ENERGINET

LONG-TERM DEVELOPMENT NEEDS IN THE DANISH GAS SYSTEM

The green transition calls for new use of the gas system

Dok. 20/00788-57

30/9/2020

CONTENTS

Appendices

INTRODUCTION

Gas becomes green

The Danish national target of a 70% reduction in greenhouse gas emissions by 2030 was set in the first follow-up climate agreement in June 2020. The agreement contains political initiatives to ensure that private oil and gas boilers for heating will be completely phased out, and a green transition of the industry that reduces fossil fuel consumption.

The Danish Energy Agency's 'Analysis assumptions for Energinet, 2020' (AF20) therefore expects that natural gas will no longer be used for energy consumption in Denmark in 2040. Gas consumption will instead be met by biogas and other green gasses.

Early dialogue and informed decision-making basis

With this report, Energinet provides an initial snapshot of some of the key requirements for changes to the gas system that the green transition will entail. The aim is to create a qualified basis for an early and informed dialogue with citizens and stakeholders about the gas system during the green transition, and the infrastructure that may accompany it.

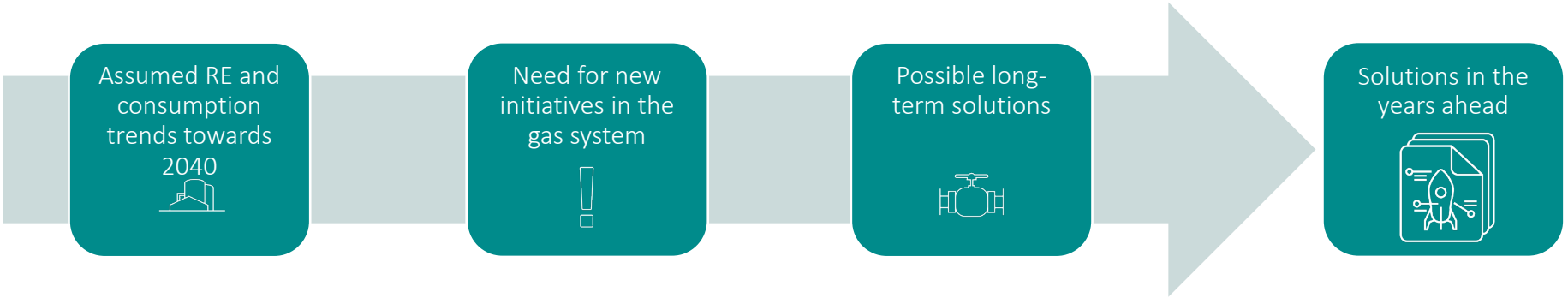
How we analyse the trend

The analysis in this report is based on the Danish Energy Agency's 'Analysis assumptions for Energinet, 2019' (AF19) supplemented by two scenarios. These two scenarios aim to capture the development of more onshore and offshore renewable energy production, and especially Power-to-X. Which are likely to be part of the long-term green transition – and are reflected in the latest political agreements, including the climate agreement of June 2020.

AF20, which incorporates the latest climate agreement, was released in August 2020. The overall estimates for energy production and consumption from AF20 have been included in this report to show the general direction, while figures from AF19 and the scenarios have been used to calculate the detailed impacts on the gas system. Specific investment decisions will always be based on the most recent analysis assumptions available at the time.

Where can you find out more?

This report is a more readable extract of a larger report on the development needs in the gas system. The information and messages in this report are described in more detail in the background report, available on this link: www.energinet.dk/udviklingsbehov2020. See also the Glossary on page 14.



The long-term development needs for the gas system presented in this report are part of Energinet's overall planning process. Based on the long-term analyses, specific projects will be launched in which a final solution to address the needs determined. This work will involve investigating both new infrastructure and alternative solutions.

LONG-TERM DEVELOPMENT NEEDS IN THE GAS SYSTEM – CORE MESSAGES

1. **The production and consumption of renewable energy will grow significantly towards 2040**
   The green transition of the gas system will primarily involve strong growth in the production of green gas. Green gas production in Denmark is expected to meet the entire Danish gas consumption in 2040.

