Biogas Outlook 2022

Production and use of biogas in Denmark
2021-2035

Biogas Danmark

Preface

Biogas Outlook 2022 focuses on the expected development and effects of biogas production and use up to 2035

The purpose of Biogas Outlook 2022 is to provide a thorough insight into the development within the production and use of biogas from available bioresources, including the potential to utilize captured CO_2 from biogas for CO_2 storage (CCS) and Power-to-X (CCU).

At the same time, the publication conveys a quantity of data and factual information about the derived effects of biogas in climate, agriculture, recirculation of nutrients, water environment, gas market and employment.

The scenarios in Biogas Outlook 2022 are based on the forecasts for biogas production and gas consumption in the Danish Energy Agency's Climate Status and Projection 2022 (KF22), supplemented with data from Aarhus University, University of Southern Denmark, Energinet, Evida and several other sources.

Therefore, the current changes in the energy markets and the economy are not included in the database for this edition of the Biogas Outlook. In some areas – for example, the market value of natural gas and the climate footprint of electricity and gas consumption – we have included data from the first half of 2022.

The development options are described for the two scenarios below:

The **" Danish Energy Agency scenario"** is based on the Energy Agency's production forecast for biogas, which implies an increase in biogas production to 51 petajoules (PJ) in 2030 based on existing framework conditions and already decided and defined subsidy schemes and the development in gas consumption described in KF22. Biogas Danmark calculates all derived effects based on the expected composition of the biomass base for this production.

The **"Biogas Danmark scenario"** describes the consequences of Biogas Danmark's recommendation to use market incentives in the form of CO_2 substitution requirements for transport etc., instead of creating new subsidy schemes. The politically decided subsidy schemes are brought forward to two tenders with subsidies from 2024 to 2026, after which further development will be unsubsidized biogas. This requires stricter framework conditions in the transport sector, which can increase the production of unsubsidized biogas by 10 PJ from 2027. In this scenario, it is assumed that the political initiatives agreed in the settlements in June 2022 further reduce gas consumption in the heating sector and industry compared to KF22.

Biogas Outlook is not intended as a report to be read from start to finish but rather as a reference where you can find the most important factual information and data about biogas in Denmark. The energy crisis has created great interest in and much debate about biogas, and there is a need more than ever for a place to find critical facts about biogas. Biogas Outlook 2022 is Biogas Danmark's contribution to this.

Enjoy!

Henrik Høegh
Chairman of Biogas Danmark

Frank Rosager
Director in Biogas Danmark

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Two scenarios – Danish Energy Agency and Biogas Danmark

Central prerequisites and outlines for the two scenarios

Danish Energy Agency scenario (KF22)

The Danish Energy Agency's scenario is a so-called frozen policy scenario based on the framework conditions adopted when the Energy Agency's Climate Status and Projection 2022 (KF22) [1] was prepared.

The Energy Agency's scenario implies a development in biogas production based on the Energy Agency's forecasts for both the existing support scheme and the planned biogas supply until 2030(2). The Danish Energy Agency does not include unsubsidized biogas in the forecast.

The development in gas consumption is based on KF22.[1]

Since the Energy Agency's forecasts only have a detailed use of livestock manure, Biogas Danmark has prepared a distribution of the other available biomasses used in the Energy Agency's scenario. This distribution is based, among other things, on data from the latest biomass report to the Agency.

Biogas Danmark has made its own climate calculations as well as calculations of CO_2 storage and Power-to-X potential for the Energy Agency scenario.

Biogas Danmark scenario

The Biogas Danmark scenario builds on the Energy Agency's forecasts and deviates from the frozen policy principle.

The development in biogas production is based on Biogas Danmark's recommendation to drop new support schemes after 2027 and advance the politically decided biogas supply, which will contribute to faster growth in biogas production.

Due to high gas prices in the coming years, Biogas Danmark expects a faster utilization of the production capacity at the existing biogas plants and that new framework conditions in the transport market, in particular, may lead to increased production and use of unsubsidized biogas from 2027.

The development in gas consumption in the Biogas Danmark scenario is based on the new focus on phasing out gas consumption in both heat supply and industry. This is supported politically and by the market with record-high gas prices. The Danish Energy Agency's warnings to cut off the gas supply to companies causes them to switch to fossil oil.

