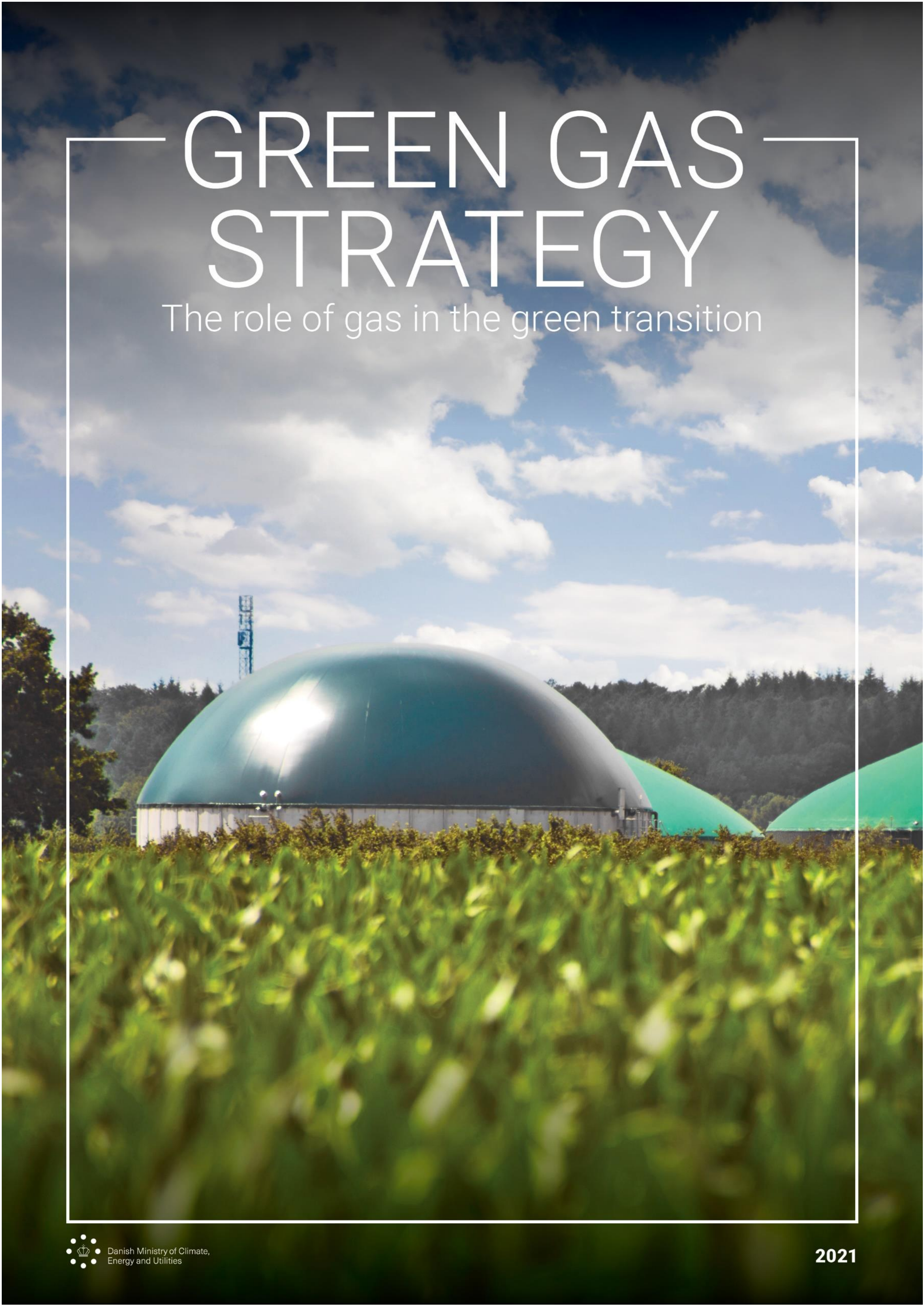


GREEN GAS STRATEGY

The role of gas in the green transition

Danish Ministry of Climate, Energy and Utilities

2021

Table of Contents

Table of Contents 1

Introduction..........2

About the Danish gas system 3

Denmark's future gas system..........6

The potential of green gases 10

How will gas consumption change in the future?..........13

Evolution of tariffs..........18

The Government's ambitions for Denmark's future gas consumption and gas infrastructure........21

Objective 1: Green gas must supplement electrification and be used in areas where it offers the greatest value..........22

Objective 2: Green gas in industry must support jobs in Denmark and provide economic growth and employment opportunities 25

Objective 3: The transition to green gas must occur with consideration for competitive tariffs and on commercial terms 27

Objective 4: Green gas must eventually be able to compete on market terms..........28

Objective 5: Green gases must be produced sustainably 30

Objective 6: The development of green gas production and gas infrastructure must include a high level of public involvement and take into account biodiversity and the environment..........31

Objective 7: The gas system must support and be used for the green gases of the future 32

Objective 8: The gas system needs to be adapted to efficiently support Denmark's future energy system, contributing flexibility and security of supply 35

Objective 9: Denmark must help further the development of a well-functioning European market for green gases 37

Vision for the role of gas in the green transition 40

Introduction

In 2021, the highest temperatures on record were recorded in Europe, the US and Canada, reaching around 50 degrees Celsius in some areas. Germany and Belgium experienced severe floods, while forest fires raged in Siberia and Southern Europe. These extreme events are evidence that anthropogenic climate change is a reality. The latest climate report from the UN's International Panel on Climate Change (IPCC) shows that climate change is accelerating faster than previously believed, and its gloomy conclusions call for immediate and urgent international action on climate change.

At the global level, climate change is the largely the result of years of coal, oil and natural gas consumption. In Denmark, greenhouse gas emissions have declined significantly since 1990, thanks in particular to the transition from producing electricity and heating with coal and oil to producing energy from renewable sources.

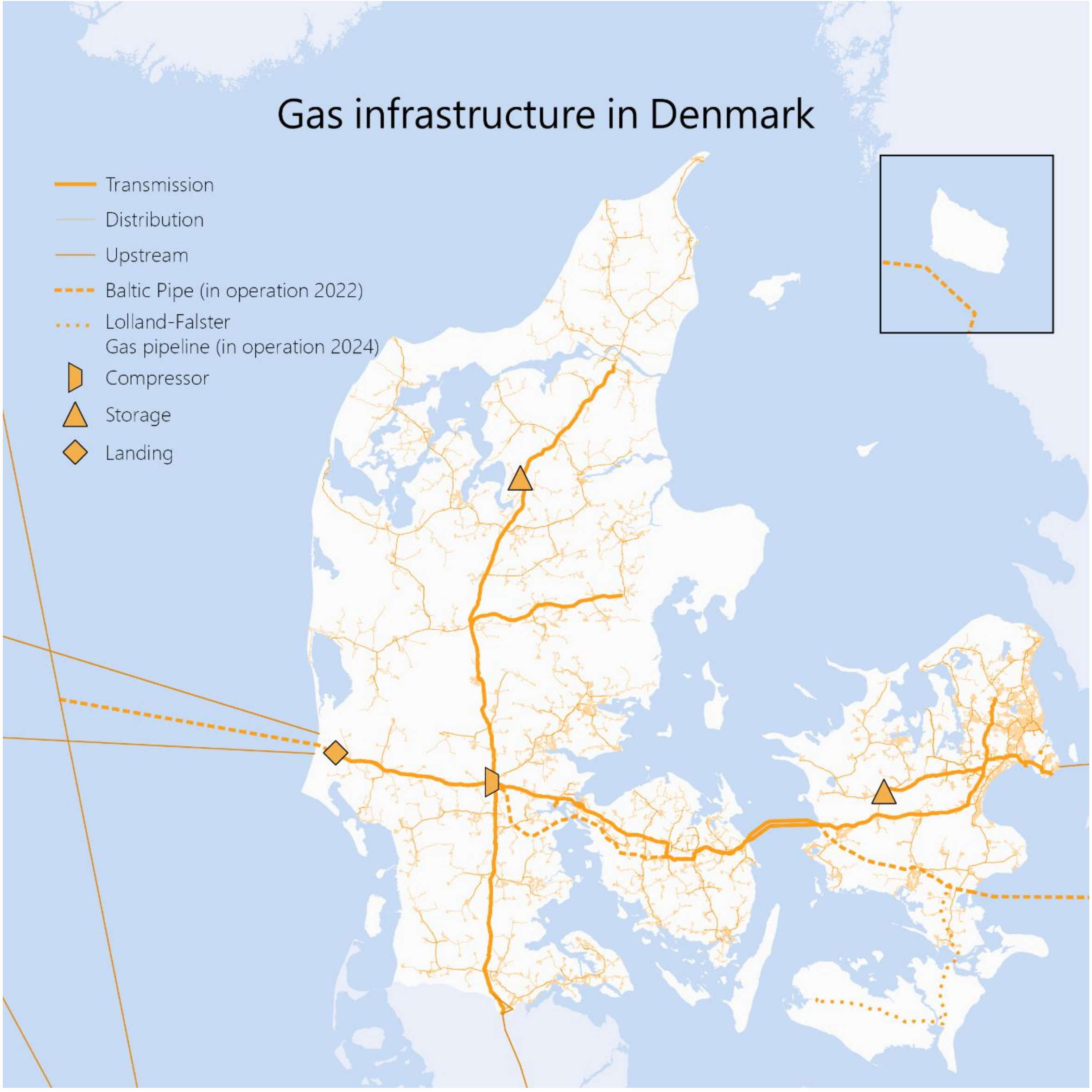
The Government of Denmark has set ambitious targets to reduce greenhouse gas emissions by 70 percent by 2030 and for Denmark to achieve climate neutrality by 2050. All assets must be deployed to achieve the objectives of the green transition. Denmark must continue to make progress towards replacing fossil fuels with renewable energy from wind power, solar power and green gases. Among other things, this will entail using green gases in areas where electrification is not feasible for technological or economic reasons, especially in relation to heavy industry.

The Danish gas system must be an asset in the green transition. Gas produced from renewable energy sources can replace fossil fuels and thereby lower greenhouse gas emissions. Biogas is an important source of green energy in this regard and can aid in the green transition of Denmark's energy supply. Danish gas consumption anno 2021 consists of around 20% biogas and 80% natural gas, yet already by 2030, biogas will make up 70% of gas consumption while natural gas will only make up 30%, making Denmark's gas consumption the greenest in Europe.

Yet it is not only gas consumption that contributes to the green transition. Denmark's gas infrastructure can also be used for other purposes than transporting and storing natural gas. In the long term, it will be possible to transport other green gases - such as hydrogen - via gas pipelines, allowing the gas system to support the development of Power-to-X (PtX) technologies and establish links between more sectors adding more flexibility and resilience to our future green energy system.

About the Danish gas system

Today, the Danish gas system transports methane in a mix of fossil natural gas and green biogas. As demand grows for green gases and fuels in the future, it is expected that several parallel gas systems will be needed, e.g. for hydrogen and CO_2. Accordingly, there are many important decisions that will need to be made, including how Denmark's maintained and well-developed gas system can best be used as an asset in the green transition.



The Danish gas system supplies gas to consumers across most of the country. Gas consumers receive gas via the distribution systems which are linked to the 'gas motorway', i.e. the transmission system. Gas is stored in Energinet's two underground gas storage facilities in North Jutland and on Zealand to even out seasonal fluctuations in gas consumption and ensure enough gas is available for emergency situations. Currently, gas is primarily transported from the North Sea via the transmission system to the distribution systems, but in certain places, it is also possible to transport gas the other way, i.e. from distribution systems to transmission systems, via so-called backhaul facilities. Since 2014, biogas plants have produced green biogas, which is upgraded and fed into the gas system (typically at the distribution level). Energinet estimates that the entire Danish gas system has an estimated replacement value of around DKK 50-60 billion.

The transmission system functions as the backbone

Energinet is a state-owned company that owns and operates the gas transmission system, which can be regarded as the ‘backbone’ of the gas system. Today, the transmission system consists of around 900 km of pipelines which have historically transported natural gas from the Danish part of the North Sea to the distribution systems. The transmission system runs through all of Denmark, tying every region together. It also connects Denmark’s gas infrastructure to Sweden and Germany via the North Sea, and the upcoming Baltic Pipe connection will allow Denmark to transport gas to Poland as well. The Danish gas system is accordingly part of the overall European gas system and gas market.

The distribution system distributes gas via 18,000 km of pipelines

The state-owned company Evida is responsible for the regional distribution system, which transports gas the last bit of the way to the individual consumers. The distribution system consists of around 18,000 km of pipelines distributing gas both regionally and locally. It was originally designed to receive natural gas from the transmission system, but today, biogas plants also feed biogas directly into the distribution system.

Two underground gas storage facilities

The Danish transmission system is connected to two underground natural gas storage facilities based in Lille Torup (North Jutland) and Stenlille (Zealand). The gas storage facilities have enough capacity to store several months of gas consumption and are therefore used to manage seasonal fluctuations in consumption, which is typically higher in the winter. Gas Storage Denmark, a subsidiary of Energinet, owns and manages Denmark’s two underground gas storage facilities.

What other gases can be transported in the Danish gas system?

Today, the Danish gas system transports methane in a mixture of natural gas and biogas, collectively referred to as system gas. As demand grows for green gases and fuels in the future, it is expected that several parallel gas systems will be needed, e.g. for hydrogen and CO_2.

FACT BOX 1: Gases that can be transported via gas infrastructure	
Natural gas	Natural gas is formed from decomposing plant and animal matter being exposed to intense pressure and heat under the surface of the Earth for millions of years. Even though it emits approximately 40% fewer greenhouse gases per kWh than coal or oil, natural gas is still a fossil fuel. Natural gas mainly consists of methane.
Biogas	Biogas is made by degassing organic residues such as liquid manure from agriculture, sewage sludge and other types of biomass waste. According to the IPCC’s Guidelines, biogas is considered CO_2-neutral, as it is typically made from organic residues that would have otherwise released greenhouse gases into the atmosphere over time. Some biogas plants use small amounts of energy crops and feed-grade residues to achieve sufficient degassing rates. Biogas is a combination of gases and typically consists of around 50-70% methane and 30-50% CO_2. Biogas is upgraded at an upgrading plant by removing CO_2 from the biogas, which allows it to attain the same quality as natural gas. In this paper, the term biogas is used to refer to upgraded biogas. The upgraded biogas is fed into the gas system and transported together with natural gas (collectively referred to as system gas). Upgraded biogas is also called biomethane. The term ‘raw biogas’ is used when referring to biogas that is not fed into the gas system. Raw biogas is typically used directly at local combined heat and power (CHP) plants.
E-methane	The CO_2 derived from upgrading biogas or biomass-fired CHP plants can be used to produce methanised gas (also known as e-methane). Along with hydrogen from electrolysis, CO_2 from sources such as biogas can be converted to methane through a

	process called methanisation. This e-methane can subsequently be fed into the gas system. E-methane is CO2-neutral if the hydrogen is produced from renewable energy and the CO_2 is biogenic, i.e. derived from organic residues and the like.
Hydrogen	Hydrogen is largely non-existent in its pure form, but can be extracted from fossil or renewable energy sources. The latter is called “green hydrogen”, and can be produced via the chemical process of electrolysis based on electricity from renewable energy sources. Electrolysis entails creating hydrogen by decomposing water into oxygen and hydrogen gas with the help of electricity. The process allows hydrogen to be produced from electricity, turning into a store of energy. Hydrogen can be stored and used directly as fuel in the transport sector, but also for producing fuels such as methanol, ammonia or aviation fuel, which can be used in the aviation and shipping sectors, for example. This makes hydrogen a building block for new green fuels, which is referred to as Power-to-X (PtX).

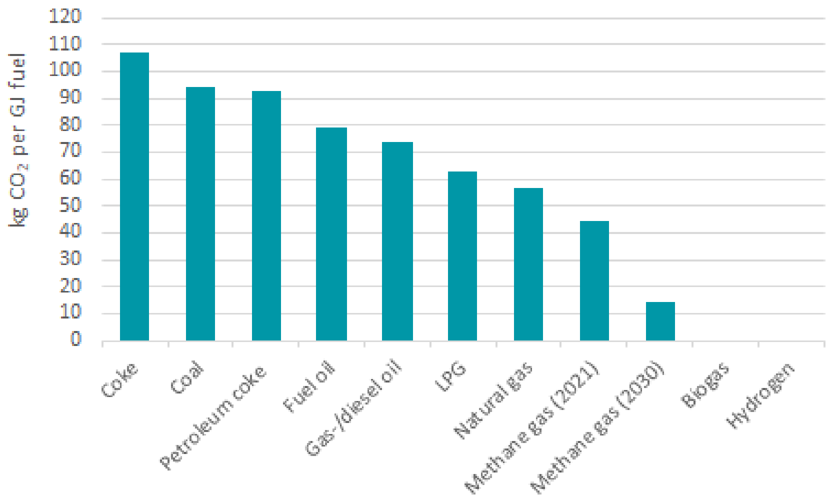


Figure 1: CO_2 emission factors for various fuels. For example, 56.54 kg of CO_2 is emitted per GJ of natural gas consumption.
Source: Danish Energy Agency, Energy Statistics 2019.