2. **Natural gas will continue to be transported in the gas system alongside green gasses**
   Even though all gas consumption is met by green gas, natural gas will still flow in the gas system. Natural gas from the North Sea and Germany will continue to be transported to Poland and Sweden, and to and from the gas storage facilities.

3. **Gas consumption is changing as a result of the green transition**
   Danish natural gas consumption has to be completely phased out by 2040. This means, for example, that gas used for heating homes and for heat and power production will be drastically reduced through electrification and increased district heating production. Gas consumption in the industry is expected to decline overall. This decline might be lower than expected due to parts of the industry converting from coal and oil to gas.

4. **Changes in consumption and production entails adjustments of the gas system**
   The combination of lower gas consumption and greater biogas production will mean that the gas supply flow will be reversed, and it will be necessary to transport gas away from the distribution grids. The entire gas system will have to be adjusted to make this possible.

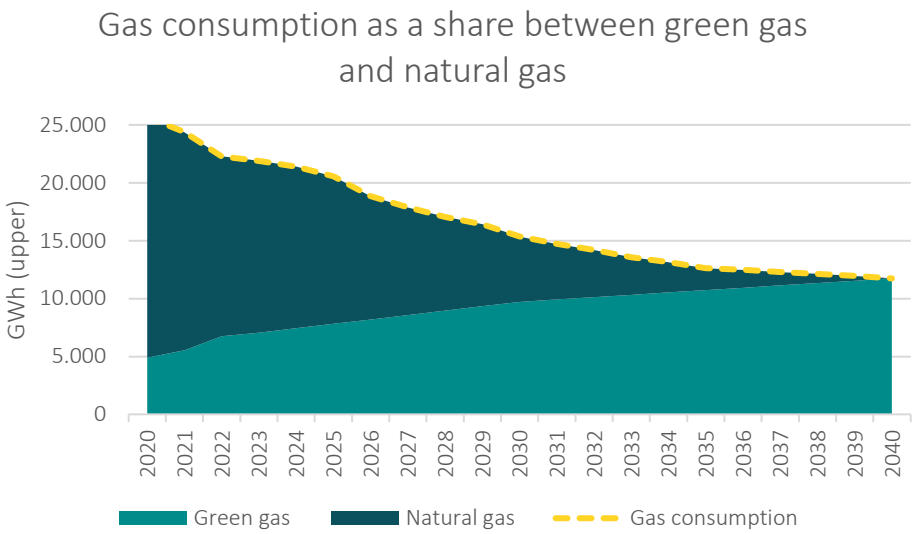
5. **Power-to-X can lead to both increased renewable gas production and increased gas consumption**
   Depending on the use of technology, Power-to-X and new green fuels may influence the development of the gas system in different ways. The production of hydrogen through Power-to-X technology may increase biogas production and create fuel for the transportation sector at Gas-to-Liquid plants. The location of Power-to-X plants will be key to how to develop the gas infrastructure. It will be possible to modify parts of the gas system for transporting hydrogen in the long term.

THE GAS SYSTEM FACES MAJOR CHANGES AS A RESULT OF THE GREEN TRANSITION

Green transition for gas is accelerating

The future of the green transition for gas has been laid out more and more clearly in recent years.

Biogas has already seen strong growth in recent years, meeting the equivalent of 11% of Danish gas consumption in 2019. The climate agreement of June 2020 contains feed-in subsidy for increased biogas production in the coming years. This is one of the reasons why the Danish Energy Agency expects that all of the Danish gas consumption can be supplied solely from biogas and other green gases in 2040, and that the gas consumption will be almost halved.



Transport of natural gas and conversion to biogas

The gas system in Denmark is part of the infrastructure that has to support a more climate-friendly energy supply for society.