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Summary of results

Significant climate and environmental benefits from biogas expansion

Both scenarios for expanding biogas production show significant gains in the form of the substitution of fossil gas, reduction of Denmark's climate footprint, less pressure on the aquatic environment and recirculation of nutrients.

The Biogas Danmark scenario involves a faster deceleration in gas consumption combined with increased growth in biogas production, which from 2027, releases a significant amount of biogas that can be used in trucks, ships and planes or exported.

At the same time, the captured CO_2 from the biogas can ensure the storage of large amounts of excess electricity via Power-to-X production or provide an additional climate effect of 2.1 million tonnes of CO_2 if this CO_2 is stored underground through CCS.

In the environmental area, there is a basis for reducing nitrogen emissions to the aquatic environment of 1,600 tonnes of N and recycling 5,000 tonnes of phosphorus, both a scarce and vital resource.

The realization of the Biogas Danmark scenario can finally contribute to up to 6,000 permanent jobs in the rural areas of Denmark.

Biogas Danmark

Effect of biogas expansion	Danish Energy Agency		Biogas Danmark	
	2021	2030	2030	2035
Biogas production, PJ	**26**	**51**	**55**	**60**
Share of biogas in the gas grid, pct	26	75	100	100
Gas consumption, PJ	**85**	**65**	**55**	**60**
From the gas grid	78	52	39	35
Outside the gas grid	6	11	5	4
Available for transport and export	0	1	11	22
PtX potential, PJ				
E-methane	13	25	34	38
E-methanol	7	14	18	20
Net climate effect (mil. tonnes CO_2-eq.)	**1.3**	**3.5**	**3.9**	**4.4**
Fossil substituton	1.5	2.8	3.3	3.7
Reduction in agriculture	0.2	1.0	1.1	1.2
Methane loss and auxiliary consumption	-0.4	-0.3	-0.4	-0.5
Reduction potential (mil. tonnes Co_2-eq.)				
Potential CCS	0.7	1.5	1.8	2.1
PtX e-methane (transport)	1.0	2.0	2.5	2.8
Potential PtX e-methanol (transport)	0.5	1.1	1.3	1.5
Circular economy				
Reduced nitrogen emissions, tonnes N	1,430	1,490	1,630	1,670
Phosphorus in digested biomass, tonnes P	17,300	34,900	38,400	38,900
Employment (full-time jobs)	4,200	5,350	6,100	6,300