Figure 1 above shows that hydrogen and biogas are considered CO_2-neutral fuels. It also shows that the higher the share of biogas in system gas (21% biogas in 2021 and 75% biogas in 2030 according to the Danish Energy Agency’s 2021 Analysis Assumptions), the lower the climate impact of gas consumption due to the higher proportion of biogas in system gas.

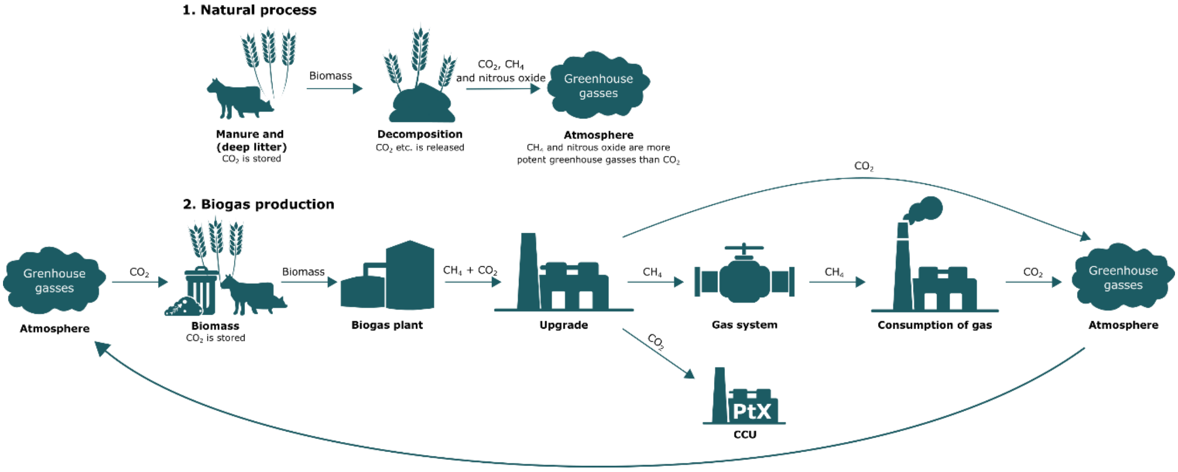


Figure 2: Biogas is a CO_2-neutral energy source
Source: Danish Energy Agency

Figure 2 shows the natural process that untreated biomass does through compared to being used for biogas production and accordingly why biogas is considered a climate-neutral energy source. When biomass such as liquid manure decomposes naturally in the field, the greenhouse gases methane, nitrous oxide and CO_2 are emitted into the atmosphere. If, on the other hand, that biomass is used for biogas production, the greenhouse gases are no longer emitted into the atmosphere but instead used for energy. Biogas is subsequently fed into the gas system, displacing the need for natural gas.

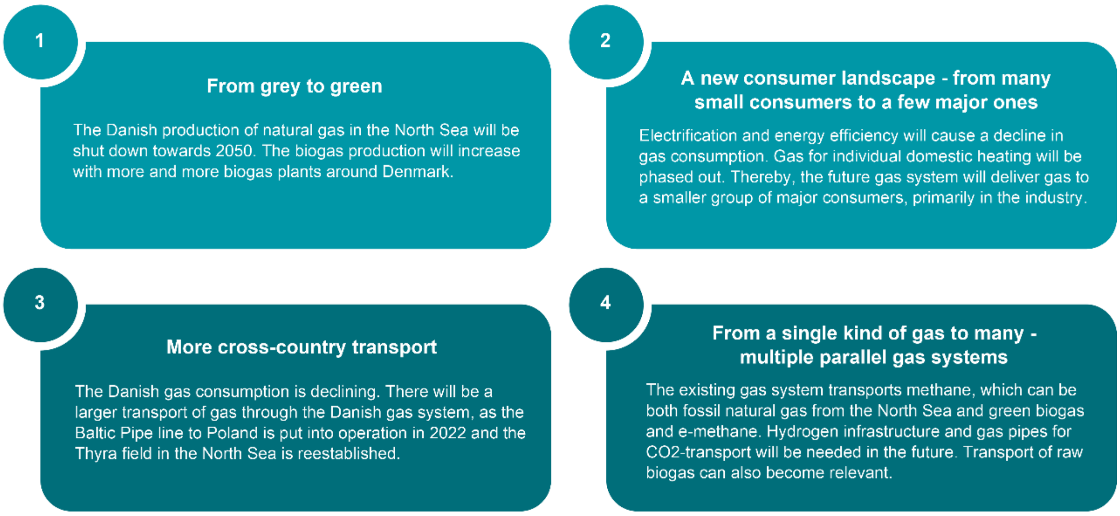
Additionally, it is possible to store and use the CO_2 from biogas production which may eventually become a relevant input for the production of future green fuels.

Denmark's future gas system

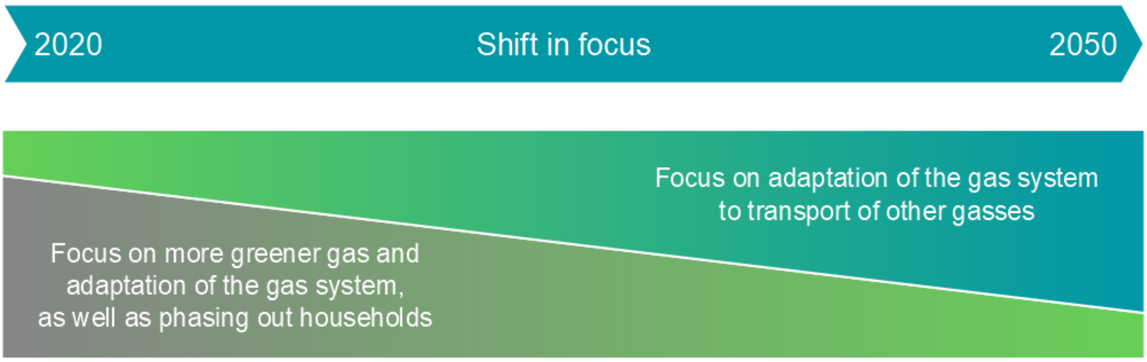
The Government's ambition is to bring about a green transition of the Danish gas system and for gas to supplement energy efficiency improvements and electrification as part of the overall green transition of the Danish energy system. The green transition carries implications for the future of Denmark's gas system, as gas consumption is expected to decline and become 100% green by 2035.

The green transition of the energy system carries implications for the future of Denmark's gas system. Initially, the country's gas infrastructure must be able to handle a decline in gas consumption, a changing consumer landscape and an increase in biogas production. In the slightly longer term - approximately from 2030 and onwards - there may arise a need to make adjustments to Denmark's gas infrastructure in order to meet the demand for transport and storage of other green gases such as hydrogen in particular, but also raw biogas and CO_2 for producing carbonaceous fuels (CCS/CCU). Furthermore, large volumes of fossil natural gas will be transported across the country to Poland, Germany and Sweden in the future.

Four overarching trends can be observed for the gas system.



These trends carry implications for the system, which is undergoing a comprehensive green transition towards greener gas consumption. Danish gas is therefore on the same green journey as Danish electricity, which is expected to become close to 100% green by 2030 according to the Danish Energy Agency's 2021 Climate Status and Outlook.



From grey to green gas production

Denmark's gas system was developed in the 1980s for transporting natural gas from the Danish part of the North Sea to Danish households and companies. As Denmark's green transition of the national energy system proceeds further, it will become possible to reduce gas consumption and ultimately entirely phasing out natural gas.

The production of green biogas and other green gases is rising, and it is expected that such gases will be able to entirely replace natural gas consumption in Denmark by 2035 (see Figure 3). However, this will be contingent on new policy measures such as further subsidising biogas production, raising levies on gas or implementing other measures to further phase out gas. With the support of a broad majority in the Danish Parliament, the Government has already allocated funds to both subsidise and promote green and competitive production of green gases on the one hand and reduce gas consumption on the other. However, further measures will be necessary to achieve 100% clean gas consumption by 2035.

Additionally, it may become necessary to make changes to Denmark's gas infrastructure to connect biogas production to consumers. Biogas plants are typically connected to the gas system at the distribution level close to agricultural areas, while future gas consumers such as industrial enterprises may be located much further away.

Overall, political decisions related to gas production, transportation and distribution resulted in Danish gas consumption consisting of 20% biogas already at the end of 2020.

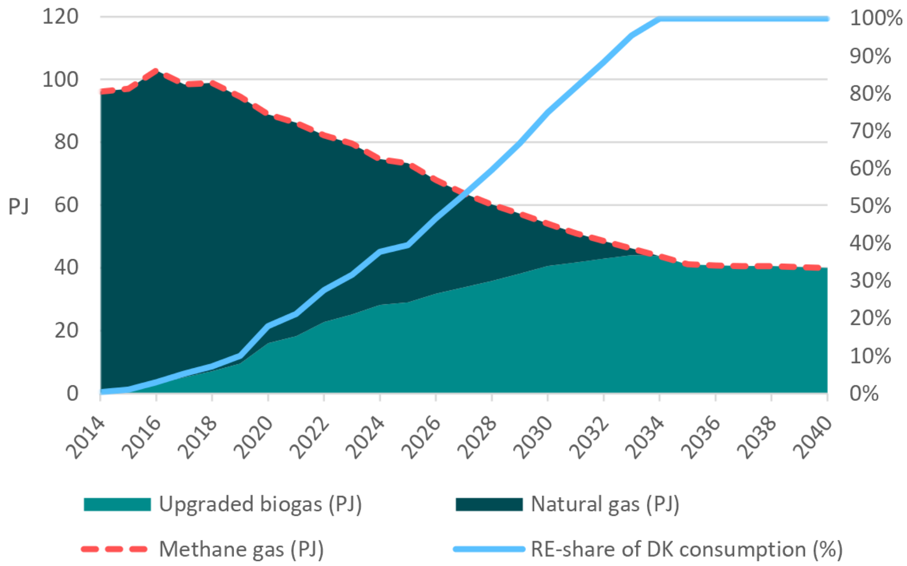


Figure 3: Consumption of methane gas by energy type and share of renewable energy in gas consumption. Source: The Danish Energy Agency's 2021 Analysis Assumptions for Energinet (AF21).

A new consumer landscape - from many small consumers to a few major ones

Today, gas is supplied to a variety of consumers, including the following:

- Industry and other enterprises using gas for space heating and process energy
- Households that use gas for domestic heating, etc.
- CHP plants that use gas to produce electricity and district heating

Roughly 430,000 households in Denmark are heated with gas from approximately 330,000 gas burners, amounting to 1.2 million tonnes of CO_2 emissions annually. In addition to that are 20,000 businesses that use gas for heating or industrial processes as well as approximately 250 utility companies that use gas for electricity and heat generation.

The green transition of Denmark's energy supply will entail a decline in gas consumption and Danish industry accounting for a higher share of the country's gas consumption. District heating and electric heating pumps are climate-friendly and economically sensible alternatives to gas burners for heating individual dwellings. This means that while gas is currently being distributed to every household on residential roads in Denmark, in the future, it is expected to mainly be distributed to a smaller group of major consumers. The expectation is that in the long term, there will not be a need for a widespread distribution system for residential areas.

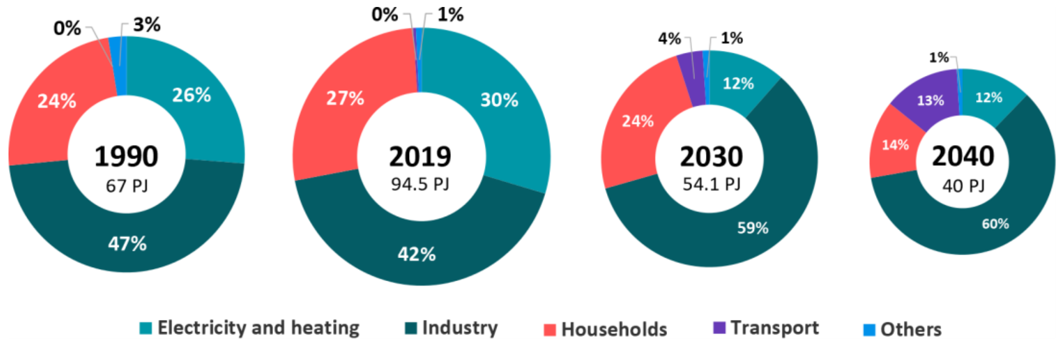


Figure 4: Distribution of Denmark's consumption of system gas by sector in 1990, 2019, 2030 and 2040. The distributions in 2030 and 2040 are based on AF21. The size of the circles represents the relative size of total system gas consumption, which was 67 PJ in 1990 and 94.5 PJ in 2019. According to AF21, the total system gas consumption is expected to decline to 54.1 PJ in 2030 and 40 PJ in 2040.
Source: AF21.

This means that gas in Danish industry can contribute to Denmark's green transition when used in processes where it replaces fossil fuels. Firstly, the shift from coal and oil to gas in industrial processes will positively impact Denmark's climate balance, as natural gas is less harmful to the climate than coal and oil. Secondly, a growing share of renewable energy-based gas consumption *may* be able to eventually eliminate CO_2 emissions from Danish industry under a number of assumptions.

FACT BOX 2: What is a petajoule?

A petajoule (PJ) is a unit typically used to denote late amounts of energy as an alternative to the unit terawatt-hour (TWh). One TWh is equivalent to 3.6 PJ. According to the Danish Energy Agency's projections, total system gas consumption could reach 40 PJ by 2040. This corresponds to 11 TWh, or more than 11 billion kWh.

Denmark's total annual system gas consumption is expected to reach 23.9 TWh - equivalent to 86 PJ - in 2021. In comparison, electricity consumption is expected to reach 35.2 TWh, or 127 PJ (Source: AF21).

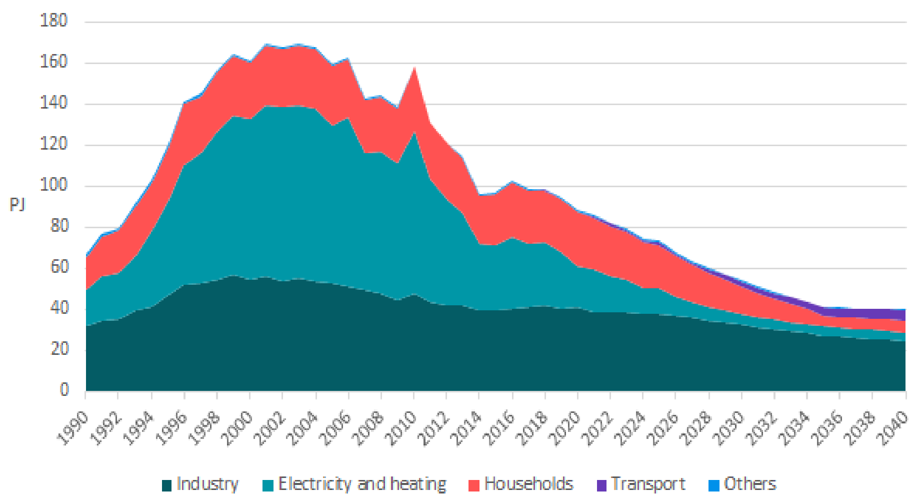


Figure 5: Gas consumption by sector. Gas consumption peaked in the early 00s and has declined significantly since 2012.
Source: Danish Energy Agency, AF21

More cross-country transport

Denmark is part of the European gas system and currently transports gas to Germany and Sweden. However, Denmark's gas infrastructure will soon play an even more central role in the European gas system as a result of the country's agreement with Norway and Poland to establish the Baltic Pipe link. The Baltic Pipe project will create an international gas supply corridor running through the Norwegian, Danish and Polish gas systems for many years to come and transport fossil natural gas - about 3-4 times that of Denmark's national gas consumption - from Norway to Poland via Denmark. The transport through Denmark helps keep transmission tariffs stable while the Danish gas system transitions to green gas. Therefore, the Danish gas system will still transport fossil natural gas for many years to come even while the share of green gas in Danish gas consumption significantly increases.

From a single kind of gas to many - multiple parallel gas systems

Denmark's transition of the gas sector has thus far been focused on biogas production. However, more green gases and CO_2 may come into play as we approach the year 2030, primarily green hydrogen, but also raw biogas, pyrolysis gas and e-methane.

The Danish gas system can store and transport energy without significant losses. Therefore, assuming the demand exists, there may arise a future need for several different gas systems that can transport different types of green gases in parallel. The Government is therefore exploring the possibilities of establishing hydrogen infrastructure and a hydrogen market framework, as set out in the Government's Power-to-X strategy. It is likely that parts of the existing gas system can also be reused or converted to transport these new gases. Whether that would be the right solution depends on the time perspective, demand as well as specific technical and economic factors.

The potential of green gases

Gas produced from renewable energy sources can replace fossil fuels, thereby lowering greenhouse gas emissions. The Government sees biogas as an important green gas that can contribute to the green transition of Denmark's energy supply. It is believed that there will be sufficient biomass resources to produce the amount of biogas needed to meet the forecasted demand in 2040. In the future, other green gases may come into play. Potential candidates include e-methane or hydrogen, but they are currently more expensive to produce than especially renewable electricity, but also biogas.

Biogas

For a number of years now, Denmark has supported the production of biogas. Backed by a broad majority in Parliament, the 2012 Energy Agreement included subsidies for upgraded biogas, after which production took off. The share of upgraded biogas in the gas system reached 20% by the end of 2020 - equivalent to 16 PJ - and continues to increase. An additional 7 PJ of raw biogas - which is mainly used in local CHP plants - was produced in Denmark that year as well.