The gas system will play a new and important role in the future, and significant changes to the system are already happening, which affect the way we currently operate it:

1. As the production of green gas increases, the gas system serves as the link between green gas production and consumption.
2. When Baltic Pipe is operational and natural gas has to be supplied from the Norwegian fields in the North Sea to Poland, the gas system's capacity will be almost fully utilised for a number of years.
3. The gas grid must continue to handle the demand for Danish North Sea gas and biogas in our neighbouring countries, such as Sweden.

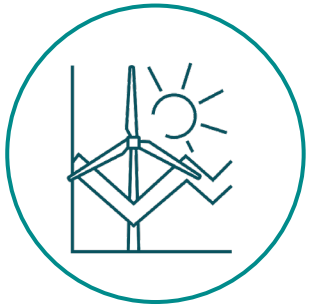
The Danish gas system must be adjusted to support a green transition

The gas system was originally designed to transport natural gas from a few major points, such as the North Sea, into the extensive distribution grid that supplies gas to businesses and homes. In step with the green transition, the supply picture for gas is being reversed, with green gas now being produced locally and distributed throughout the gas system.

The combined effect of these trends means that the general gas system must be adjusted. Firstly, it must be developed to support more recompression of gas than has traditionally been the case. Secondly, it must support reduced Danish gas consumption, based on green gases.

THREE FACTORS, IN PARTICULAR, SIGNIFICANTLY CHANGE THE DEVELOPMENT NEEDS FOR THE GAS SYSTEM

It is clear from this report that there is a considerable need for initiatives in the gas system, if it is to support the green transition all the way to the goal of a climate-neutral society in 2050. In other words, changes and adjustments are necessary. However, three factors in particular will have a significant impact in the near future on the scope, type and location of the measures that will be necessary in the general gas system.



INCREASED LOCAL PRODUCTION OF RENEWABLE GAS

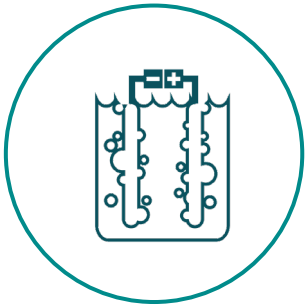
Danish natural gas consumption has to be completely phased out by 2040. This means e.g. that gas used for heating homes and for heat and power production will be drastically reduced through electrification and increased district heating production.

Green gas production in Denmark is expected to be able to meet the entire Danish gas consumption in 2040. Production occurs decentralised.

BALANCE BETWEEN PRODUCTION AND CONSUMPTION

The gas system was designed with a view to supplying gas from a central source, but the green transition is resulting in a reverse flow. In many places, biogas must be transported away from the areas where it is produced. This is due to both a lower gas consumption and increased biogas production.

The changes in consumption and production means that the gas system has to be adjusted to suit the new requirements.



GREEN FUELS

Depending on the use of technology, Power-to-X and new green fuels will have very different consequences for the development of the gas grid.

Power-to-X can be used to increase biogas production, produce green fuels at e.g. Gas-to-Liquid plants, and be used to directly produce hydrogen, which can serve purposes in other contexts.

The location of Power-to-X plants will be crucial for how to develop the gas infrastructure.

BIOGAS SURPLUSES IN LOCAL AREAS

The figure shows where biogas surpluses will arise in 2040. Under AF19, surpluses primarily arise at Ll. Selskær and Ringsted. Under the assumptions in the scenarios, numerous areas in Jutland and on Zealand will have considerable biogas surpluses.

BIOGAS MUST BE TRANSPORTED AWAY FROM LOCAL AREAS

The extent of biogas surplus will depend on market trends

Growth in biogas production in Denmark will increase the need to transport green gas from local areas to the central gas system, enabling use in other local areas, export or storage.

How much surplus of local biogas production we will see depends on precisely how the market develops. For example:

- How steep a curve the growth in biogas production will follow in the coming years?
- What will biogas be used for in 2040? Only to supply traditional energy to industrial processes and, to a lesser extent, for heat and power, or will biogas also be used in the production of green fuels?

These are some of the factors that will influence exactly how much biogas and other green gases the gas system has to handle in the future – and when the needs will arise.

