacts can be reduced or completely avoided when specific and detailed planning of where to place the pipelines and other plants has taken place in connection with a coming EIA process. It is therefore assessed that there are no environmental problems which directly prevent any of the alternatives described.

The strategic environmental assessment was submitted for consultation in October/November. Ten consultation responses were received within the consultation deadline. The consultation responses do not give rise to any changes in the plan, and they have not pointed to any shortcomings in the environmental assessment.

# 7. Distribution

## 7.1 Capacities and offtake

Supplies to the individual M/R stations in the transmission system and to the individual consumers must be maintained in normal situations as well as in emergency situations with very low daily mean temperatures. This is ensured by analysing the systems and assessing natural gas offtake from each M/R station.

Due to the variation in gas consumption during the day, the transmission system is analysed by means of dynamic calculations over several days. The distribution systems are analysed solely on the basis of static calculations of the situation during the hour of the day when consumption peaks.

### 7.1.1 M/R stations

Each year, Energinet.dk assesses whether the individual M/R stations are capable of meeting the supply requirements based on historical data and an estimate of expected maximum offtake at the daily design temperature. The possible supply via an M/R station depends on inlet pressure and outlet pressure from the station. Outlet pressure is determined by the regional companies, whereas the inlet pressure is determined by the current load situation. Energinet.dk makes a base case calculation once a year, stating the expectations for the maximum network load during the coming winter.

For winter 2010/2011, the capacity of the individual M/R stations has been computed on the basis of the calculated minimum inlet pressure based on offtake at a daily mean temperature of -13° C and on the basis of the outlet pressure determined by the regional companies. Station capacities are stated in Table 7.1, in which the presumed offtakes during the peak day and average peak hour are also shown. It should be pointed out that the station capacities shown are based on the inlet pressure and outlet pressure stated in the table, and that the outlet pressure in some cases may be lower. Total offtake as a function of the daily mean temperature is illustrated in Figure 7-1.

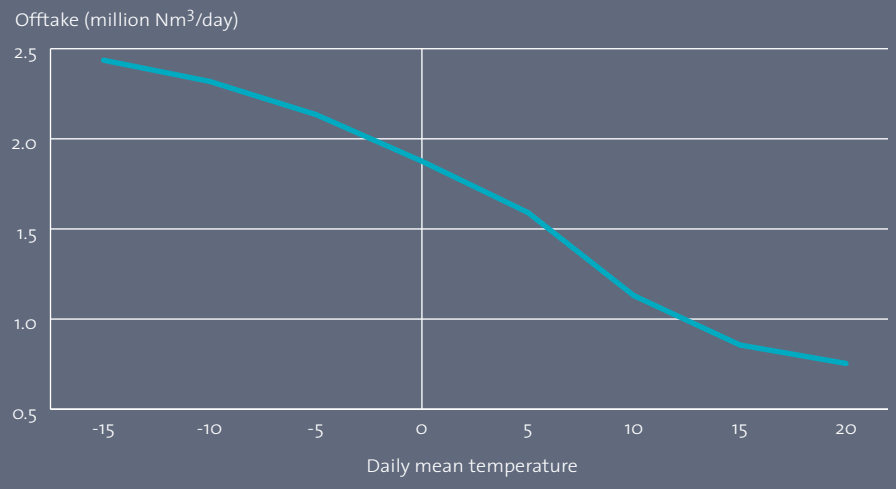


Figure 7-1: Relationship between daily mean temperature and total natural gas offtake in Denmark.