Biogas is a green, climate-neutral gas. In Denmark, biogas is primarily produced from biomass consisting of residues from agriculture, industry and households, i.e. domestic resources that would otherwise have been burned in incineration plants or used as fertiliser, emitting greenhouse gases into the atmosphere. Using that biomass for biogas lowers agricultural emissions while also making gas consumption more climate-friendly.

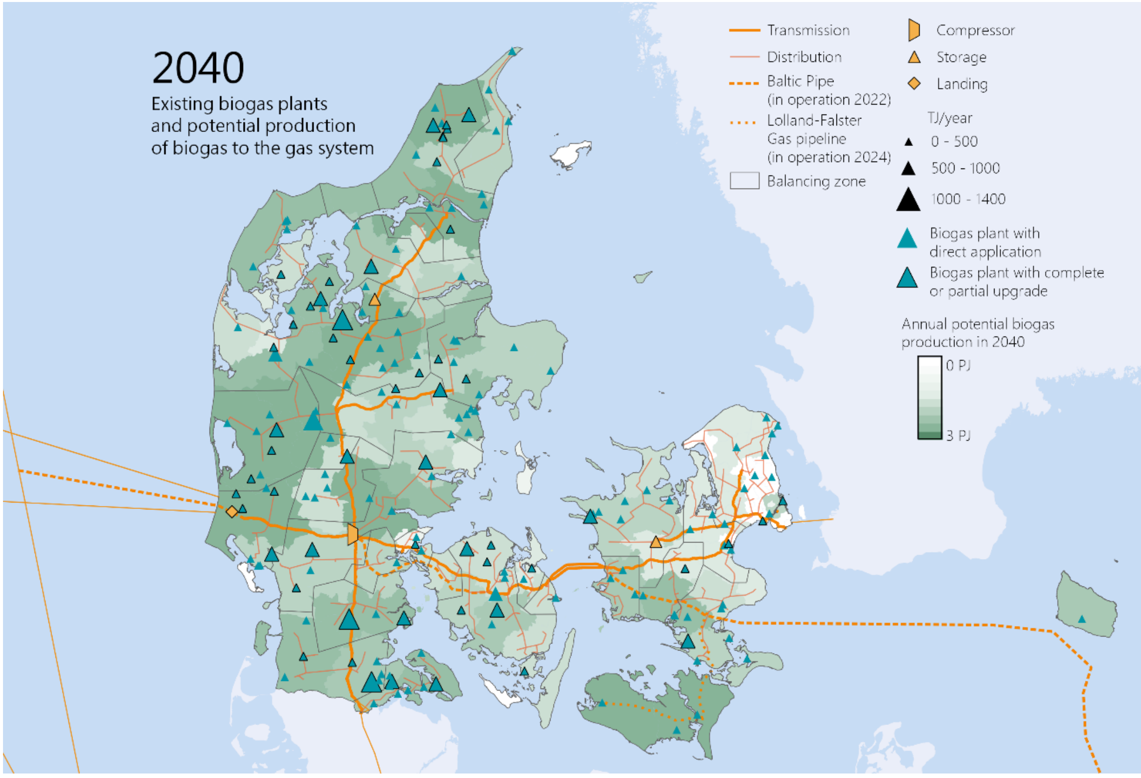


Figure 6: Distribution of Denmark's biomass sources for biogas.
Note: The map shows the potential production of biogas based on the geographical distribution of biomass sources in Denmark as well as the location of biogas plants in 2021. The map shows biogas plants that either fully or partially upgrade the biogas for the Danish gas system. The coloured areas indicate individual municipalities in the gas distribution system and the potential extent of biogas production in 2040 based on the expected biomass resources in each municipality.
Source: Danish Energy Agency

An analysis conducted at the University of Southern Denmark in 2020[1] found that the potential for the presently available domestic biomass resources for biogas production is estimated to be around 55 PJ by 2030, and biogas production is collectively expected to increase to around 50 PJ by 2030 based on adopted policy measures. 80% of that biogas is expected to be upgraded and fed into the gas system, while the remainder is expected to be used directly for industrial purposes and for electricity and heat generation.

It is believed that there will be sufficient domestic biomass resources to produce the amount of biogas needed to meet the forecasted demand in 2040, even in the possible eventuality of greater competition for domestic biomass resources as society transitions towards climate neutrality. The expectation that there will be sufficient biomass for biogas production is predicated on technological progress and improved production forms for individual types of biomass, especially liquid manure and straw. Two trends in particular are expected in this regard:

- Biogas yields from liquid manure will increase in the future via methods such as more rapidly sluicing out liquid manure from livestock buildings
- The production plants will become better at decomposing and exploiting biomass, i.e. a higher biogas yield per kg. of biomass. Straw in particular is expected to play a larger role in future biogas production.

Depending on technological advances and the possibilities for using straw, an overall domestic biomass-based biogas potential of between 74 to 94 PJ/year is expected by 2040. Currently, we

[1] https://ens.dk/sites/ens.dk/files/Bioenergi/energiafgroedeanalysen_med_bilag.pdf

only use a small part of the total potential straw offers for biogas, but it is expected that from 2030 and onwards, straw will be used in biogas production to a significantly larger extent than today.

Biomass resources are also expected to be in demand among other sectors, potentially increasing competition for them. For example, a demand for green fuel in heavy transport can draw upon biomass resources, as biogas in combination with hydrogen from PtX plants can be used to produce methanol or aviation fuel for the transport sector. In addition, biomass can also be used for other purposes, e.g. in pyrolysis plants. However, it is expected that pyrolysis plants will be able to make use of the residue from biogas production and thus reduce competition for biomass. Finally, it is expected large quantities of straw will no longer be needed for combined heat and power production when the straw-based CHP plants are converted to electricity-based heat pumps as we draw closer to 2040.

Power-to-X for hydrogen production

Hydrogen can be produced from electricity generated by renewable energy sources such as solar and wind power. This hydrogen can be used to produce a range of other gases and fuels. Technically, hydrogen can also be mixed into the gas system to a lesser extent, although this has not been factored into the scenarios below as the technical potential of doing so is considered too limited. The gas system can also play an important role in supplying fuel plants with green gas - specifically green molecules - for the production of future green fuels that will be used in industrial processes as well as for aircraft, ships and heavy transport.

Power-to-X in biogas production

The PtX technologies can also be used in biogas production. Thus far, the focus in Denmark has been on upgrading biogas by removing the CO_2 from it and emitting it into the atmosphere where it came from. However, there is a growing interest in using PtX in biogas production to produce e-methane and feed it into the gas system. E-methane can be seen as a form of biogas upgrading where the CO_2 content in the biogas is combined with hydrogen from a PtX plant to produce even more green gas. By using PtX in biogas production, the technical potential of biogas production could rise from 74-94 PJ to 111-165 PJ/year by 2040. For e-methane to become a viable fuel, however, subsidies for e-methane production would have to be brought down to the level of biogas subsidies. Whether that is possible will become evident in the planned tenders for green gases. At the same time, considerable potential lies in exploiting the biogenic CO_2 that is produced via the biogas plants' upgrading processes, which is expected to amount to 1.4 million tonnes by 2030. Among other things, biogenic CO_2 can be used to produce carbonaceous fuels such as methanol or aviation fuel.

Scenarios for biogas production

Four scenarios have been developed for the potential of green gas production up to 2040:

- **Potential with e-methane:** This scenario illustrates a theoretical potential where CO_2 from the upgrading plants is increasingly used to produce e-methane, combined with full utilisation of biomass from straw and residues from agriculture and households.
- **Potential based on biomass:** This scenario illustrates a theoretical use of available biomass from straw and residue from agriculture and households.
- **The Danish Energy Agency's 2021 Analysis Assumptions for Energinet (AF21):** This scenario is based on the Danish Energy Agency's analysis outlook for system gas. The scenario solely includes biogas up to 2030, but other types of green gases (e.g. hydrogen or e-methane) are included in the slightly longer term, where unsubsidised green gas is also used for transport or exported.
- **Subsidised biogas:** This scenario illustrates the expected development from the Danish Energy Agency's 2021 Climate Status and Outlook (KF21), i.e. a 'frozen policy' eventuality. The scenario only includes subsidised biogas based on current and future subsidy schemes that have already been adopted. Production is phased out in this scenario as the subsidies expire.

These scenarios should not be interpreted as expected scenarios. The scenarios illustrate that it may become technically feasible to cover Denmark's total gas consumption with green gas in all the gas strategy's consumption scenarios, provided there the demand and willingness to pay for green gas exists.

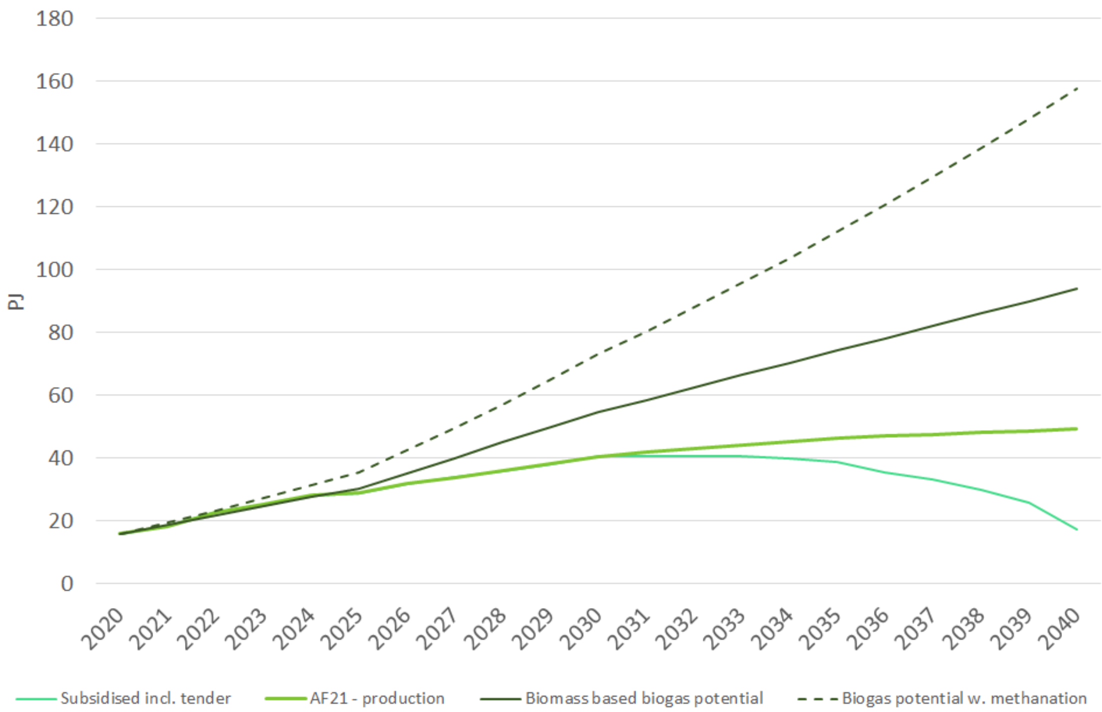


Figure 7: Technically feasible development paths for biogas production.
Source: Danish Energy Agency

How will gas consumption change in the future?

Towards 2040, a general decline in Danish gas consumption is expected, resulting in lower greenhouse gas emissions as gas consumption decreases and the share of green gas in the gas system increases. The strategy includes a number of consumption scenarios that show how the green transition of Denmark's gas system - aside from the development of green gas production - also depends on how much and how quickly the country can reduce its gas consumption.

A general decline in Danish gas consumption is expected towards 2040. In light of that, this strategy presents a number of scenarios showing possible theoretical outcomes for future gas consumption for industry, households, CHP production and transport.

The reason for outlining the outcome range for future gas consumption with these scenarios is that consumption levels carry implications for when gas consumption will be entirely green as well as the cost for transporting gas, i.e. gas tariffs. With lower gas consumption and fewer customers in the future, there will be fewer users to pay for the gas system, which would - all else being equal - lead to higher tariffs.

The baseline scenario is the Danish Energy Agency's Analysis Assumptions (AF21), while the other scenarios assume either faster or slower phaseouts of gas consumption in individual sectors.

Four consumption scenarios

The consumption scenarios below illustrate possible theoretical outcomes towards 2040:

- **Base scenario:** A middle-ground scenario based on AF21. The development path in AF21 outlines the most likely developments in the field of energy, assuming the politically agreed targets are met. Among other things, AF21 is based on political decisions, meeting the 70% objective and the long-term goal of achieving climate neutrality by 2050. AF21 accordingly assumes additional political initiatives such as subsidy schemes, higher levies and measures to further phase out gas.
- **High consumption:** A scenario based on the baseline scenario in relation to individual heating as well as electricity and heat production. At the same time, it assumes a maximum level of gas consumption in Danish industry, and thus also new industrial consumers. The scenario assumes that only a small part of industrial processes in general are electrified. In addition, the scenario assumes that large parts of industrial coal and oil consumption is converted to gas consumption. The transport sector's gas consumption is also assumed to rise, in part due to greater use of gas in shipping and heavy road transport.
- **Low consumption:** This scenario assumes a minimal level of gas consumption in Danish industry. It assumes that large parts of industrial process energy consumption is electrified and made more efficient. The scenario also assumes a full phaseout of gas for individual heating and for public electricity and heat production by 2030.
- **Combination scenario:** This scenario assumes a maximum level of gas consumption in Danish industry as well as a full phaseout of gas for individual heating in 2030. Among other things, this scenario can help illustrate implications on tariff development if gas is not at all used for individual residential heating but used to a great extent in industrial processes.

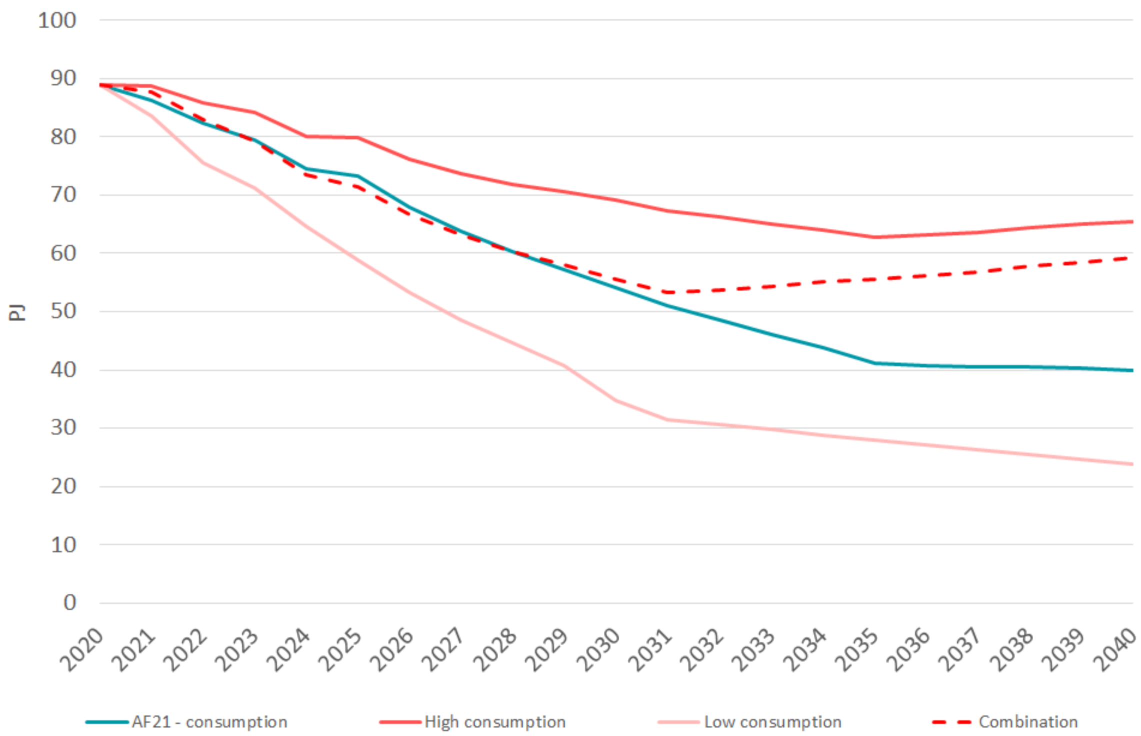


Figure 8: Consumption scenarios in the gas strategy
Source: Danish Energy Agency

There are major differences in gas consumption in the four scenarios, ranging from just under 24 PJ to 66 PJ in 2040.