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Biogas potential and demand

The biogas potential is greater than the need

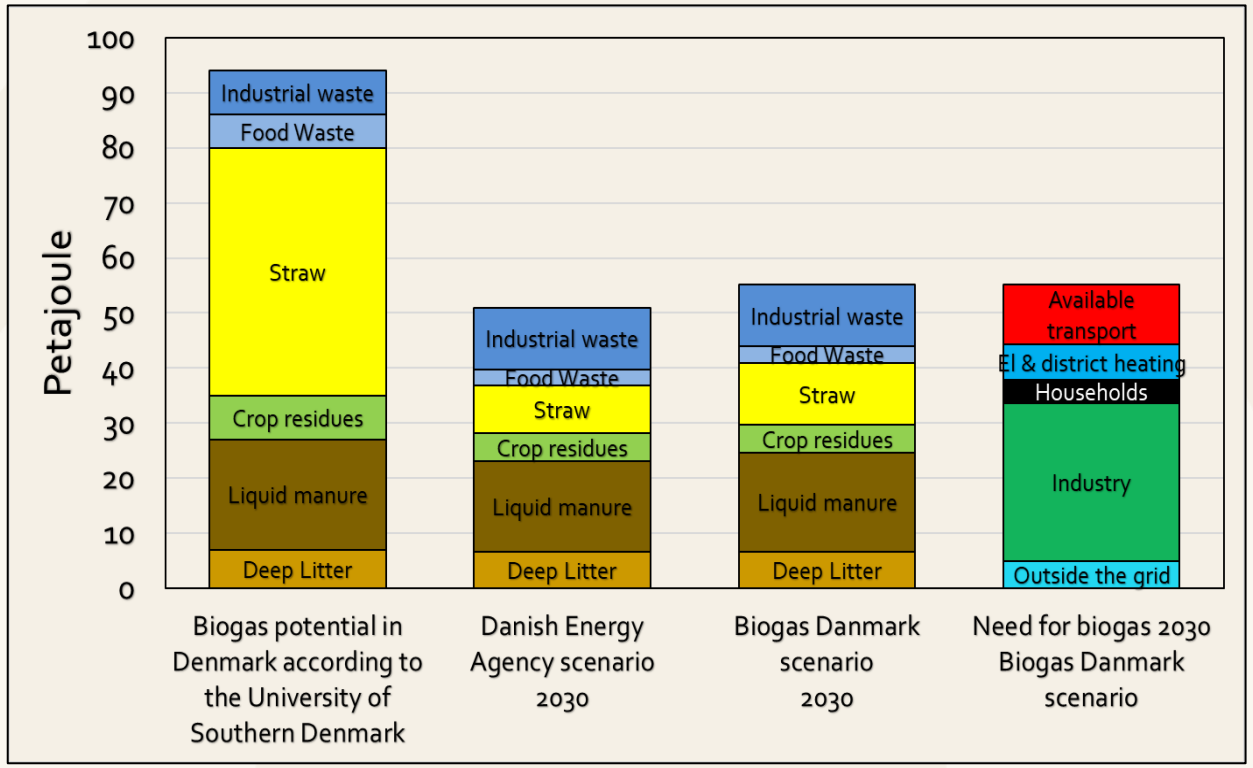
The total bioresource in the form of livestock manure and residual products from households, industry, and agriculture that can be utilized for biogas production amounts to 94 petajoules (PJ), according to a report prepared by the University of Southern Denmark for the Danish Energy Agency[3].

There are thus ample resources to fulfil the Danish Energy Agency's production forecast of 51 PJ in 2030, along with Biogas Danmark's recommendation to reach a total biogas production of 55 PJ in 2030 and 60 PJ in 2035.

Only a tiny part of the straw resource is utilized. In the future, grain fields may supply grass that currently provides straw.

Biogas Danmark's recommendation makes it possible to cover the expected gas consumption, including 10 PJ of biogas for heavy transport in 2030 and more than 22 PJ in 2035.

Biogas potential, bioresources and need for biogas in 2030



The left column shows the biomass potential for biogas production as calculated by the University of Southern Denmark. [3] The two middle columns show raw material input in 2030 in the Danish Energy Agency and Biogas Danmark scenarios distributed among different bioresources. The right column shows the sale of the produced biogas in the Biogas Danmark scenario.

Biogas Danmark

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Biogas supply - two scenarios

Faster and more significant biogas expansion.

In the Climate Agreement for Energy and Industry in 2020, funding was set aside for a tender scheme expected to deliver approximately ten petajoules of new biogas production by 2030.[4] The Climate Agreement for Green power and Heat from June 2022 decided to advance one tender scheme, so it expires in 2025 rather than 2026. At the same time, it was decided to cut this tender by DKK 30 million. DKK for financing measures in connection with the regulation of fugitive methane emissions. [5]

Biogas Danmark recommends that, politically, an increasing market pull for unsubsidized biogas is established through CO_2 substitution requirements and reimbursement of Co_2 tax for biogas delivered through the gas grid.

At the same time, it is advocated that the already allocated pools be brought forward for payment in 2024-2026 via two equal tenders. This means that dependence on fossil gas can end as early as 2027.There is currently a lot of activity in planning both completely new biogas plants and expansions of existing plants. An estimate from Biogas Danmark shows that there are roughly 70 projects under development with a total potential of 35 petajoules of biogas.

There is the potential to cover the biogas expansion in both scenarios.