| M/R station | Expected offtake during peak day (-13° C) | Expected offtake during average peak hour (-13° C) | Calculated inlet pressure | Agreed setpoint | M/R station. Calculated capacity -13° C | Expected capacity requirements of distribution companies | Measured peak hour 01-05-2009 to 30-04-2010 |
|---|---|---|---|---|---|---|---|
| | 1,000 Nm³/d | Nm³/h | Barg | Barg | Nm³/h | Nm³/h | Nm³/h |
| Amager Fælled | 38 | 2,537 | 50.3 | 16.6 | 14,104 | 5,700 | 3,815 |
| Billesbølle | 93 | 4,371 | 59.6 | 17.1 | 9,091 | 4,763 | 4,985 |
| Brande | 81 | 3,916 | 64.2 | 35.4 | 11,059 | 12,000 | 4,894 |
| Brøndby | 1,487 | 62,629 | 51.6 | 33.9 | 118,011 | 102,000 | 69,456 |
| Dragør | 211 | 9,156 | 50.7 | 16.6 | 23,039 | 12,000 | 9,803 |
| Egtved | 1,047 | 45,998 | 63.4 | 35.4 | 60,609 | 63,000 | 53,488 |
| Ellidshøj | 187 | 8,455 | 68.0 | 35.4 | 42,275 | 20,000 | 9,748 |
| Frøslev | 666 | 29,813 | 56.2 | 35.4 | 38,169 | 38,000 | 35,008 |
| Haverslev | 284 | 13,686 | 69.3 | 35.4 | 26,388 | 34,000 | 28,241 |
| Helle | 13 | 646 | 64.7 | 16.0 | 8,543 | 600 | 836 |
| Herning | 2,012 | 85,477 | 64.7 | 47.6 | 152,497 | 140,000 | 102,656 |
| Højby | 406 | 19,310 | 57.7 | 18.3 | 126,985 | 27,592 | 24,861 |
| Karlslunde | 483 | 21,960 | 53.0 | 17.9 | 83,742 | 80,000 | 37,666 |
| Karup | 266 | 11,805 | 66.3 | 35.4 | 28,878 | 26,000 | 13,055 |
| Koelbjerg | 409 | 19,758 | 59.2 | 18.3 | 39,223 | 26,433 | 35,613 |
| Køge | 498 | 22,747 | 53.4 | 17.9 | 37,195 | 40,000 | 34,312 |
| Lille Selskær | 451 | 20,621 | 60.4 | 35.4 | 39,625 | 32,000 | 22,064 |
| Lille Torup | 60 | 2,733 | 71.3 | 35.4 | 8,911 | 10,000 | 3,098 |
| Lilballe | - | - | 61.9 | 3.6 | 8,859 | 2,500 | 2,461 |
| Lynge | 1,497 | 62,749 | 49.0 | 32.7 | 129,324 | 106,000 | 71,216 |
| Middelfart | 64 | 2,842 | 60.8 | 17.1 | 9,269 | 2,728 | 3,097 |
| Måløv | 1,999 | 83,389 | 49.5 | 17.9 | 106,000 | 106,000 | 62,400 |
| Nyborg | 37 | 1,716 | 56.6 | 17.1 | 8,645 | 2,095 | 2,921 |
| Nybro | 52 | 2,421 | 65.9 | 17.1 | 4,024 | 3,200 | 2,683 |
| Nørskov | 307 | 13,495 | 63.7 | 35.4 | 24,088 | 21,800 | 16,492 |
| Pottehuse | 187 | 9,374 | 61.7 | 35.4 | 33,916 | 13,000 | 8,124 |
| Ringsted | 663 | 28,973 | 54.2 | 25.0 | 37,481 | 39,000 | 38,480 |
| Slagelse | 278 | 12,707 | 55.9 | 16.7 | 38,067 | 17,900 | 21,178 |
| Sorø | - | - | 55.1 | 17.9 | 37,776 | 0 | 26,792 |
| St. Andst | 354 | 16,392 | 62.2 | 35.4 | 40,253 | 27,000 | 22,752 |
| Stenlille | 627 | 27,471 | 59.2 | 17.7 | 37,788 | 38,400 | 29,280 |
| Sydhavnen | 18 | 819 | 50.2 | 3.6 | 5,792 | 3,000 | 1,326 |
| Taulov | 56 | 3,019 | 61.2 | 35.4 | 34,571 | 7,100 | 4,868 |
| Terkelsbøl | 335 | 15,055 | 57.5 | 35.4 | 21,250 | 21,300 | 22,720 |
| Torslunde | 194 | 8,532 | 52.8 | 17.9 | 32,792 | 32,000 | 15,688 |
| Ullerslev | 147 | 6,409 | 57.1 | 17.1 | 8,717 | 6,934 | 6,997 |
| Vallensbæk | 132 | 5,498 | 51.9 | 17.9 | 33,685 | 32,000 | 24,921 |
| Varde | 166 | 8,119 | 65.3 | 35.4 | 39,898 | 25,000 | 13,630 |
| Viborg | 1,523 | 65,234 | 68.0 | 35.3 | 95,125 | 110,000 | 76,096 |
| Aalborg | 1,383 | 62,102 | 67.1 | 44.3 | 155,793 | 116,000 | 70,992 |

Table 7.1: Expected offtake, calculated inlet and outlet pressure and capacities for M/R stations in the transmission system in normal supply situations at a daily mean temperature of -13° C. The expected capacity requirements of the distribution companies are also shown.