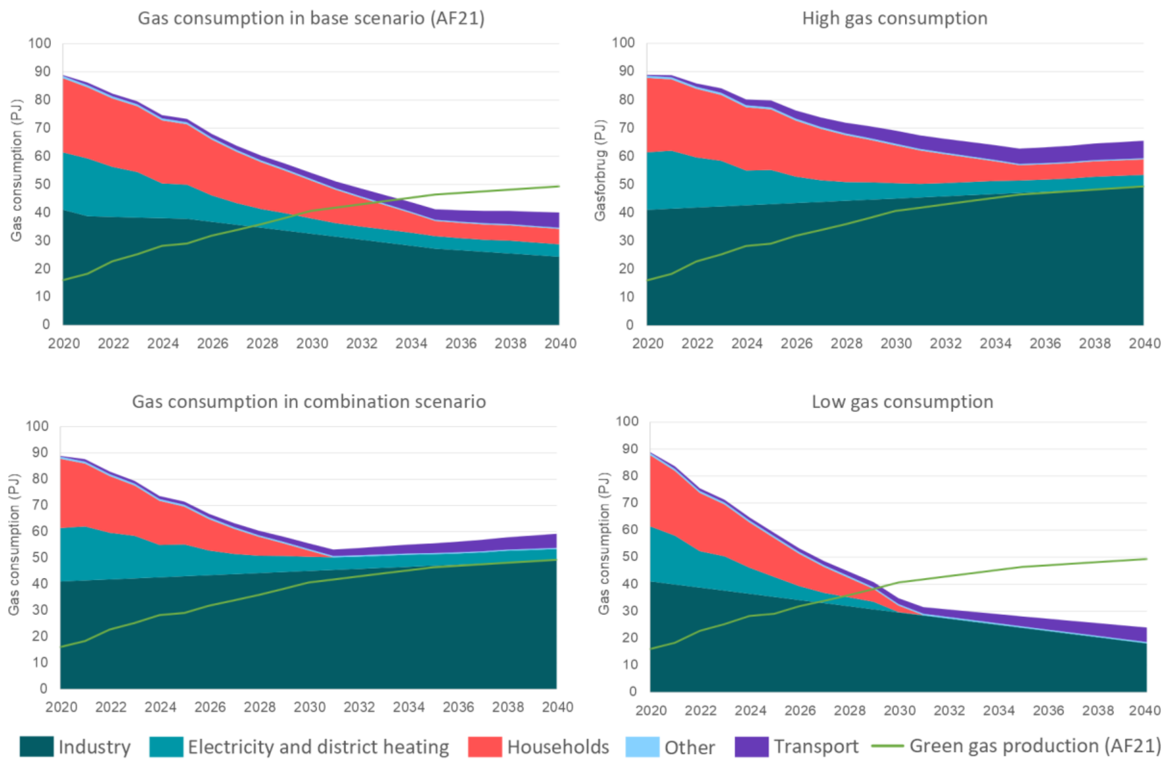


Figure 9: Gas consumption development by sector in four scenarios as well as a green gas production scenario. Source: Danish Energy Agency

The baseline scenario (AF21) in Figure 9 shows that gas consumption could potentially become 100% green by 2035, while gas consumption in the high consumption scenario and combination scenario will not become entirely green before 2040, assuming the baseline scenario's (AF21) level of biogas production. However, it will be technically possible to achieve entirely green gas consumption in all the consumption scenarios with other combinations of the production scenarios (see Figure 10). Generally, these scenarios illustrate that the pace of the green transition of the gas sector depends not only on how much and how quickly Denmark can reduce its gas consumption, but also on how much green gas can be produced.

The green intersection: Fully green gas production achievable by 2035

Figure 10 illustrates a variety of paths to *'the green intersection'*, where gas consumption can be fully covered by green gas production. Several paths exist to achieving the full green transition of the gas system, which could occur at different times. Based on the Danish Energy Agency's analysis assumptions, it is expected that we can hit the green intersection before 2035, although this depends on factors such as the measures agreed in 2020 being implemented and the launch of further policy initiatives.

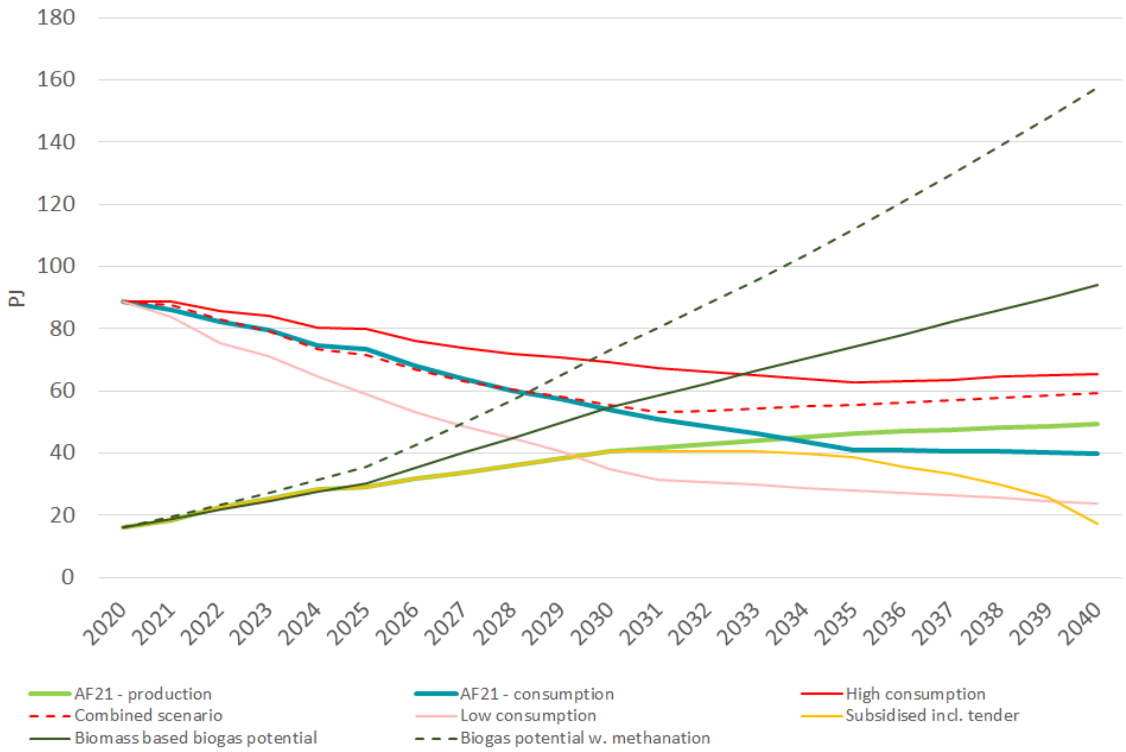


Figure 10: The green intersection, i.e. where gas consumption and green gas production meet at the same level
Source: Danish Energy Agency

Gas in industrial processes

Energy for industrial processes is considered one of the areas in which biogas - and eventually, other green gases - can be used to reduce emissions of greenhouse gases, and the consumption scenarios show that Danish industry is expected to account for a large part of Danish gas consumption in the future. Yet there is also considerable potential to reduce gas consumption in industrial processes and businesses through energy efficiency improvements and electrification. The forthcoming Green Tax Reform is also expected to encourage a faster reduction in the consumption of fossil natural gas in areas where greenhouse gas emissions can be reduced at a relatively cheap cost from a socioeconomic perspective. Additionally, the reform is also envisaged to encourage the use of gas in areas where it is socioeconomically sensible, e.g. as an alternative to coal.

The size of future gas consumption by Danish industry and businesses depends largely on the feasibility of electrification for each enterprise, the incentives that exist for electrification and the feasibility of combining electricity and gas. Figure 11 shows a technical outcome range for Danish industry's future gas consumption as being between 18 and 49 PJ in 2040. The low consumption scenario assumes the electrification of every possible part of Danish industry. The low consumption scenario also assumes the conversion to gas from coal, oil, etc. in the parts of Danish industry where electrification is not possible.

In the high consumption scenario, it is assumed that any industry that can fully or partly use gas for process heat will exclusively use gas. For example, this would entail the cement industry transitioning entirely to using gas. The remaining part of the industry which can be electrified is assumed to become fully electrified. The higher band of the outcome range reflects an expectation of less flexible energy consumption, with each sector only being covered by a single type of energy supply: electricity or gas.

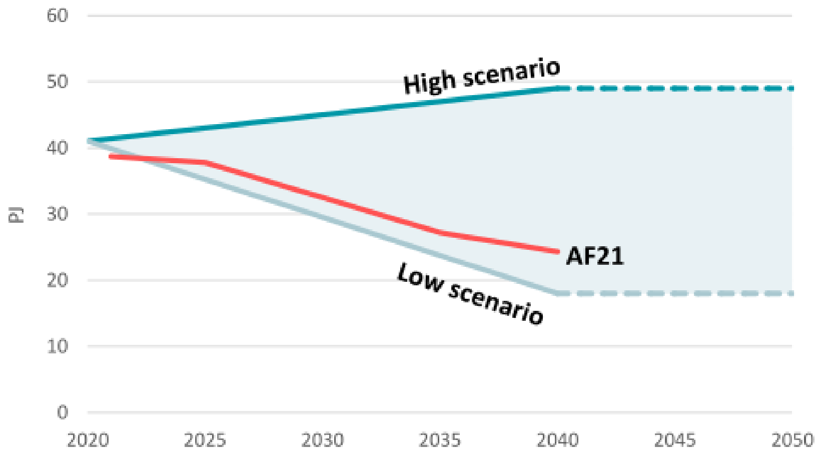


Figure 11: Outcome range for system gas consumption in Danish industries and businesses according to the Danish Gas Strategy's industry analysis.
Note: The outcome range is compared to industrial and commercial system gas consumption according to AF21. System gas consumption in the high scenario reflects system gas consumption for industry and business in the "High consumption" scenario, while consumption in the low scenario reflects consumption in the "Low consumption" scenario.
Source: Danish Energy Agency

The clearest electrification potential is often found in industrial processes that rely on low- and medium-temperature process heat (typically up to 150 °C). However, a number of high-temperature processes can also be electrified, albeit only at a major cost to the company. The technological solutions to the green transition of low- and medium-temperature process energy are known, but require further development in terms of cost and operational stability in some cases. Affordability is the greatest barrier to electrification of low- and medium-temperature process heat, which is often associated with major investment costs as the price of electricity is higher than for gas and fossil fuels such as coal, coke and oil. It can be difficult for companies to achieve positive operating economies with such investments, which can take a long time to pay off.

The high-temperature processes, i.e. processes that require temperatures above 150 °C, are commonly associated with cement production, metallurgy processes, insulation material production and brickworks. At present, the options for fully electrifying high-temperature processes in manufacturing industries are not cost-effective, as they typically require a major investment and increase running costs. Further electrification of high-temperature processes therefore relies on technological advances. The potential of and barriers to the green transition of process energy in industry are further elaborated upon in the Green Industry Analysis.

The transition of Danish industry from coal and oil to natural gas would have a positive impact on Denmark's climate balance, as natural gas is less harmful to the climate than coal and oil. Therefore, system gas could allow Danish industry to take a further step in reducing greenhouse gas emissions in areas where energy efficiency improvements and electrification are either not possible or insufficient. As green gas will increasingly make up a greater share of Danish gas consumption - and is expected to reach 100% in the long term - the transition of Danish industry to system gas would become entirely climate neutral in the long run.

CO_2 emissions vary across consumption scenarios

CO_2 emissions in the Gas Strategy consumption scenarios vary. Figure 12 illustrates the level of CO_2 emissions in each of the consumption scenarios outlined above. As biogas production increases and gas consumption generally decreases, the climate impact will decrease accordingly, as less gas being consumed and a higher share of green gas in the gas system results in lower greenhouse gas emissions.

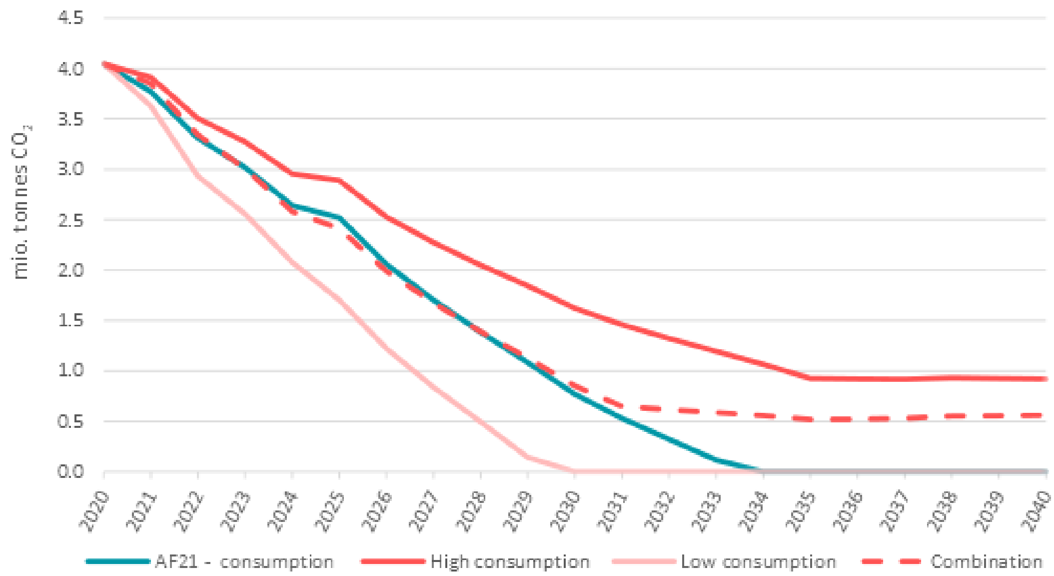


Figure 12: CO_2 emissions from system gas consumption in the Gas Strategy's consumption scenarios.
Note: The emissions assume a production of biogas corresponding to the production levels in AF21.
Source: Danish Energy Agency

Evolution of tariffs

It is expected that Danish industrial enterprises will in the future account for the majority of Danish gas consumption. One of the determinants of the international competitiveness of these companies is their access to energy supplies and that their total energy costs are on par with the cost of energy in other countries. A gas bill is primarily made up of the cost of the gas itself as well as fees and tariffs. Fluctuations in the price of gas will typically have a greater impact on annual gas costs than tariff changes. Tariffs do have an impact, however, as while the price of the gas itself is determined at international exchanges, Danish tariff increases only impact Danish companies

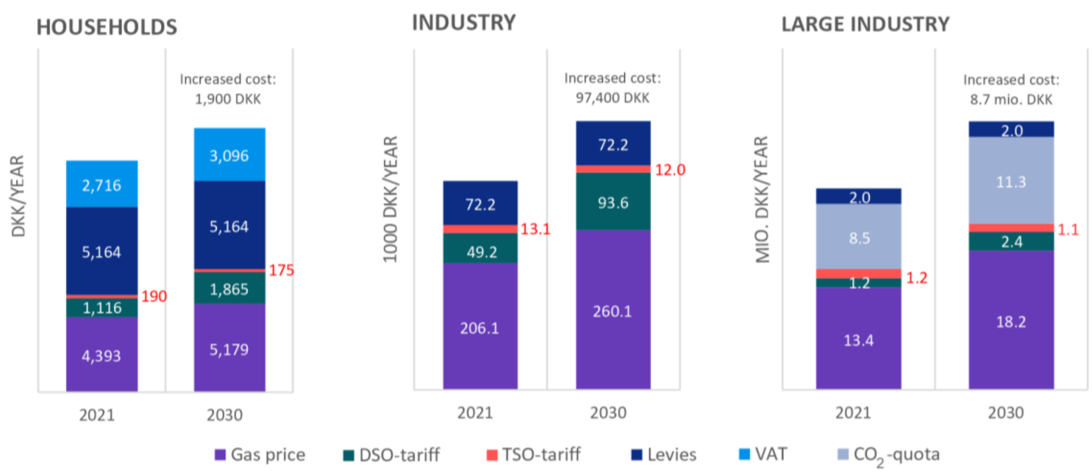


Figure 13: Examples of the breakdown of the total gas bill in 2021 and 2030 respectively.
Note: The figure shows a gas bill for 2021 and 2030 for three different types of consumers: Households (annual gas consumption of 1,637 m^3), small businesses (annual gas consumption of 112,500 m^3), large industry (annual gas consumption of 10 million m^3). The gas bill is calculated on the basis of Evida Nord's tariffs. The overall gas prices are based on the Gas Price Guide and expected price developments for gas prices and emission allowance prices in AF21. In addition, the calculation assumes no change in levies. Gas price including storage means that no separate costs for storage are added, as it is assumed that these costs are already included in the price when the gas is offered to consumers or on the gas exchange.
Source: Danish Energy Agency and Evida

FACT BOX 3: What are tariffs?

The maintenance, expansion and running operation of the gas system is funded by gas consumers and over users of the gas system. This funding is collected through gas tariffs. Tariffs are payments for transporting gas through the gas system.

The state-owned companies Energinet and Evida collect the tariffs at the transmission level and distribution level, respectively.

In the future, the level of tariffs will especially depend on changes the level in gas consumption as well as production of green cases. With gas consumption expected to decline along with the number of gas consumers, there will be fewer users to share the costs of the gas system in the future.

Distribution tariffs rise in line with the green transition

The scenarios of the Gas Strategy show that distribution tariffs are expected to rise as a consequence of a decline in gas consumption and the green transition. The scenarios also show that speed is an important factor: The faster gas consumption is phased out, including in relation to individual domestic heating, the more tariffs will rise for the remaining gas consumers, which are expected to be mainly industrial enterprises.

In total, distribution and transmission tariffs currently make up around 10-20% of a gas bill. Based on future gas consumption projections from the Danish Energy Agency's 2021 Analysis Assumption (AF21), this share is expected to rise to somewhere between 10 and 24 percent of the total gas bill by 2030.