The climate agreement from June 2020 increases biogas growth

The extent of biogas surplus in local areas relative to consumption is likely to be underestimated when it is calculated based on AF19. This is because AF19 was released before the climate agreement in June 2020, which projects a faster phase-out of natural gas and more funding for biogas in the coming years.

Based on model calculations of supply and demand using AF19, Energinet estimates that there will be surplus of biogas at Ll. Selskær and Ringsted before 2040, while the scenarios with 100 % green gas consumption will show a surplus throughout large parts of the gas grid. The surplus at Ll. Selskær will already arise in 2022.

The local biogas surplus arises due to both increased biogas production and declining gas consumption.

REDUCED TRANSPORT TO LOCAL GRIDS

The figure shows that some of Energinet's meter and regulator stations that supply gas to the distribution system will be used less in the future. Under the scenarios, the need to supply gas from the transmission grid to the distribution grid will be reduced or eliminated altogether in many places up until 2040.

PHASING OUT NATURAL GAS FOR DANISH CONSUMPTION WILL CHANGE THE USE OF THE GAS SYSTEM

Consumption will drop and be increasingly met by locally produced biogas

As consumption decreases and a larger share of gas consumption is met by local biogas, the need to transport gas from the transmission system to the distribution system will be reduced.

One challenge is that the meter and regulator stations which supply the distribution system with gas are designed to handle much higher gas consumption than will be needed in the future. The stations must therefore be adjusted to also function with a lower gas supply.

This trend is already evident with AF19.

When gas consumption is met by green gas, self-sufficient areas will arise

In the scenarios and AF20 biogas production increases to meet the entire Danish gas consumption.

There will be areas which are self-sufficient with biogas as a result. These areas will require no gas supplied from the transmission system during a normal year. All gas consumption will be met by local production, and the connection to the transmission system will primarily be used if the need arises to transport gas from the distribution system to the transmission system. For these areas, the role of the stations will be to stand by for times when consumption is higher than normal. For example, if it gets very cold.

There are also examples of multiple stations supplying the same distribution grid. The reason is that some distribution grids are connected together in order to better handle the biogas surplus.

The stations must therefore be modified to suit the very different mode of operation in the future. It may also be relevant to consider whether some stations will become redundant over time.

POTENTIAL WAYS OF ADAPTING THE GAS SYSTEM

Potential changes to the gas system towards 2030 based on the scenarios, on customer enquires, and legal requirements for changes to the gas system.

VARIOUS ADJUSTMENT OPTIONS FOR THE GAS SYSTEM TO HANDLE THE GREEN TRANSITION

Current and future projects

One of the key challenges of the green transition is that an increasing surplus of biogas will arise in local areas, which needs to be utilised elsewhere. This can be done by transporting biogas from the distribution system to the transmission system (recompression), connecting local grids in the distribution areas or making use of the biogas locally in other ways.

Energinet is currently building recompression stations in Viborg, Terkelsbøl and Højby. Energinet and Evida are also working together on a project at Ll. Selskær at the time of writing. Solutions being investigated at Ll. Selskær includes Energinet establishing a recompression station, Evida establishing a gas connection between existing local areas, or Energinet lowering the pressure in one of the transmission pipelines between Egtved and Frøslev. Interconnecting areas will minimise the need for recompression stations.

In 2023, Energinet has to begin rerouting one of the gas pipelines on west Funen to make way for a new railway line. Energinet is also currently investigating the possibility of establishing gas supply to Lolland and Falster (see page 11).

Conversion to 100 % green gas

The need to handle surplus biogas in the gas system can be met by establishing new infrastructure (e.g. new gas connections and recompression stations), but it is also necessary to evaluate other solutions in order to avoid overly expensive solutions:

- Offer biogas surpluses on the local market to increase gas consumption for short periods of time.
- Reduce the pressure in parts of the transmission grid so that the gas can flow freely from the distribution system to the transmission system and avoid the need for recompression stations.
- Other solutions outside the control of Energinet and Evida. Examples include establishing production of transportation fuels using gas from the gas system or connecting new gas consumers, who want green gas from the gas system, to replace coal and oil consumption.