Agreed subsidy and proposals for advancement

New subisidy (Mil. DKK)	2024	2025	2026	2027	2028	2029	2030
Planned biogas subsidy	**200**	**120**	**0**	**75**	**75**	**90**	**88**
Yearly subsidy	200	320	320	395	470	560	648
Biogas Denmarks proposal	**170**	**339**	**170**	**0**	**0**	**0**	**0**
Yearly subsidy	170	509	678	678	678	678	678
New biogas production (PJ)							
Planned biogas subsidy	**2.9**	**1.7**	**0.0**	**1.1**	**1.1**	**1.3**	**1.3**
Yearly subsidy	2.9	4.6	4.6	5.7	6.8	8.1	9.4
Biogas Denmarks proposal	**2.5**	**5.0**	**2.5**	**0.0**	**0.0**	**0.0**	**0.0**
Yearly subsidy	2.5	7.5	10.0	10.0	10.0	10.0	10.0

The rows "Planned biogas subsidy" and "Biogas Danmark's proposal" show when the subsidy is expected to be paid out for the first time from the pools. The subsidy runs for 20 years from the year the subsidy is paid out for the first time. Biogas Danmark's proposal to change the tender scheme process will result in significantly faster growth in biogas production. The tender criteria are designed so that when natural gas prices reach DKK 120 per GJ, the subsidy is reduced DKK beyond DKK 120 per GJ, which means that support payments are reduced or stopped when gas prices are very high.

Biogas Danmark

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Development in biogas production and biomass utilization

Biogas Danmark's proporsal for biomass utilization

The Danish Energy Agency expects that in 2030 the Danish biogas plants will utilize 90 percent of the subsidy commitment capacity and reaches 51 petajoules (PJ). After this, the Danish Energy Agency expects production to fall to 43 PJ in 2035 because the subsidy for electricity-producing biogas plants will cease in 2032. [2]

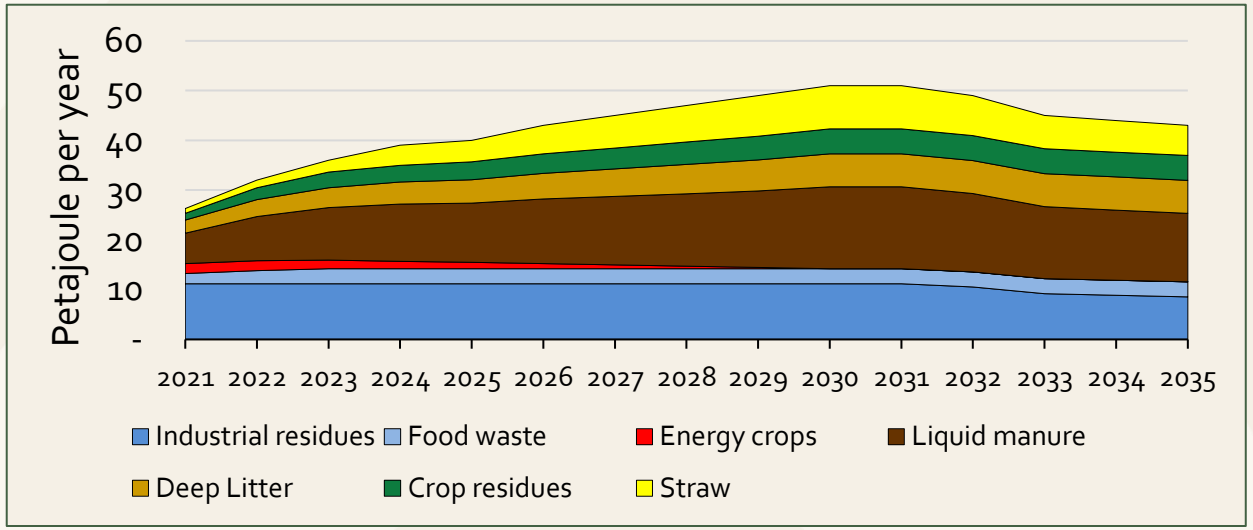
Biogas Danmark assumes that from 2027 90 percent will the utilization of the subsidy commitment capacity be achieved due to high gas prices. For Denmark to become independent of Russian gas more quickly, Biogas Danmark proposes bringing forward all biogas tender schemes so that the new biogas production starts in 2024-2026.

Furthermore, Biogas Danmark expects that increasing demand will give the electricity-producing biogas plants the opportunity for continued production, where roughly half of the production will instead be supplied to the gas grid.