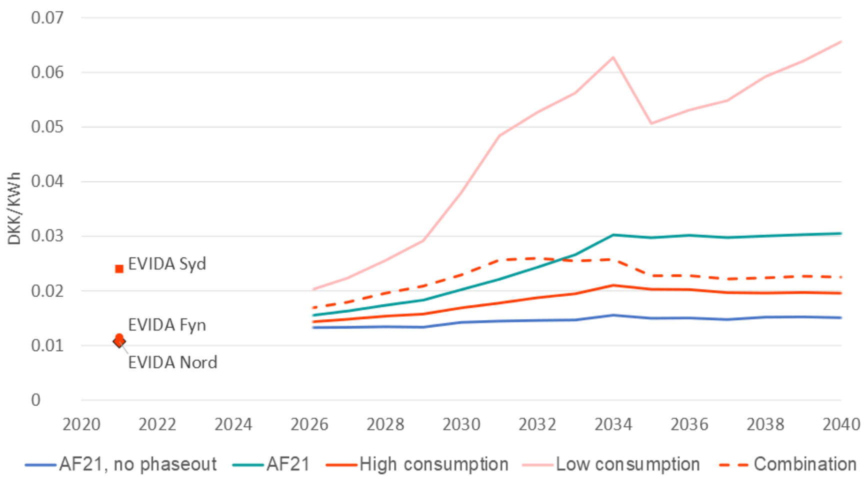


Figure 14: Change in distribution tariff for the biggest industrial consumers with a consumption greater than 35 m³/year, calculated on the basis of the Gas Strategy's consumption scenarios.
Note 1: Evida has three different tariff levels towards 2024. This is because Evida consists of three merged companies: HMN, DGD and Naturgas Fyn. These are now part of the Evida Group and go by the names Evida Nord, Evida Syd and Evida Fyn, respectively. As the three companies were merged into Evida with different historical debts (regulatory debt), it was decided that the companies would maintain different tariff levels until the debt is written off in all three companies by the end of 2023.
Note 2: The change in distribution tariff has been calculated on the basis of Evida Nord's tariffs. However, the figure also shows the annual tariffs for Evida Syd, which are currently higher than Evida Nord's tariffs. Therefore, the rise in tariffs will not be felt quite as significantly by Evida Syd's customers. "AF21, no phase-out" assumes a scenario where gas consumption follows AF21, except that household consumption remains at the same level as today.
Source: Danish Energy Agency

The above figure shows that tariffs will especially increase in a scenario where individual gas burners have been completely phased out by 2030, combined with a sharp reduction in industrial gas consumption as assumed in the “low consumption” scenario.

It has been calculated how much the industrial sector’s tariffs will rise if all Danish gas burners are disconnected by 2030, 2035 and 2040. As shown in Figure 15, a rapid phaseout of household gas burners would entail significantly higher tariff payments in the short and medium term compared to a more gradual phaseout of gas burners.

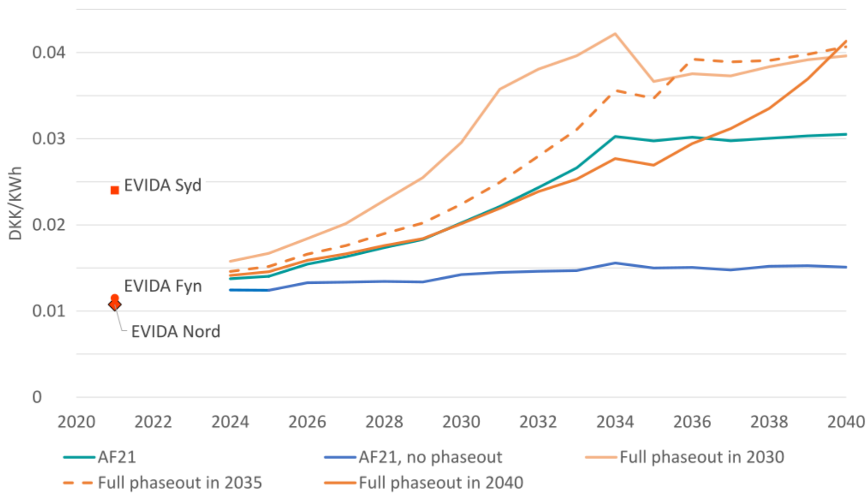


Figure 15. Impact on distribution tariffs as a consequence of phasing out gas burners.
Source: Danish Energy Agency and Evida

Unless Evida actively implements cost reductions as household customers disappear, it is likely that the tariff level will remain the same in 2040 regardless of how quickly individual gas burners are phased out.

Transmission tariffs will remain at approximately the same level as today

Unlike distribution tariffs, transmission tariffs are less sensitive to the green transition of Denmark’s gas system. Energinet has customers that supply Danish and international gas consumers as well as transit customers that transport gas through Denmark.

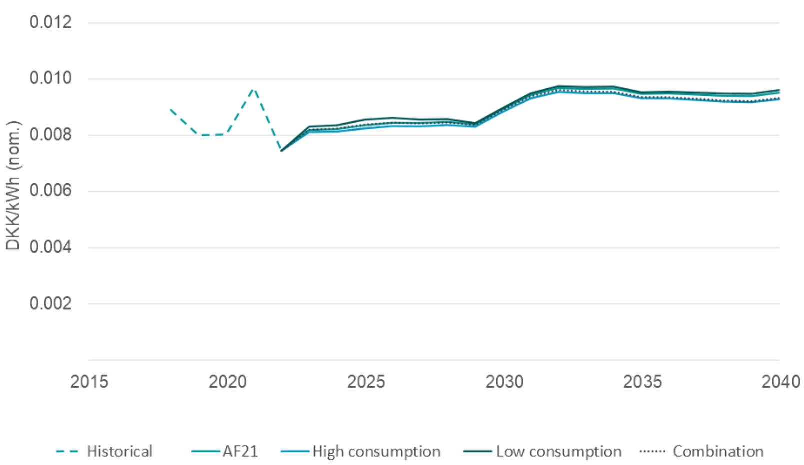


Figure 16: Change in average transmission tariff for all transport customers.
Source: Danish Energy Agency and Energinet

In connection with the Baltic Pipe project, Energinet has signed contracts to transport large volumes of gas to Poland via the future supply corridor. The large amount of gas that will be transported will allow tariffs to be kept stable even while Danish gas consumption declines and transitions to green gas.

The Government's ambitions for Denmark's future gas consumption and gas infrastructure

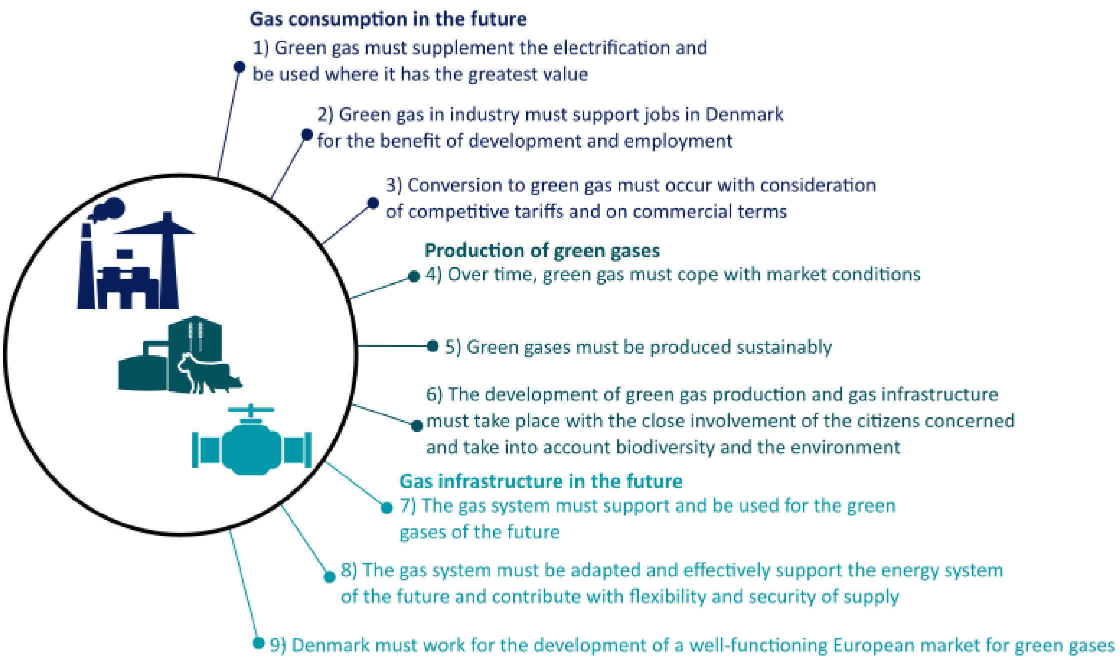
The Danish Government has launched a wide range of measures to reduce as well as convert Danish gas consumption. However, more decisions will need to be taken to achieve Denmark's ambitious climate objectives. The strategy therefore consists of nine interrelated objectives that make up the Government's policy goals in relation to the gas sector. Together, the objectives show how a future green gas system can be developed rapidly, cost-effectively and appropriately.

The Green Gas Strategy builds on a number of decisions and measures taken by the Government along with a broad parliamentary majority since 2019 when the Government took office.

Decisions and measures since 2019	
Dec. 2019	**Agreement on the Climate Act** The Danish Climate Act turns the 70 percent target into Danish law and ensures that Denmark assumes a leading role in the green transition, raises ambitions and inspires the whole world to climate action.
Mar. 2020	**The Government's Climate Partnerships** Recommendations from the Climate Partnership for Energy-Intensive Industries aimed at ensuring such industries use gas to a greater extent in the future.
Jun. 2020	**Climate agreement for energy and industry, etc.** Phaseout of gas burners: Approx. DKK 4 billion in subsidies towards 2026 earmarked for encouraging households to replace oil and gas burners to district heating and heat pumps. In addition, levies on heating were adjusted to make it more costly to use fossil fuels for heating and cheaper to use green electricity for heating. Regulations were also adjusted to encourage the conversion of areas from natural gas to district heating. Subsidy tenders for biogas and other green gases: DKK 13.6 billion has been earmarked towards 2050 for new national subsidy tenders for producing biogas and other green gases. Green transition of industry, etc.: The Business Fund (which provides energy efficiency improvement grants to Danish businesses) will receive approx. DKK 2.5 billion more (including derived losses from levies) through the Climate Agreement and Green Tax Reform Agreement.
Sep. 2020	**Cooperation agreement with Aalborg Portland** The Government signed a cooperation agreement with Denmark's biggest emitter of CO_2, the cement producer Aalborg Portland, which commits the company to reduce its emissions by at least 660,000 tonnes of CO_2 by 2030.
Dec. 2020	**The North Sea Agreement** The North Sea Agreement sets an end date for the extraction of Danish oil and natural gas in the North Sea, ensuring that fossil natural gas extraction from the Danish part of the North Sea will cease by 2050.
Dec. 2020	**Adoption of proposed legislation on new forward-looking economic regulation of Energinet** Forward-looking economic regulation which ensures the regulation of Energinet also takes account of future costs and changes in the energy system in light of the green transition.
Dec. 2020	**Green Tax Reform (higher and uniform taxes on greenhouse gas emissions)** Higher and more uniform taxes on emissions of greenhouse gases will be introduced towards 2030.
Dec. 2020	**Green transition of road transport** Among other things, the agreement introduces a CO_2 displacement requirement which promotes the use of fuels - including unsubsidised biogas - that can help reduce CO_2 emissions from road transport. The CO_2 displacement requirement includes the promotion of PtX fuels.
Feb. 2021	**Gas pipeline to Lolland-Falster** The gas pipeline is especially intended to serve local industry such as Nordic Sugar's sugar mills in Nykøbing Falster and Nakskov. The gas pipeline will also allow biogas to be produced on Lolland-Falster in the future which can be fed into the gas system.

May 2021	**Adoption of proposed legislation on adjusted economic regulation of gas distribution** Forward-looking economic regulation which ensures the regulation of the gas distribution system also takes account of future costs and changes in the energy system in light of the green transition.
Jun. 2021	**Agreement in principle on CO_2 storage** Agreement on a roadmap for CO_2 storage, including 1) creating a basis for safe and environmentally sound storage of CO_2 underground, 2) enabling Denmark to import and export CO_2, and 3) initiating further studies to identify new storage sites in Denmark.
Sep. 2021	**Roadmap for a green Denmark** Towards 2025, the necessary decisions will be taken to achieve the 70% target by 2030. As early as in 2022, the Government will present an industry proposal as well as an energy and utilities proposal that will create the framework for realising the climate potential of Denmark's industrial and energy sector in the long term.
Nov. 2021	**Beyond Oil & Gas Alliance (BOGA)** At the COP26 climate summit, Denmark and Costa Rica launched the world's first global alliance to end the extraction of oil and natural gas in the North Sea. Core members commit to supporting an adjustment of oil and gas production in line with the Paris Agreement targets.
Dec. 2021	**The Government's Green Gas Strategy, Strategy for Power-to-X as well as a broad political agreement on carbon capture, transport and storage**

The Green Gas Strategy presents the Government's nine interlinked objectives that represent the Government's policy goals for how the Danish gas system can transition towards green gas while remaining competitive. Collectively, the objectives lay out the future of gas consumption, sustainable production of green gases and the infrastructure of the Danish gas system. Establishing a clear direction serves to provide certainty and predictability for users as well as help ensure security of supply in the overall energy system. Tariffs should also be kept at a competitive level and as low as possible to minimise their impact on gas consumers.



Objective 1: Green gas must supplement electrification and be used in areas where it offers the greatest value

Because green gas is most expensive to produce than green electricity, the Government's ambition is that green gas will primarily be used in sectors where electrification is difficult, such as energy-intensive industry. Gas should also not be used beyond a necessary extent for electricity and heat production, but there will continue to be a demand for gas. Gas offers flexibility in the energy system by providing storage, peak load and *adjustability. Gas supplements energy efficiency improvements and electrification, and it can contribute to significant CO_2 reductions in Danish industry, e.g. by transitioning high-temperature processes away from coal and oil to gas.*

The Government's ambition is to develop an energy supply that is both green *and* secure. This requires Denmark to take ambitious action towards reducing and focusing gas consumption as well as supplying biogas and other green gases to Danish gas consumers. The Government's ambition is to ensure the gas we consume in Denmark is green and to ensure that green gases are used in areas where they provide the most affordable solution to reducing greenhouse gas emissions. Accordingly, green gas is important to Denmark's green transition and energy supply, both today as well as in the future.

A reduction in gas consumption will make a clear difference in Denmark's climate balance for as long as part of the country's gas consumption comes from natural gas, as any reductions will constitute a cut in fossil natural gas consumption up to the day where the country produces as much green gas as it consumes. The CO_2 reduction potential of cutting gas consumption in Denmark is therefore significant. Ways of doing so include electrification, energy conservation and converting to district heating anywhere that it is technically and economically feasible to do so. One of the Government's priorities is to establish a framework that gives future energy consumers the right incentives to make the right green choices and encourage consumers in general to make green choices.

However, all of Danish society cannot be electrified, and certainly not within the near future. At the same time, the production of green gases is associated with a relatively high level of subsidies compared to those for renewable electricity generation, which is further reason to reduce gas consumption in Denmark. Accordingly, gas consumption should be reduced while green gas should primarily be used in areas where electricity from renewable sources is not a viable alternative.

Phaseout of individual gas burners

One of the ways gas is used today is for individual domestic heating and public heat production through the district heating system. In individual homes, district heating and electric heating pumps are often socioeconomically beneficial and climate-friendly alternatives to gas burners.

To accelerate the green transition of heat supply, the June 2020 Climate agreement for energy, industry, etc. included a number of initiatives to promote the phaseout of gas burners. The climate agreement also entailed the initiation of an analysis on how gas consumption for individual home heating could be phased out. The Government intends to analyse concrete and effective measures towards a future energy and supply proposal in 2022, where the Government is also expected to present a proposal for new possible measures to reduce gas consumption for individual heating.

The figure below shows how a gradual reduction of gas for individual domestic heating could potentially contribute to CO_2 reductions if higher levies and other measures are implemented to phase out the use of gas for domestic heating.