In all cases, it is important that the solutions are found in collaboration with Evida, market participants and the authorities, to ensure an optimal solution for the entire energy system.

PRODUCTION OF GREEN FUELS REQUIRES DIFFERENT SOLUTIONS DEPENDING ON MARKET DEVELOPMENTS

Two pathways for green fuels – using hydrogen or biogas as the base

Energinet's scenarios for developing an energy supply that targets a 70 % reduction in carbon emissions in 2030 and climate neutrality in 2050 describe two alternative directions for the energy system. The two scenarios have been used to investigate the impacts of various pathways to achieve the climate goals for the gas system

The development of the gas system depends largely on how hydrogen will be used in the Danish society, and how fuel will be provided for the transportation sector.

One development path is the production of green fuels using hydrogen and CO_2 from biomass, e.g. in the combined heat & power sector or directly from biogas plants. Such technology is the basis for fuel production in the blue scenario. Fuel production takes place outside the gas system, using part of the biogas resource directly. The result would be that the gas system has to be adjusted to handle very low gas consumption.

Another technology for the production of green fuels for the transportation sector is Gas-to-Liquid, which can produce liquid fuels using green gas supplied via the gas system. Gas-to-Liquid has been investigated in the yellow scenario. The need for transport fuels in Denmark is high compared to gas consumption. Gas-to-Liquid would therefore involve a significant increase in the need to transport gas.

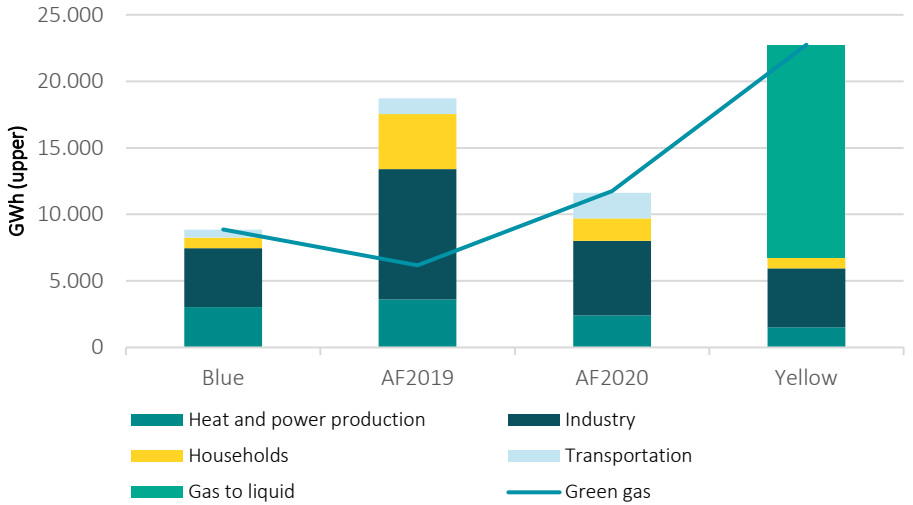
The two scenarios describes different developments in the gas consumption compared to AF20, which lies above (the yellow scenario) and below (the blue scenario) the gas consumption in AF20.

Increasing energy from wind and solar power offers new perspectives for the gas grid

The production of hydrogen by electrolysis using surplus electricity from wind turbines and solar power plants is likely to be a key new element in the Danish and European energy systems in the coming years.

Hydrogen can either be used as a direct energy supply, or in combination with other raw materials to produce a series of carbon-neutral products, which have otherwise typically been produced from oil and natural gas.

Gas consumption in 2040 for the analysis assumptions and scenarios



Hydrogen can be used as a direct source of energy, e.g. for heavy industrial processes such as steel and cement production. It can also be used in the production of green fuels, with or without re-use of CO_2 (e.g. biogas plant or biomass combustion). Such green fuels are likely to be used in heavy transport (trucks, ships and aeroplanes), in particular.