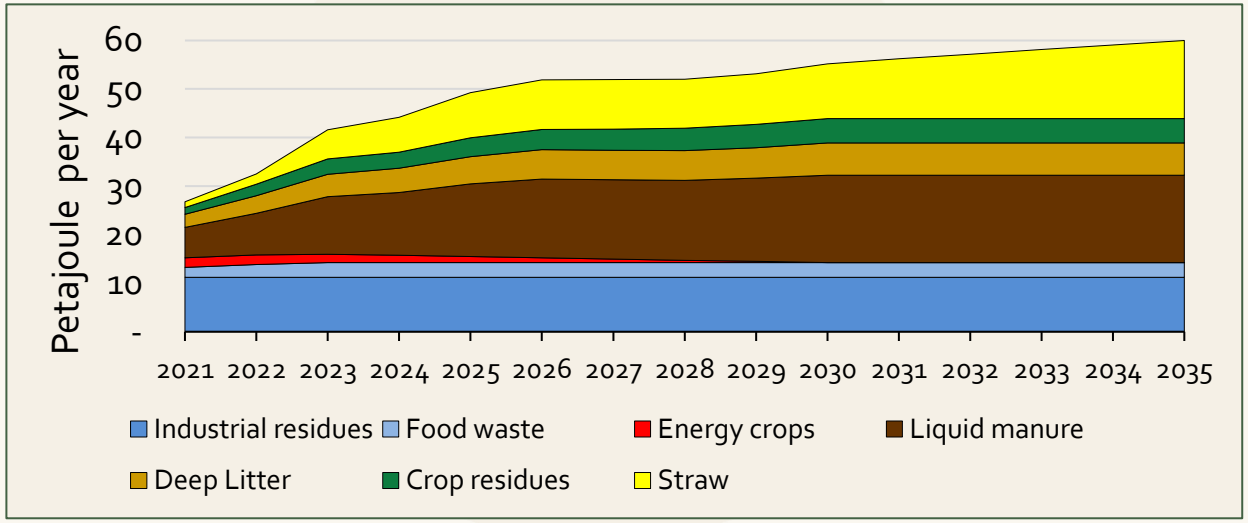
Finally, the Biogas Danmark scenario includes increased production of unsubsidized biogas of 10 petajoules from 2030 through market forces from the transport area's heavy land transport, planes, and ships.

Biogas Danmark

Biogas production by bioresources in PJ– Danish Energy Agency scenario



Biogas production by bioresources in PJ– Biogas Danmark scenario



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Coverage of gas consumption

Biogas can cover 100 percent of gas consumption in 2027

The Danish Energy Agency's scenario is based on the Danish Energy Agency's forecast of Climate status and projection for 2022. It indicates that gas consumption will decrease by approximately 20 petajoules towards 2030 and 38 petajoules towards 2035.[1]

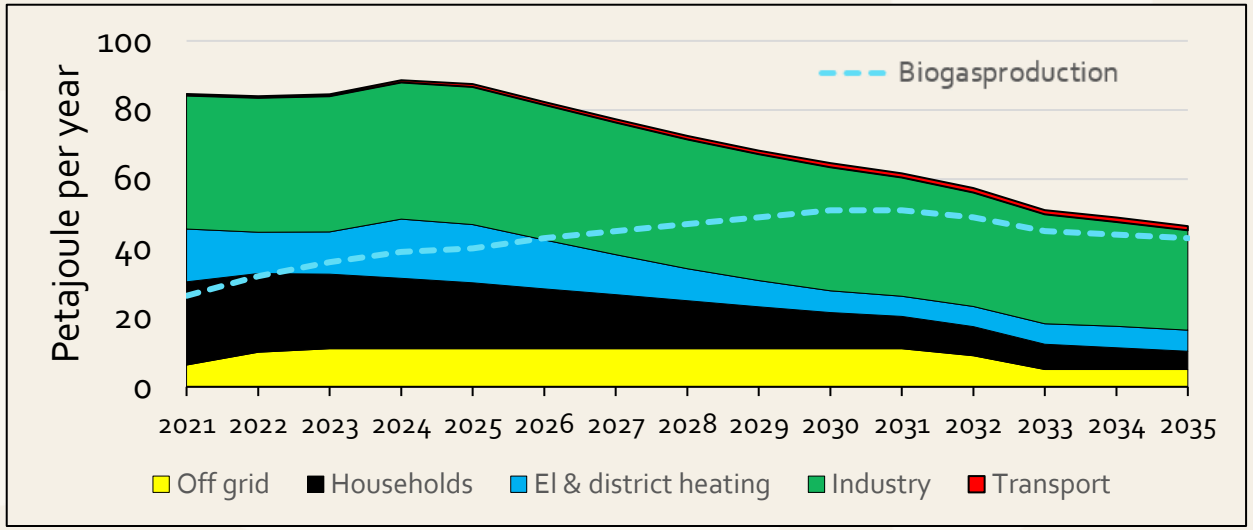
With the Danish Energy Agency's forecast for biogas production, biogas will cover approximately 78 percent of the expected gas consumption in 2030 and 92 percent in 2035. There is a continued natural gas consumption of roughly 13 petajoules in 2030 and approximately 3.5 petajoules in 2035.[1]