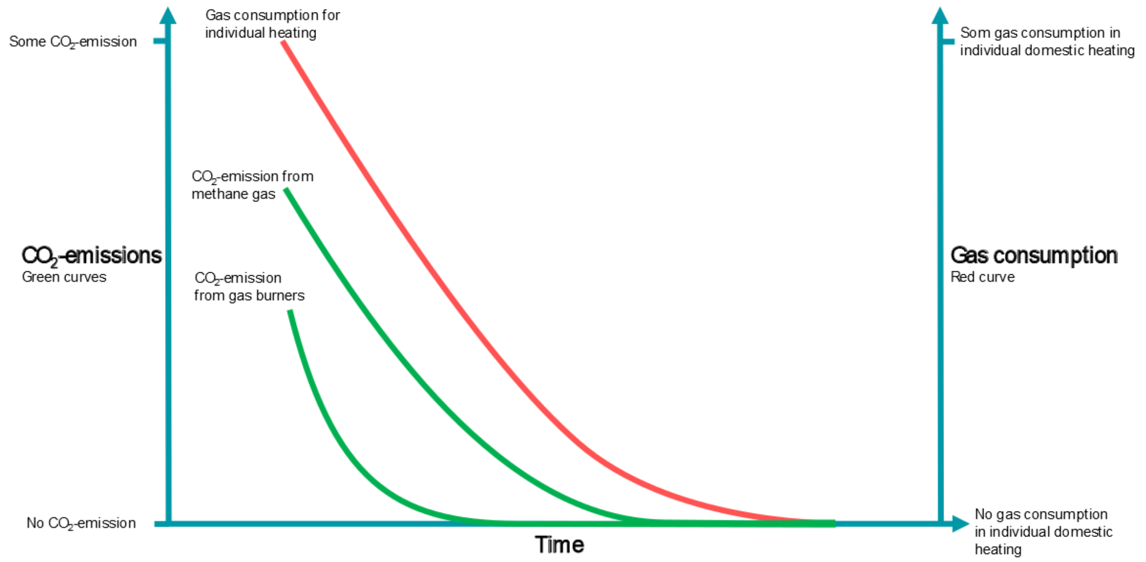


Figure 17: Possible phaseout of gas consumption for individual heating and CO_2 reductions.
Note: This figure illustrates potential paths towards a total phaseout of gas consumption and requires additional instruments such as bans that would need to be approved by the European Commission.
Source: Danish Energy Agency

FACT BOX 4: How does a reduction of gas consumption contribute to the green transition if we replace fossil natural gas with green biogas?

There are several reasons why the Government would like to see gas - even green gas - primarily be reserved for sectors that are difficult to electrify.

Firstly, Denmark has good alternatives to individual heating, as district heating and electric heat pumps are often socioeconomically beneficial and climate-friendly alternatives to gas burners.

Secondly, Danish-produced biogas that is used in Denmark is considered carbon-neutral. This means that biogas displaces fossil natural gas every time a household replaces their gas burner with a better alternative (e.g. a heat pump), as this eliminates that household's need for biogas, which can be used elsewhere in Denmark instead. The CO_2 reduction potential is therefore greater than the actual emissions from gas consumers, as the share of biogas in gas consumption will increase every time a household replaces natural gas heating with something else. Conversely, a household that converts to gas today would correspondingly increase the consumption of natural gas.

Thirdly, green gases are more expensive to produce than renewable electricity, which is why such gases should be prioritised for areas where they provide the greatest value.

Gas must continue to contribute to security of supply

Gas must not be used beyond a necessary extent for electricity and heat production, but there will continue to be a demand for gas. Gas offers flexibility in the energy system by providing storage, peak load and adjustability. Therefore, gas will remain a valuable resource through its capacity to contribute to electricity as well as heating security in difficult periods such as cold winter periods. The flexibility that gas-based electricity and heat generation can provide will become increasingly important.

Gas can create value in industry

The Government's ambition is for green gas to primarily be used in sectors where electrification is difficult, which is especially the case in heavy industry. Parts of Danish industry have the potential to reduce CO_2 emissions through energy efficiency improvements and electrification. These are not always viable solutions, however, which is why green gas serve as a third alternative to help reduce industrial greenhouse gas emissions.

The transition from coal and oil to gas in industrial processes will have an immediate positive impact on Denmark's climate balance, as natural gas is less harmful to the climate than coal and oil. Additionally, a growing share of green gas consumption *may* be able to eventually eliminate CO_2 emissions from Danish industry under a number of assumptions. This means that gas in Danish industry can contribute to Denmark's green transition when used in processes where it replaces fossil fuels.

Green gas can thereby contribute to the Government's ambition to bring about the green transition of Danish industry. In certain industrial sectors, gas will be a more long-term solution while in others, it will play a transitional role until other technologies are developed and matured. Danish industry should have the right incentives to reduce their CO_2 emissions. Accordingly, the Government will present an industry proposal in 2022 which will chart the course to realising the reduction potential in Danish industry and show the rest of the world how to build a green industrial sector.

Potential for green gas in transport

Significant possibilities exist in relation to using green gas for transport, especially heavy transport. However, it is uncertain how much gas will be used for transport in practice.

In Denmark's domestic shipping sector, gas-powered vessels are currently limited in number, although there are a few gas-powered ferries serving small islands. There are also relatively few gas-powered trucks and vans on Danish roads, and the use of biogas in road transport is correspondingly limited. However, biogas for heavy transport could contribute to the green transition of the transport sector, especially domestically for heavy road transport.

In the future, a CO_2 displacement requirement will be introduced in road transport, giving unsubsidised biogas an advantage due to being a sustainable fuel. Biogas has a very high CO_2 displacement capability, as it is waste-based unlike first-generation biodiesel. EU displacement requirements for road transport can only be met without the use of other subsidies. The use of unsubsidised biogas will therefore be able to contribute to further CO_2 reductions, as the CO_2 displacement requirement in road transport could further increase biogas production.

In the long term, i.e. after 2030, there is potential for green gases - such as biogas, e-methane and hydrogen - to be used as building blocks for the production of green fuels for shipping, aviation, etc. The Government will therefore present a proposal in 2022 for the transition of air traffic, followed by a proposal in 2023 for sustainable fuels for the transport sector and shipping. Finally, the Government will launch a strategy for the green transition of heavy road transport by 2022.

Objective 2: Green gas in industry must support jobs in Denmark and provide economic growth and employment opportunities

The green transition must support employment in Denmark. By serving as a replacement for coal and oil, green gas can help support Danish industrial and commercial jobs in sectors where electrification or energy conversation is not possible or viable.

The Government has observed a great deal of interest from Danish industry and business in taking responsibility for the green transition and reducing their climate footprint. Energy efficiency improvements and electrification will prove instrumental in this regard.

Electrification plays an important role in the green transition of industry and commerce because it significantly contributes to CO_2 reductions. At present, however, electrification is not a feasible alternative for all companies and industrial manufacturing processes, such as companies that have manufacturing processes requiring very high temperatures. For other companies, electrification would require such major refurbishments and new investments that would render them unable to continue operations or retain a workforce in Denmark.

For these companies, access to gas at competitive prices is crucial, and the Government sees the Danish gas system as an important complementary component to aid in the general push towards electrification and energy efficiency improvements.

The green transition must support employment in Denmark

Denmark's green transition must not lead to Danish jobs being lost or relocated abroad. If the policy framework for green energy supply to industry and business reduces competitiveness compared to other countries, Denmark may lose manufacturing companies and jobs. Therefore, the possibility of Danish industry to obtain green gas is an important tool to implement the green transition while also supporting employment in Denmark.

The Government and a broad majority of the parties of the Danish Parliament have successively boosted efforts related to the green transition and focused energy efficiency improvements initiatives in Danish businesses. In total, approximately DKK 3.9 billion has been allocated to the competitive subsidy scheme for private enterprises (the Business Fund/*Erhvervspuljen*) to offer companies financial support for their green transition from 2020-2029. In addition, Denmark's two largest emitters of CO_2 - cement producer Aalborg Portland and sugar producer Nordic Sugar - will be connected to the Danish gas system in the future. These are examples of how gas can help displace coal and oil consumption in parts of industry where electrification is difficult or expensive. Gas can thereby both contribute to CO_2 reductions as well as the retention of Danish jobs.

Denmark must be an international leader in green solutions

Danish gas consumption is currently the greenest in Europe. Denmark is a leader in the transition to green gases, and Danish industry and business have a tradition of being innovative and competitive on a global scale. These Danish strengths can contribute to Denmark becoming a leader in the production and export of green gases such as hydrogen to the European market, and to Denmark retaining and attracting companies by enabling them to produce goods with a low climate footprint.

The Government's ambition is to create appropriate framework conditions that help Denmark become an important European and global player in green solutions, thereby benefiting Danish exports and employment.

CASE: Gas pipeline to Lolland-Falster

On 1 February 2021, the Government announced that a gas pipeline will be established from South Zealand to Lolland-Falster, which has not been connected to the Danish gas system so far. The new pipeline will also enable the area to produce biogas which can be fed into the Danish gas system.

The gas pipeline will supply gas to industry in the area, including the two sugar mills in Nakskov and Nykøbing Falster, which will no longer be allowed to use coal and oil in sugar production due to EU legislation. The gas pipeline can help support continued employment at Lolland-Falster's largest workplace, Nordic Sugar's sugar mills in Nykøbing Falster and Nakskov, which employ around 350 people and where some 750 local beet growers supply the factories with sugar beet. In addition, several other manufacturing companies have indicated their intention to be connected to the pipeline.

In August 2021, the company Dansk Biokemi announced plans to establish production of so-called biopolymers for bioplastics, bringing at least 100 new jobs to Nakskov. Nakskov's future access to the gas system was a crucial factor in that decision.

The gas pipeline can thereby contribute to the green transition in general, ensure that green growth also benefits Lolland-Falster and support local jobs so that people can continue to work in all parts of Denmark.

Objective 3: The transition to green gas must occur with consideration for competitive tariffs and on commercial terms

Tariff increases in Denmark can impact the competitiveness of Danish industrial enterprises. It is important that the green transition of the gas system is well-planned so that tariffs can be maintained at a competitive level for the benefit of gas consumers.

The Government's ambition is for gas tariffs to remain at a level where Danish industrial enterprises and other gas consumers can obtain gas at competitive prices in the future as well. Energinet and Evida must therefore continue to make it commercially viable to operate gas infrastructure in Denmark at low prices for the benefit of consumers.

Two factors in particular may lead to higher tariffs: First, a decline in gas consumption means that the costs of operating the gas system are shared among fewer users. Secondly, there will be a need to transport green gas between different areas in Denmark as the decentralised production of green gases increases, with less gas being consumed where it is produced.

Tariffs must be kept down to support Danish employment

Jobs and businesses must be retained and developed on Danish soil in parallel with an effective green transition. This is a prerequisite for Denmark to be seen as a green frontrunner abroad.

As household gas consumption is phased out, the increasing tariffs will be covered by the remaining customers, which is expected to be mainly gas-consuming industrial companies. Tariffs only make up a small part of the total gas price, but for Danish companies in direct competition with foreign companies, tariff levels can make a crucial difference.

The scenarios also highlight the impact of tariff increases on the overall gas bill (see

End date for phase-out of gas furnace		Increase in tariffs (2021-2030)		Increase in gas bill (2021-2030)	
Basis scenario (AF21)	Households	700 DKK	56 %	1,900 DKK	12 %
	SMV	43,400 DKK	70 %	97,400 DKK	22 %
	Large industry	1,129,200 DKK	48 %	8,731,000 DKK	25 %
Full phaseout in 2030	Households	1,400 DKK	109 %	2,600 DKK	16 %
	SMV	83,900 DKK	135 %	137,900 DKK	29 %
	Large industry	2,244,900 DKK	95 %	9,846,700 DKK	27 %
Full phaseout in 2035	Households	900 DKK	68 %	2,100 DKK	13 %
	SMV	52,800 DKK	85 %	106,800 DKK	24 %
	Large industry	1,388,300 DKK	59 %	8,990,200 DKK	26 %
Full phaseout in 2040	Households	700 DKK	56 %	1,900 DKK	12 %
	SMV	4,300 DKK	69 %	96,900 DKK	22 %
	Large industry	1,116,600 DKK	47 %	8,718,400 DKK	25 %

Table 1). Tariff increases do not impact the overall gas bill to the same extent as emission allowances and fluctuations in the market price of gas, but while the market price is global and emission allowances are European, tariffs are national and therefore play a major role in the competitiveness of companies.

End date for phase-out of gas furnace		Increase in tariffs (2021-2030)		Increase in gas bill (2021-2030)	
Basis scenario (AF21)	Households	700 DKK	56 %	1,900 DKK	12 %
	SMV	43,400 DKK	70 %	97,400 DKK	22 %

	Large industry	1,129,200 DKK	48 %	8,731,000 DKK	25 %
Full phaseout in 2030	Households	1,400 DKK	109 %	2,600 DKK	16 %
	SMV	83,900 DKK	135 %	137,900 DKK	29 %
	Large industry	2,244,900 DKK	95 %	9,846,700 DKK	27 %
Full phaseout in 2035	Households	900 DKK	68 %	2,100 DKK	13 %
	SMV	52,800 DKK	85 %	106,800 DKK	24 %
	Large industry	1,388,300 DKK	59 %	8,990,200 DKK	26 %
Full phaseout in 2040	Households	700 DKK	56 %	1,900 DKK	12 %
	SMV	4,300 DKK	69 %	96,900 DKK	22 %
	Large industry	1,116,600 DKK	47 %	8,718,400 DKK	25 %

Table 1: Expected increase in total transmission and distribution tariffs assuming phaseout of household gas consumption for individual heating at different points in time.
Note: The table illustrates the increased cost of tariffs and gas bills from 2021-2030 for three different types of consumers: Households (1,637 m^3), small businesses (112,500 m^3), large industry (10 million m^3). The increase is calculated on the basis of Evida Nord's tariffs. The overall gas prices are based on the Gas Price Guide and development of gas prices and ETS emission allowance prices in the analysis assumptions (AF21) and assume no change in levies.
Source: Danish Energy Agency and Evida

The future design of tariffs must be adapted to the green transition

Denmark's gas system plays an important role in the country's energy supply and green transition. It is therefore important that the gas system operates efficiently and on commercial terms. The Government will work to keep gas tariffs as low as possible so that gas-consuming industrial enterprises that face challenges with electrification are impacted to the least possible extent. To that end, the Government, with a broad majority of the parties of the Danish Parliament, adopted two legislative proposals to future-proof the regulation of Energinet and Evida. In the future, regulation will take into account expected developments in the gas sector rather than merely being based on historical costs. Evida and Energinet will thereby be able to better adjust their costs to factor in aspects of the green transition, including the expected decline in gas consumption.

In addition, the Government will continue to create incentives for using green gas. At the same time, the Government's ambition is to continue to incentivise companies to electrify their processes wherever possible.

Objective 4: Green gas must eventually be able to compete on market terms

The gas of the future must be sustainable and competitive on market terms. Thus far, green gas has required a high level of subsidies compared to other renewable technologies such as solar or wind power. With the new subsidy scheme for biogas and other green gases introduced in the 2020 Climate Agreement, the goal is to support the development of green and competitive biogas production through tenders, which can significantly reduce the need for subsidies. Green PtX fuels are not yet competitive compared to fossil and bio-based alternatives, which is why a clear framework is necessary to help ensure the potential of PtX technologies is realised.

The Government's ambition is to build a green and competitive future for gas. *Thus far, green gas production has required a relatively high level of subsidies compared to producing renewable electricity from solar or wind power, for example.*

Competitive biogas

Together with the parties to the Climate agreement for energy and industry, etc. of June 2020, the Government has allocated DKK 13.6 billion to a new subsidy scheme for biogas and other green gases running until 2050. The goal is to support green and competitive biogas production through tenders, which is expected to significantly reduce the need for subsidies. At the same time, the tenders are expected to contribute to the share of renewable energy in gas consumption reaching 70% by 2030.

In the future, technological advances are expected to make green gases cheaper, albeit still more expensive to produce than to renewable electricity. The cost of biogas production is expected to decrease in the future, potentially eliminating the need for subsidies in the long term. If it eventually becomes possible to produce biogas without subsidies, biogas production will become a matter of weighing the cost of production versus sales price, as in most other markets.

It is also expected that the production of upgraded biogas can be optimised in line with the growing demand for CO_2 for storage or utilisation (CCS/CCU). With the planned expansion of biogas production, the supply of CO_2 for capture, storage and utilisation is expected to increase by as much as 1.4 million tonnes by 2030.

Competitive expansion with PtX technologies

It is expected that PtX technologies will gradually gain ground due to the potential of PtX to contribute to the production of green fuels for the industrial and transport sectors. Hydrogen, ammonia, methanol and aviation fuels are examples of fuels currently being produced from oil and natural gas, but which can also be produced from renewable electricity with the help of PtX technologies.

Already at this point in time, several actors are planning to establish PtX plants in Denmark on a large scale by 2030. However, green PtX fuels are not yet a competitive alternative to fossil and bio-based fuels due to the high costs associated with the production of hydrogen and other PtX fuels. Electricity prices and tariffs, along with the costs of the PtX plant itself, make up the majority of the production costs. The Government aims to establish a clear framework for the expansion of PtX technologies with its PtX Strategy.

Expected costs for green gas production

The cost of green energy production varies considerably depending on the type of energy. It is expected that the production of green electricity will remain the cheapest source of renewable energy compared to biogas and other renewable fuels. The cost of green gas production should be viewed alongside the production of alternatives such as electricity, which is significantly cheaper, but also in the context of what each of these types of energy can be used for in the overall energy system.

Figure 18 shows that the potential production costs are greater for PtX technologies than renewable electricity and biogas. This is due to greater uncertainty about future electricity prices and tariffs. However, the production cost of hydrogen is expected to decrease in the long term. Biogas is believed to remain cheaper than PtX-based green gases for a number of years, which is why biogas is expected to play a more prominent role in the transition of the Danish gas system in the short term in spite of the considerable technical potential of PtX technologies.

Worth noting is that the production costs for biogas should not be compared directly with the production costs for renewable electricity, as these are two different energy products. Biogas possesses properties that electricity lacks and can be used in areas where electricity cannot. Additionally, biogas can be stored in large quantities in the existing infrastructure, create a flame and very high temperatures.