The assessment of the M/R stations' capacity includes both the actual realised peak hour and the expected offtake at -13° C from the distribution companies and from Energinet.dk's model. The assessment of whether the required capacity is available is thus based on an overall assessment of these inputs. The realised peak hours and those expected in Energinet.dk's model may differ.

The reason for this is, among other things:

- Energinet.dk's model is based on daily offtakes and states a mean consumption estimate at -13° C
- In the model, ring connections may provide expected offtakes which differ significantly from the model
- Realised peak hours may be high due to atypical offtakes, eg refilling of a downstream network or customers with very large offtakes.

There are a few examples in Table 7.1 where measured peak hour exceeds station capacity. This is due to the fact that the station inlet pressure is calculated conservatively at a temperature of -13° C while the inlet pressure during the measured peak hour is higher, for which reason station capacity during the measured peak hour is correspondingly higher than indicated in Table 7.1.

### 7.1.2 Gas from Germany

Gas imports from Germany on interruptible conditions became possible from 1 October 2010. This gas will be imported based on market demands and the transmission network's pressure requirements. The minimum pressure for gas from Germany is 68 barg in Ellund. Imports from Germany will not lead to limitations in M/R station capacity in relation to the expected capacity requirement.

### 7.1.3 Design of distribution network

In connection with the preparation of the 2008 Plan for Security of Natural Gas Supply, detailed analyses were made of the relationship between temperature and gas consumption for each M/R station in the transmission system. The purpose was to uncover any congestion in the system. These analyses are deemed to also cover Gas in Denmark 2010.

When assessing consumption especially at very low daily mean temperatures, it is important to consider the simultaneity of various types of consumption to ensure that the capacity requirements for the M/R stations stay realistic. The assessment of offtake at very low temperatures is hampered by the fact that no relevant metered data are available for daily mean temperatures lower than approximately -7° C. Ring connections also make the assessment of the individual M/R stations difficult.

## 7.2 Special security of supply issues in the individual distribution areas

### 7.2.1 Naturgas Fyn Distribution

The M/R stations supplying Naturgas Fyn Distribution A/S are assessed to have sufficient short-term and long-term capacity. Naturgas Fyn assesses that gas consumption will decline in the coming years.

### 7.2.2 DONG Gas Distribution

Overall, Energinet.dk's M/R stations are assessed to have sufficient capacity to cover DONG Energy's requirements for the coming winter 2010/2011. Where the Egtved, Frøslev, Terkelsbøl and Stenlille stations are concerned, the relationship between capacity limits and peak hour expectations is, however, of such a

nature that it calls for the planning of a capacity increase. The need for such an increase is further illustrated by the expected introduction of gas with a lower calorific value.

### 7.2.3 HNG Distribution and Naturgas Midt-Nord Distribution

In 2009, gas supplies have been maintained for all consumers in HNG's and Naturgas Midt-Nord's licence areas when disregarding pipelines which have been dug through locally and consumers that have signed interruptibility agreements with Energinet.dk.

The M/R stations in the transmission system and the distribution systems in HNG's and Naturgas Midt-Nord's licence areas are assessed to have sufficient capacity for the coming winter 2010/2011.

To assess whether the existing supply systems have sufficient capacity for the next ten years, HNG and Naturgas Midt-Nord have initiated analyses of the development in gas consumption and the consequences of changes in gas quality.

### 7.2.4 Gas supplies to Copenhagen

In connection with converting production from using city gas to using city gas based on natural gas/air in November 2007, Københavns Energi has looked into whether it would be possible to have the linepack in Energinet.dk's 80 bar network made available in the event of supplies to Copenhagen being interrupted.

Københavns Energi's city gas network is a ring-connected network which must be kept pressurised as the penetration of air may disrupt gas supplies in Copenhagen. It is therefore vitally important that the supply of the gas raw material is maintained at a pressure of a least 15 bar at the Strandvænget and Kløvermarken gasworks.

Inadequate gas supplies to Københavns Energi's city gas network may have major socioeconomic consequences, and it is thus the assessment of Energinet.dk that security of supply in Copenhagen area must be increased.

In addition to reserving linepack in the 80 bar network, a manual bypass was established in 2010 at Mørkhøj station between HNG's 37 and 39 bar network so that Strandvænget gasworks can quickly receive supplies from Stenlille storage facility. Energinet.dk has also established a new remote-controlled valve at Torslunde M/R station so that gas from Stenlille can be sent direct to the Lynge pipeline in the event of a breakdown of the main transmission pipeline.

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