The strong growth in the production of renewable energy from solar and wind power in the coming years can lead to different requirements for the development of the gas grid, depending on which underlying industrial structure for the production of green fuels becomes dominant.

CASE: GREEN GAS – LOLLAND-FALSTER

Green gas for industries on Lolland and Falster

Energinet and Evida are currently investigating options for the construction of a new gas pipeline that connects the Zealand gas system with Lolland and Falster.

The potential gas pipeline is a good contemporary example of the green transition and the future use of the gas system.

The gas pipeline could allow local companies, including the sugar factories on Lolland and Falster, to replace their existing coal and oil-based energy supply with climate-friendly biogas.

The gas pipeline addresses several needs in the green transition:

1. It allows the sugar factories and other industries to replace their fossil-fuel-based energy supply with carbon-neutral biogas.
2. It facilitates the establishment of local biogas production on a scale that would otherwise not be profitable.
3. It creates geographical balance between consumption and production, since green gas can be transported to Zealand in periods with low gas consumption on Lolland and Falster.

Internal network for solar and wind power

Lolland-Falster is one of the areas of Denmark seeing the highest growth in land-based renewable energy plants, and this is putting strain on the electricity system. It may therefore make sense to convert some of the surplus electricity from renewable energy production in the area into hydrogen or other green gases.

Long-term, the gas pipeline between Zealand and Lolland-Falster could thus be used to transport hydrogen or green gases produced using wind or solar energy. In addition to being a clear example of the contribution of biogas to the green transition, in the slightly longer term the gas pipeline might thus also become part of a new green energy system involving hydrogen and Power-to-X, which connects the power system and gas system symbiotically.

ILLUSTRATION: ENERGINET

Hydrogen infrastructure

As a key element of the green transition, hydrogen has received a lot of focus during the past year.

Energinet has performed tests that show that up to 15% hydrogen volume can be handled in the natural gas system. Further studies are yet to be conducted whether gas consumers can handle such a high level and if neighbouring countries will allow the incorporation of hydrogen.

The current gas infrastructure can serve as a starting point for a future hydrogen transmission grid. Declining gas consumption combined with more decentralised green gas production paves the way for parts of the transmission grid to be converted to hydrogen in the longer term.

APPENDICES

CURRENT GAS SYSTEM AND PROJECTS IN CONSTRUCTION PHASE

Baseline for analysis of the development needs in a greener gas system

The analysis of future needs for the gas system is based on the current infrastructure, including approved projects in the construction phase. The figure to the right presents an overview of the entire gas system and projects which have already been approved and are in the construction phase.

The Danish gas system

The Danish gas transmission grid consists of approx. 900 km of pipelines, while the distribution grid consists of approx. 17,000 km of pipelines. The transmission grid is connected to the distribution grids at 43 meter and regulator stations (M/R stations), which filter, meter, inject an odorant into the gas for safety reasons and regulate the pressure down to the level in the local distribution grids.

Energinet owns and operates the transmission system, and Evida owns and operates the distribution grids.

Gas is primarily transported from the transmission grid to the distribution grids, but recompression stations have been established at two M/R stations (St. Andst and Brande), which allow gas to be transported in the other direction – from the distribution grids to the transmission grid. The recompression stations compress the gas to match the pressure in the transmission grid, meter the gas, and remove the odorant again.

The Danish gas system also consists of two gas storage facilities – Ll. Torup in northern Jutland and Stenlille on Zealand – which are owned and operated by Gas Storage Denmark.

Approved projects in the construction phase

- Biogas recompression at M/R Terkelsbøl
- Biogas recompression at M/R Højby
- Biogas recompression at M/R Viborg
- Biogas recompression at M/R Brande
- Baltic Pipe – which connects Denmark to Poland and the Norwegian part of the North Sea
- MR-Newtech – technology upgrades of M/R stations
- Mobil M/R – a mobile M/R station for emergency and maintenance tasks
- Nonnedalen pipeline – reinforcement project

Baltic Pipe

Baltic Pipe is a gas transport pipeline which is under construction. It will make it possible to transport gas from Norway to Poland via Denmark. The construction of Baltic Pipe marks the biggest physical change to the Danish gas system since it was established. The gas volume Baltic Pipe can carry is approx. four times greater than the current Danish gas consumption. When Baltic Pipe is in operation, there will therefore be a very high flow of natural gas from Norway to Poland through Denmark. Baltic Pipe also entails a new supply connection to Denmark from the Norwegian natural gas fields.