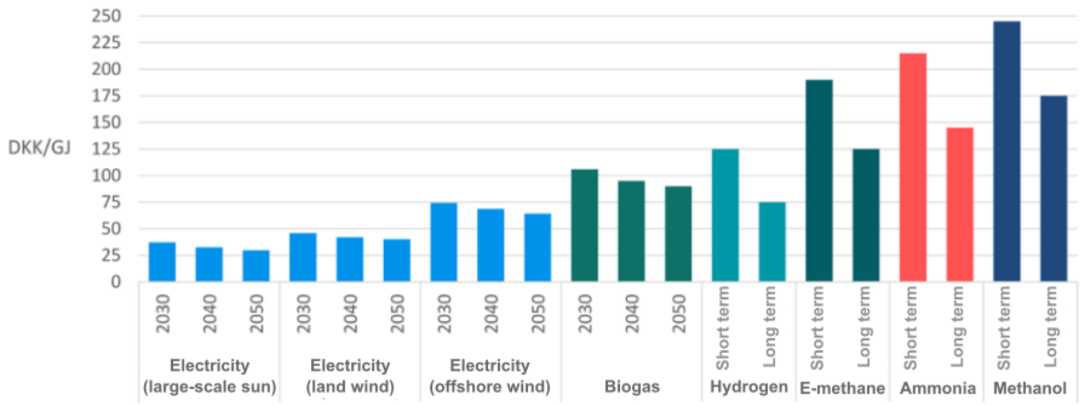


Figure 18: Socioeconomic production costs for electricity, biogas, hydrogen, e-methane, ammonia and methanol.
Note: The figure illustrates the socioeconomic production cost of producing one unit of energy from a given technology. Thus, the figure does not illustrate the cost of the service that the fuels can be used to provide (heat, electricity, mileage, etc.), as there will be a loss of energy in a given process. The energy loss typically differs from one process to another.
Source: The Danish Energy Agency's Technology Catalogue

Green gases on market terms

The Danish Energy Agency's analyses show that Danish-produced PtX fuels can become competitive alternatives to fossil fuels by 2040, on par with or cheaper than biofuels and PtX fuels produced in other countries, if production costs for hydrogen and PtX are reduced and accompanied by robust and appropriate framework conditions. The government will therefore work to ensure that biogas - in line with other PtX gases - can eventually compete on market terms. A clear legal framework which ensures fair competition will be important in this context. Competition on market terms can reduce the need for subsidising the production of green gas.

Pyrolysis technologies in development

Pyrolysis technologies are also being developed in parallel with biogas and PtX technologies. When plant and animal biomass, such as straw and manure, is processed at very high temperatures (typically 600 degrees Celsius), it is converted into biochar and a mixture of gas and oil. Biochar is a charred residue that can sequester large amounts of CO_2 and store it for hundreds of years. Pyrolysis can thus contribute to CO_2 reductions in agriculture, as carbon from agricultural residues can be captured and stored in biochar rather than evaporating into the atmosphere. However, gases from pyrolysis cannot be introduced into the existing gas infrastructure, as this would require extensive cleaning of the pyrolysis gas. A small 200kW pilot plant under the Technical University of Denmark will therefore be scaled up and tested on a larger 2 MW scale in the near future. The results of the project will help shed light on the future potential and possibilities pyrolysis may offer. The Government has also allocated funds for the development of pyrolysis technologies in the 2020 Finance Act.

Objective 5: Green gases must be produced sustainably

The Government's ambition is for green gas to be as sustainable as possible and have the lowest possible indirectly negative environmental and climate effects. Among other things, this means that biogas production must minimise its reliance on energy crops and that the methane loss from biogas plants must also be reduced to a minimum.

As the production of biogas and other green gases increases, it will become necessary to ensure that the production process is also fully sustainable. The Government will work towards creating the most appropriate framework conditions to ensure that biogas and other green gases are produced sustainably and without any inadvertent harmful effects.

Biogas must therefore be based on sustainable biomass so that it is produced sustainably with the least possible indirect, negative environmental and climate impacts. Already today, Danish biogas is primarily produced from residues and only to a lesser extent from energy crops. This places Denmark among the best in the EU in terms of the climate impact of biogas production. The Government's ambition to create sound framework conditions for sustainable production of biogas is complemented by the EU's Renewable Energy Directive, which has recently introduced more stringent requirements for the types of biomass used for biogas production. However, this does not mean that every aspect of sustainable biogas production has been solved, and the Government still sees a need to strengthen efforts in two areas in particular:

Reducing the use of energy crops

Biogas replaces fossil gas, which emits large amounts of CO_2 in relation to Denmark's calculated greenhouse gas emissions. However, the use of energy crops for biogas production, such as maize, beet and cereals, has a negative impact on the environmental and climate footprint of biogas production. This is first and foremost because energy crops take up land that could otherwise be used for other purposes. Secondly, there are greenhouse gas emissions and negative environmental consequences associated with the production of energy crops. Finally, the amount of biogas we produce is expected to grow, which could result in the biogas plants consuming more energy crops unless restrictions are introduced.

Accordingly, the Government and a broad majority of the Danish Parliament decided on 30 June 2021 to tighten requirements for the use of energy crops for biogas production. Already in 2022, the energy crop cap will be lowered from 12% to 8%. By 2024, it will be lowered even further to an expected 4%. The use of maize as an energy crop will also be phased out by 2025.

The Government and parties to the agreement have agreed to lower the current energy crop cap significantly by 2030. In the short term, however, it is not possible to completely avoid the use of energy crops for biogas production, as a number of small biogas plants depend on energy crops and many plants also use energy crops to process and use straw in their biogas production processes. As a follow-up on the latest political agreement on energy crops, the Government will therefore present a proposal in 2022 for how to further lower the energy crop cap by 2030.

Reducing methane loss

Methane loss from certain biogas plants amounted to an average methane loss of 2.5% of biogas production in 2021. It is important to reduce methane loss from biogas plants, as methane is a potent greenhouse gas and emissions reduce the positive climate impact of biogas production. One of the Government's priorities is to ensure that Danish biogas plants emit as little methane as possible, which is why the Government is looking at possibilities for how to regulate the issue. The new regulatory measures are expected to be in place by 1 July 2022. The Government welcomes the forthcoming EU legislative proposal on regulating methane emissions in the energy sector through a common monitoring system.

Objective 6: The development of green gas production and gas infrastructure must include a high level of public involvement and take into account biodiversity and the environment

Denmark is a green frontrunner with a population that supports the green transition. We must retain that popular support. It is therefore crucial that the path towards achieving the climate targets is planned with the Danish public and appropriately considers Denmark's environment and wildlife.

Establishment of biogas plants

The green transition in the gas sector is expected to entail the establishment of an additional 10-15 biogas plants that will be connected to the gas system by 2030. The impact of these plans on Danish households is expected to be relatively modest. The expansion of the biogas plants could, however, temporarily affect the public during the construction phase, and biogas plants can also be a source of obnoxious smells (typically caused by operational issues). The transport of biomass to and from biogas plants may also result in more road traffic.

Expanding biogas production is necessary for the green transition, and one of the Government's priorities is to ensure that the expansion occurs optimally and in close dialogue with affected households. At the same time, the expansion must occur on commercial terms and serve the interests of gas consumers. Denmark's municipalities are obliged to designate areas suited for biogas production, which means that the public is already involved at the earliest stages where plans are still being drafted and revised. The environmental impact assessment stage of new biogas plants also requires public involvement.

Maintenance of existing gas pipelines
In order for gas consumers to have access to the increasing amount of biogas in the future, certain parts of the existing gas system may need to be reinforced with new gas pipelines and other adjustments. This would require construction work that may be disruptive for a limited period, but gas pipes do not create lasting inconveniences for the public, nature, wildlife or the environment once established.

Expansion of pipelines
In the long term, once the technology has matured, it may become necessary to establish entirely new pipelines outside the existing gas system to transport hydrogen or CO_2. This would entail temporary construction projects to establish new hydrogen and CO_2 pipelines which could affect Danish households located nearby such projects. It is therefore important to the Government that existing pipelines are repurposed to the greatest possible extent to minimise any inconvenience to the public in connection with the green transition of the gas system. The expansion of Denmark's gas system, e.g. for hydrogen, should also go hand-in-hand with protecting biodiversity and the environment.

Objective 7: The gas system must support and be used for the green gases of the future

Denmark's gas infrastructure must be utilised to its fullest potential in the green transition. There may be a future need to transport CO_2 and green gases such as hydrogen and raw biogas. Accordingly, it may become necessary to establish new infrastructure in some areas, while in others, it may be more appropriate to repurpose existing gas pipes. It will also be necessary to establish market rules for hydrogen that can create a framework for Denmark's future hydrogen market, as well as regulation to support the planning and expansion of infrastructure.

A number of green gases - such as hydrogen, e-methane, pyrolysis gas and raw biogas - will come into play in Denmark in the future, and pipeline connections may be needed to transport CO_2. Biogas and e-methane are the two primary gases that can be transported via the existing gas system, as the chemical composition of hydrogen can pose challenges to gas-consuming equipment that is not able to handle high proportions of hydrogen or fluctuating hydrogen content. It is therefore expected that in the future, Denmark will need several distinct gas systems, each capable of transporting specific types of gas.

There are several advantages to repurposing parts of the gas system to transport new green gases or CO_2. Firstly, it eliminates the need to dig new pipelines and the associated inconvenience to the public. Secondly, it is significantly cheaper to repurpose existing gas pipelines. At the transmission level, it is estimated that repurposing the pipelines can reduce costs by as much as 80%. The savings potential is expected to be roughly the same at the distribution level.

Possibility of repurposing certain sections of the Danish gas system

However, repurposing gas pipelines for new gases such as hydrogen requires planning and a number of strategic choices. There are only a few pipe sections can be repurposed in the short term in Denmark. Energinet's assessment is that one of the two gas pipelines currently connecting the Danish and German gas systems between Egtved and Ellund in South Jutland can be converted to transport pure hydrogen in the near future, thereby connecting Danish PtX producers to the European hydrogen infrastructure. Similarly, parts of the gas distribution system can potentially be repurposed as gas burners for individual domestic heating are gradually phased out.

The remaining part of the gas system will remain in use for many years to come. The political decisions related to the expansion of biogas production capacity entails that the Danish gas system will be used to transport biogas for at least another two decades. Additionally, the future Baltic Pipe connection will transport large volumes of gas across Denmark to Poland until 2038, and likely beyond that. As illustrated in Figure 19, it would therefore not be possible to repurpose large sections of the existing gas system for new gases such as hydrogen.

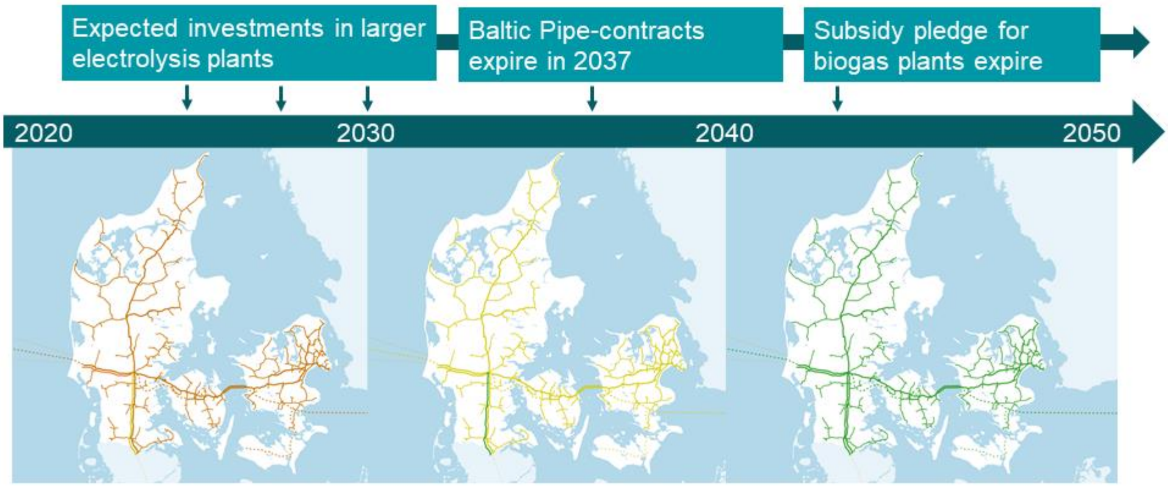


Figure 19: The map illustrates conversion possibilities in the existing gas system in the period 2020-2050.
Note 1: Orange: Agreement restricts use of the gas system to a specific purpose. Yellow: Agreement restricts use of the gas system to a specific purpose, but some sections may allow other uses. Green: The gas system can be used for other purposes.
Note 2: Already in 2025, one of the pipes from Egtved to Ellund could be converted to transport hydrogen if needed.

Appropriate placement of biogas plants

Biogas production will generally take place locally in close proximity to agriculture. An important biomass input in biogas production is liquid manure and bedding from livestock buildings, which is expensive to transport. Once the liquid manure has been degassed in a biogas plant, the degassed biomass can be used as agricultural fertiliser. Short distances between farms and biogas plants thusly limit transport costs, which is why biogas plants are often placed according to agricultural considerations. The need for accommodating decentralised gas production will continue to rise as gas is increasingly produced at biogas plants around Denmark. This need will become especially relevant once the production of biogas in a given distribution area exceeds the level of consumption in that area.

Today, the gas system operates under the principle that all new biogas plants should have the possibility to connect to the existing gas system regardless of their desired location. However, the geographical placement of biogas plants influences the costs of operating the gas system. The large volumes of biogas expected to be produced in Denmark in the coming years should therefore be fed into the existing gas system in a cost-effective way to reduce the costs of the green transition. It is therefore important that all new biogas plants are appropriately placed in relation to the existing infrastructure and overall economy.

Possible new uses for gas storage facilities

The role of gas storage facilities is also changing as the green transition progresses. The anticipated future decline in gas consumption and gas customers, along with a larger share of industrial customers over household customers, means that gas consumption patterns in Denmark will change significantly in the years to come. This is likely to lead to lower daily and annual fluctuations in gas consumption. Accordingly, gas storage facilities will increasingly be needed for short-term storage rather than seasonal storage, as industrial gas consumption is more constant than that of Danish households, which primarily use gas during the coldest half of the year. This will free up storage capacity for new applications while the gas storage facilities continue to provide flexibility to the electricity and heating sectors.

As seen in the figure below, considerable potential exists for storing energy in gas storage facilities.

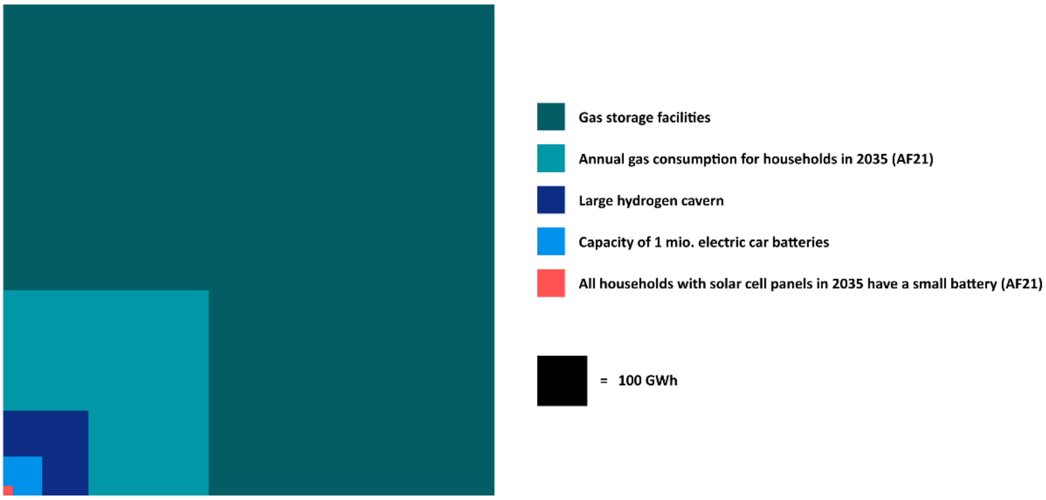


Figure 20: Storage capacity from different types of storage facilities.
Source: Danish Energy Agency

As with gas pipelines, gas storage facilities can become an important link between the expected increase in production and consumption of green gases and CO_2. These gas storage facilities can potentially be used to store hydrogen, thereby adding flexibility to the PtX value chain in the form of both short- and long-term storage. They could also play a role in the event of a future need for storing CO_2, e.g. for later use in the production of carbonaceous PtX products.

Already today, the future role of Denmark’s gas storage facilities is being tested. The gas storage facility in Lille Torup, for instance, is particularly suited for storing hydrogen or CO_2 due to being a cavern storage facility. The facility is part of the Green Hydrogen Hub consortium, which is currently exploring the possibilities of establishing an interconnected chain of green hydrogen production, hydrogen storage and use of hydrogen as an energy source for industrial processes.

A framework for Denmark’s future hydrogen infrastructure needed

As an energy form, hydrogen is not particularly widespread in Denmark yet, although interest in hydrogen is growing both in Denmark and abroad.

It is still too soon to determine how the market for hydrogen will develop in Denmark and the rest of the world. In Denmark, we have seen a burgeoning development of hydrogen clusters as well as discussions about ‘export pipelines’ to Germany. The Danish Energy Agency and Energinet have conducted a market dialogue with relevant actors on their expected needs for Denmark’s future hydrogen infrastructure. The market dialogue revealed significant interest in and the need for a hydrogen infrastructure capable of - among other things - transporting green hydrogen over long distances for export purposes. Accordingly, it may become relevant for Denmark to join the future common European hydrogen system, known as the European Hydrogen Backbone.