GLOSSARY

Transmission grid and distribution grid
The Danish gas grid consists of a primary grid (the transmission grid), which historically has distributed natural gas from the North Sea, through the distribution grids to the consumers (see the illustration on page 13). Energinet is responsible for the gas transmission grid, comprising approx. 900 km of pipelines, while Evida is responsible for the distribution grids, consisting of approx. 17,000 km of pipelines. The analyses of the demands the green transition places on the development of the gas grid in this report only cover the gas transmission grid.

M/R station
A connection between Energinet's transmission grid and Evida's distribution grids. Meters and regulates the gas pressure.

AF
Energinet has to plan the power and gas grids in line with the Danish Energy Agency's annual projections for the production and consumption of electricity, gas, district heating etc. The analysis assumptions (AF) are based on policy decisions and projections of the market and technological developments.

AF19
The Danish Energy Agency's analysis assumptions for Energinet, 2019. AF19 was published before the Climate Act and the 70% target. The assessment of future RE development in AF19 is therefore at a lower level than current assessments.

AF20
The Danish Energy Agency's analysis assumptions for Energinet, 2020. Unlike AF19, AF20 has been updated with the latest policy decisions, such as those concerning energy islands, Power-to-X and growth in solar power plants and biogas production. AF20 was published in late August 2020, while the detailed market simulations and calculations of the impacts of the green transition on the gas system in this report were prepared during 2020, based on AF19, supplemented with scenarios that include the 70% target and new technology.

Scenarios
Energinet developed the blue and yellow scenarios during 2019 and 2020, with input from stakeholders, with the aim of supplementing AF19 and projecting alternative trajectories of the green transition.

The blue scenario
In the blue scenario, Power-to-X covers Danish consumption of renewable fuels. There is also a general increase in electrification, which is supplied by a considerable expansion in offshore wind power. The consumption of biogas in the blue scenario is on par with AF20. This is because hydrogen is the main element in the production of green fuels.

The yellow scenario
In the yellow scenario, Power-to-X covers Danish consumption of renewable fuels. There is also a general increase in electrification, which is particularly supplied by a significant expansion in solar power. The consumption of biogas is significantly higher in the yellow scenario than in the other scenarios, and on par with current Danish gas consumption. This is because biogas is the main element in the production of green fuels.

Green gas
Green gas covers biogas, upgraded to natural gas quality sometimes referred to as biomethane, which is produced at biogas plants from livestock manure and organic waste from food consumption. It also covers hydrogen, which is split from water by electrolysis using green power from wind and solar energy.

Power-to-X
Denotes the process in which power from renewable energy sources is used to extract hydrogen from water via electrolysis. Hydrogen can be used as an independent green energy source, or as a component in green fuels or other green products (hence the 'X').