In order to realise the potential of hydrogen projects in Denmark, the actors in the market dialogue also highlighted the need for a clear regulatory framework. There are key barriers that need to be removed, and the Government also needs to ensure that clear rules are in place to prepare Denmark for the establishment and expansion of hydrogen infrastructure. The Government has accordingly initiated a 360-degree review of existing regulation to identify barriers (e.g. related to the environment, security, planning and levies) to the development of a hydrogen market and infrastructure. The goal is to make it easier for Danish and international companies to produce and use PtX products.

The future of Denmark's hydrogen market and infrastructure will depend on a number of factors, including political decisions at the national and European level as well as technological and commercial developments.

The Government is drafting new national regulations to create the right framework conditions for establishing, operating and using hydrogen infrastructure as well as to allow existing gas pipes to be repurposed for hydrogen transport. The Government will work towards ensuring the new rules also allow the state-owned companies Energinet and Evida to own and operate hydrogen infrastructure. Additionally, Energinet and Evida must also be able to facilitate and support a national and international hydrogen market. It may also be relevant for other market actors to work with hydrogen transport.

Possible gas systems in the future

As seen in Figure 21, the future Danish gas system will likely be set up to transport different types of gas, and Danish industry will be the primary consumers of gas. In addition to biogas, the gas system may need to be capable of transporting hydrogen, CO_2 and raw biogas. How this will pan out in practice will depend on demand and opportunities. For example, it may become relevant to transport raw biogas to a combined plant where it is upgraded or converted to liquid fuels. Elsewhere, it may be relevant to transport CO_2 or hydrogen.

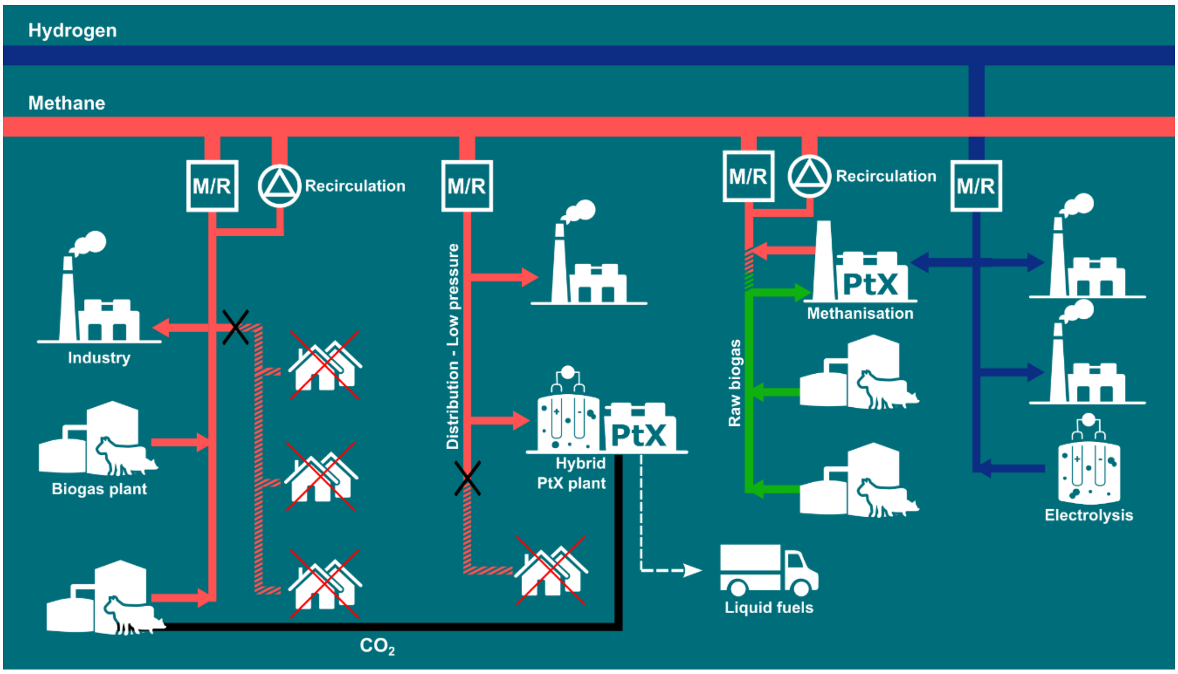


Figure 21: How the future gas system in Denmark may develop into multiple parallel systems. Source: Danish Energy Agency

Objective 8: The gas system needs to be adapted to efficiently support Denmark's future energy system, contributing flexibility and security of supply

Energy efficiency improvements and electrification are important aspects of the green transition of Denmark's energy system. Green gas will continue to be a valuable source of energy because it ties Denmark's future energy supply together, thereby contributing to security of supply and the flexibility of the energy system. Green gas can be stored and used flexibly, as gas can be used to generate electricity, e.g. when production needs to be ramped up quickly. Large volumes of gas may not be needed in the long term, but green gas is valuable in situations where other renewable sources are inadequate. The gas system can also link several sectors together and provide a more resilient energy system where it is possible to switch between different green energy sources, reducing vulnerability.

Gas must contribute to security of supply

Energy efficiency improvement and electrification are instrumental aspects of the green transition of Denmark's energy system. As Denmark's energy supply increasingly comes to rely on solar and wind power, electricity demand will exceed production more frequently than is the case today. This poses the future risk of more and longer power cuts for consumers, creating challenges for security of supply.

Technologies such as industrial batteries, individual heat pumps and district heating can provide flexibility to the electricity system, but the impact and range over time is limited for such technologies, while a gas storage facility can store energy from minutes to years. Flexibility is crucial to being able to maintain security of supply in Denmark's future renewables-based energy system. Green gas can make a major contribution in that regard. Accordingly, the Government sees green gas as an important source of energy that can be used across the entire energy system and which can be stored and used at times where the electricity generated from solar and wind power does not meet the level of demand. Gas can be used when electricity and heat production need to be ramped up quickly and when cheaper alternatives cannot provide sufficient electricity and heat. Gas will thereby be able to continue to support security of supply.

In the future, gas consumption for heat production and industry will decrease, but it is crucial that gas as an energy source is also available in the future - especially to balance the electricity system.

The role of gas in future sector integration

Historically, Denmark has been highly successful at interconnecting electricity, heat and gas supply, and we must continue to do so in the future. PtX is a new example of sector integration. PtX can entail many different things, such as producing hydrogen from renewable electricity through electrolysis.

Like hydrogen, biogas and e-methane can be used as building blocks for the production of future green fuels such as methanol and aviation fuel. Methanol and aviation fuel can be produced from synthesis gas (syngas), which is an intermediate product in PtX processes. Syngas can be produced from hydrogen and CO_2 but also biogas.

As seen in the figure below, biogas as well as the gas system in general can contribute to PtX, linking several sectors across the energy system. The figure illustrates some of the many possibilities for the role of gas in sector integration and gives examples of possible applications. Green gas and green electricity have applications in many of the same sectors in the energy system, especially the transport sector. The figure also shows that green gas can contribute to a diversified energy supply, allowing switching between different green energy sources.

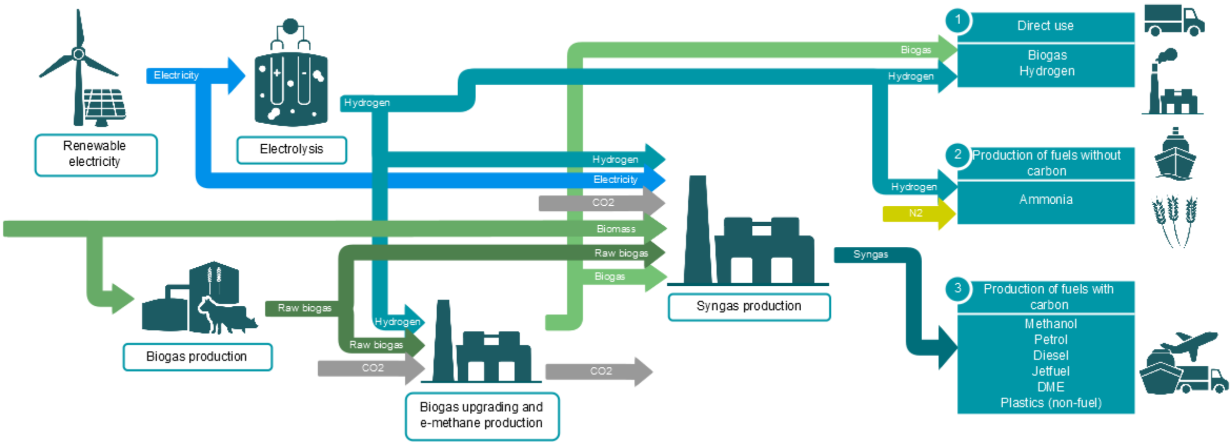


Figure 22: The role of the gas system in future sector integration.
Source: Danish Energy Agency

Denmark benefits from having a well-developed and complementary electricity, gas and heating system. Biogas, hydrogen and other renewable gases are energy sources that supplement electricity generation from solar and wind farms, but also the district heating system. Together, this can result in a more resilient energy system, making it possible to switch between different green energy sources and reducing vulnerability to unpredictable factors such as weather conditions or a change in geopolitical circumstances. The Government intends to safeguard this system.

Biogas produced from residues from agriculture, industry and households contributes to the resilience of Denmark's energy system. Surpluses or residues from one sector can be utilised as an energy source to produce biogas and other green gases.

A well-integrated supply system in which the different sectors are well-connected will, in addition to improving the resilience of the energy system, contribute to Denmark's green transition and make it possible to expend the least possible resources to achieve the greatest possible CO_2 reductions.

Objective 9: Denmark must help further the development of a well-functioning European market for green gases

Denmark must drive a cost-effective green transition in the EU, including by pushing for the development of a well-functioning European market for green gases. Among other things, there will be a need for documentation (guarantees of origin or the like) which can guarantee that gas sold as green gas stems from renewable energy sources. There will also be a need for technical challenges to be handled at the EU level to ensure that national requirements for the quality of green energy (such as biogas) does not become a technical barrier to trade for Denmark in practice.

The Danish gas system and gas market are a closely integrated part of the European gas market. For Denmark, it is important that we have a well-functioning European market where there are no restrictions on the sale of gas across borders. This benefits the EU's green transition, consumers and security of supply. Denmark must drive a cost-effective green transition in the EU, including by pushing for the development of a well-functioning European market for green gases. The Government will work towards creating a framework for a well-functioning and credible market for green gases such as biogas, e-methane, green hydrogen, etc. in Europe. The Commission's Fit for 55 package is therefore an important step in this direction.

The European Commission is expected to present a new hydrogen and decarbonised gas market package by the end of 2021, revising the existing gas package to phase out fossil natural gas and create a market for green gases and hydrogen. In addition, the European Commission is expected to present a new proposal to regulate methane emissions in the energy sector. Methane emissions are currently not regulated at the EU level, which is why this proposal is expected to include a common monitoring, reporting and verification instrument that makes it possible to estimate the need for reducing methane emissions within the EU.

The presentation of the hydrogen and decarbonised gas packaged is particularly relevant not only because Denmark is the biggest green gas consumer in the EU, but also because Danish companies have a high level of ambition in relation to developing hydrogen and PtX technologies.

Preliminary Danish priorities in the Hydrogen and Decarbonised Gas Package

- A market for green gases with a focus on renewable gases such as biogas and green hydrogen
- A common framework for the free trade of green gases across borders
- Elimination of trade barriers, including common standards for gas quality
- Development of hydrogen infrastructure, integrating rules into existing legislation
- Developing sector integration and PtX technologies

In addition, the Government is pushing for an overall EU target of 45% renewable energy by 2030.

Achieving such an ambitious target would make it important for Denmark's own positive experiences with green gas to be disseminated at the European level. It is important that Danish companies are able to operate under good market conditions, including a well-functioning European market for guarantees of origin or the like (see below) for trading green energy across national borders.

A green transition of the gas sector - not only in Denmark, but in the whole EU - implies that natural gas will be phased out in the long term. Therefore, the Government will work towards ensuring that in the future, EU funds are not used for cross-country long-term EU projects that solely entail transporting natural gas. Denmark will accordingly seek to influence the content of European Commission's proposal to revise the TEN-E (Trans-European Network for Energy) Regulation with that goal in mind. With respect to the TEN-E Regulation, Denmark has taken a leading role in an alliance with like-minded EU countries in relation to regulating this area. The proposed revision of TEN-E is still undergoing negotiation with the European Parliament.

Guarantees of origin and similar measures to ensure transparency across borders

As long as fossil natural gas remains in the gas system, there may be a need for documentation (guarantees of origin or the like) which can guarantee that gas sold as green gas stems from renewable energy sources. This is not least important in relation to the future European hydrogen infrastructure. It is crucial that this infrastructure is supported by a well-functioning market for green hydrogen and allows green gas to be exported and imported between EU Member States.

FACT BOX: Trade in green gases

When a biogas plant feeds biogas into the gas system, it is mixed with other gas. In the gas system, both biogas and natural gas are mixed to form a uniform gas. In order for the gas supplier to prove the origin of the gas supplied to the final customer, guarantees of origin are used.

Energinet issues guarantees of origin, thereby ensuring that it can be documented that a consumed volume of gas is matched by an equivalent production of green gas. This system prevents double-counting of renewable energy, allowing companies and other consumers to pay for green gas.

As the European Commission is expected to present a market model for hydrogen in the future, the Government will push for a clear framework for the development and trade of green hydrogen across the EU. A future common European hydrogen infrastructure should be reserved for green hydrogen, as opposed to hydrogen based on fossil fuels and nuclear power. This would create a basis for sector integration and thus also the development of PtX. Hydrogen should be viewed in particular for its potential to enable the green transition of heavy industry, which is why hydrogen should be prioritised for areas where it can be used in the most cost-effective way.

Uniform standards for gas quality

As biogas - and with time, other green gases - begin to make up a greater share of Danish gas consumption, the technical requirements for gas quality may face challenges as it becomes less uniform. This is because biogas contains a small proportion of oxygen, and the amount of oxygen permitted in Danish gas is higher than in neighbouring countries. Therefore, Danish gas exports to other countries such as Germany may become a challenge as biogas production increases. It is important that these technical challenges are handled at the EU level to ensure that special national requirements for the quality of green energy such as biogas does not become a technical barrier to trade for Denmark in practice.

Vision for the role of gas in the green transition

Denmark's gas system carries implications for the green transition of Denmark's energy system. The gas system is an important asset in the green transition which the Government wishes to utilise to meet Denmark's climate targets and further strengthen the country's position as a green frontrunner. Initially, the country's gas infrastructure must be able to handle a decline in gas consumption, a changing consumer landscape and an increase in biogas production. In the slightly longer term, gas infrastructure may need to be adapted to meet the demand for transporting and storing other green gases such as hydrogen.

The Green Gas Strategy makes it apparent that there are several paths to realising the goal of entirely green gas consumption, both through reducing gas consumption while also increasing production of green gas. Danish gas consumption can become 100% green by 2035 if, for instance, Denmark introduces further subsidies for biogas along with higher fees and other measures that can further contribute to the phaseout of fossil natural gas. The Green Gas Strategy also shows that Denmark has sufficient biomass resources for the green gases needed for this green transition of gas consumption.

In the future, other green gases may come into play, resulting in the development of several gas systems operating in parallel. Existing gas pipelines may therefore need to be converted for new green gases, and new pipelines may need to be established.

The Government's Green Gas Strategy sets a course aimed at ensuring that:

- gas is used in areas where electrification is not an option to the greatest possible extent. Gas production and consumption must also supplement energy efficiency improvements. Gas can play an important future role in Danish industry above all. The Government will work towards creating the right incentives for further electrification, thereby ensuring that green gas only serves as an alternative where appropriate.

- that green gas supports employment in Denmark. This will require tariffs to be kept at a competitive level to allow companies using green gas to compete internationally and produce goods with a low climate footprint.

- that future green gases are produced on market terms and able to compete with green forms of energy. The Government will accordingly work towards ensuring that green gases can eventually become competitive on market terms. To that end, it is important to establish a clear legislative framework that ensures fair competition. Competition on market terms can reduce the need for subsidising the production of green gas.

- that green gas is sustainable, i.e. with the lowest possible negative impact on the environment and climate. The Government will also work towards ensuring an appropriate green transition of the gas sector in close dialogue with affected households and with consideration for wildlife, nature and the environment.

- that Denmark's gas infrastructure is prepared to support future green gases such as hydrogen. The Government will therefore create the proper framework for establishing, operating and using hydrogen infrastructure in the future, which will also entail repurposing existing gas pipelines to transport hydrogen. The Government will also work towards creating a framework for a well-functioning and credible market for green gases such as biogas, e-methane, green hydrogen, etc. in Europe.

- that the Danish gas system contributes to flexibility and security of supply in Denmark bey continuing to interconnect the country's electricity, heat and gas systems. Sector integration will in the future also include PtX. One of the Government's priorities is to ensure the Danish energy system not only becomes green, but also capable of ensuring security of supply, and gas can play a role in that.

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