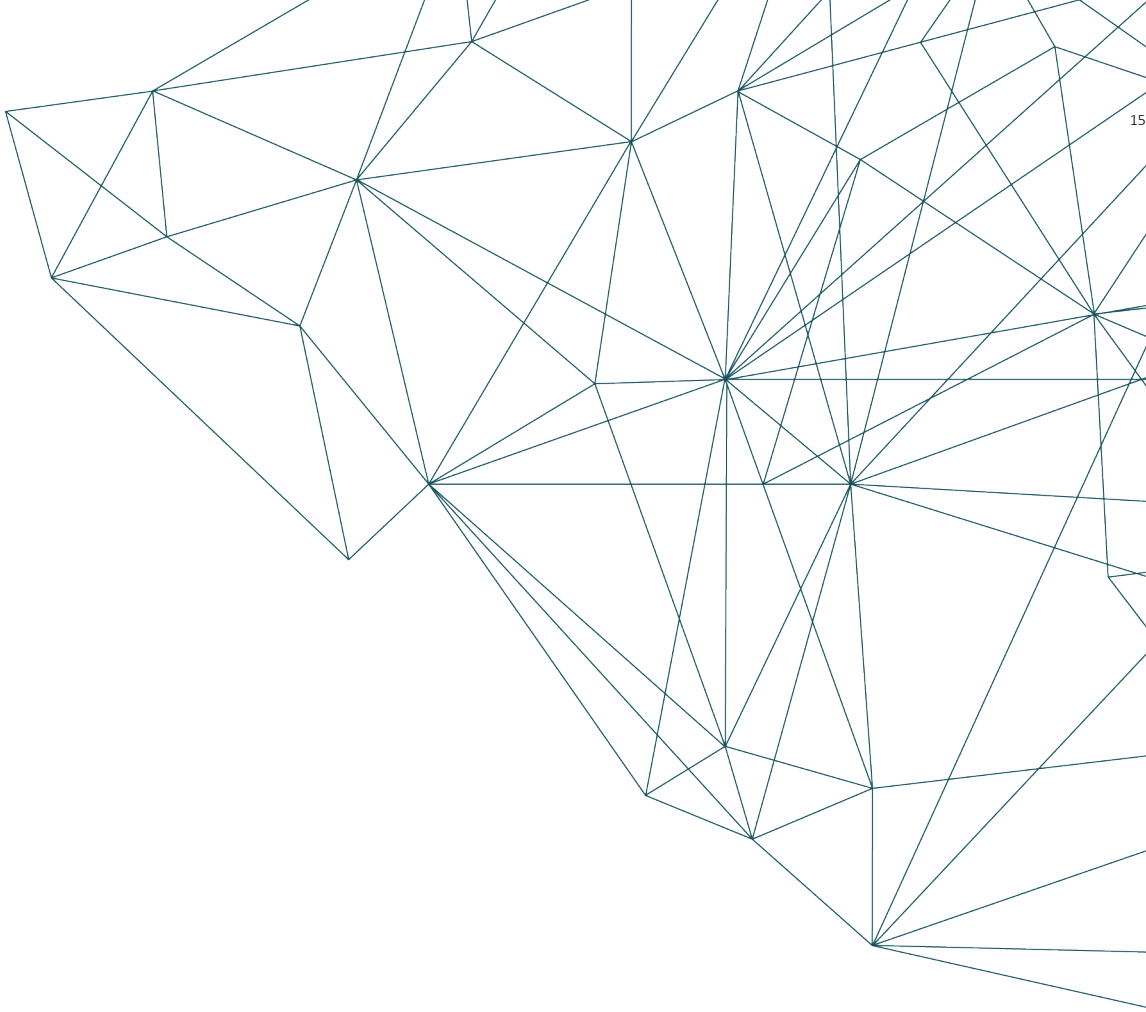
Gas-to-liquid (GtL)
Technology that produces liquid fuels based on gas. Biogas can be used, when green fuels are required.

Green fuels
Covers fuels products obtained from e.g. a Gas-to-liquid process, where green gas has been used. Examples of green fuels could be methanol, jet fuel or ammoniac to be utilised in the transportation or agricultural sector.

ENERGINET

Tonne Kjærsvej 65
7000 Fredericia
Tlf 70 10 22 44

info@energinet.dk
www.energinet.dk



Energinet er en selvstændig offentlig virksomhed ejet af staten.

Det betyder, at de publikationer m.v., som Energinet udgiver, alene er udtryk for Energinets faglige vurderinger. Disse vurderinger deles ikke nødvendigvis af klima-, energi- og forsyningsministeren, der varetager ejerskabet af Energinet på statens vegne.

Energinet bestræber sig på at være en åben og transparent virksomhed, hvor vurderinger og analyser gøres tilgængelige for alle.

Doc. 20/000788-57