The development in gas consumption in the Biogas Danmark scenario is based on the new focus on phasing out gas consumption in both heat supply and industry. This is supported both politically and by the market with record-high gas prices. The Danish Energy Agency's warnings to cut off the gas supply to companies make them switch to fossil oil.

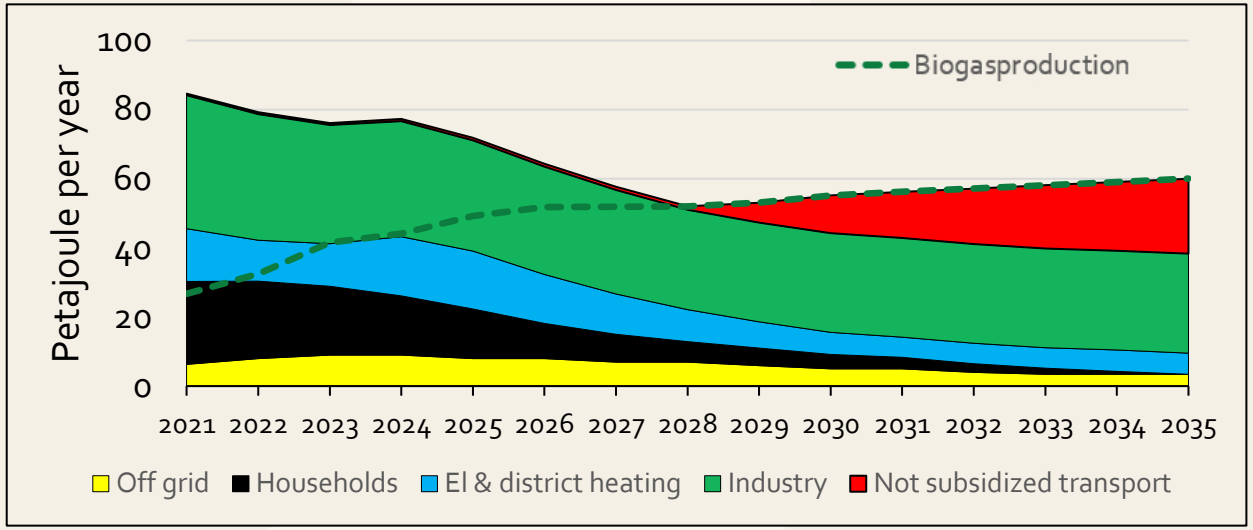
From 2027, biogas will cover gas consumption 100 percent in the Biogas Danmark scenario. An increasing surplus of biogas can then be delivered, contributing to the green transformation of heavy road freight transport and ships and planes with 22 petajoules in 2035, of which at least 16 petajoules are not in the tender scheme.

Biogas Danmark

Development in gas consumption and biogas production – Danish Energy Agency scenario scenario



Development in gas consumption and biogas production – Biogas Danmark scenario



Resume

Renewable energy in the gas grid

The Biogas Danmark scenario provides 100 percent RE in the gas grid in five years

The Biogas Danmark scenario includes a faster phasing out of gas consumption in industry and private households - and at the same time, an accelerated increase in Danish biogas production than is expected in the Danish Energy Agency's latest forecast in Climate status and projection 2022.[1]

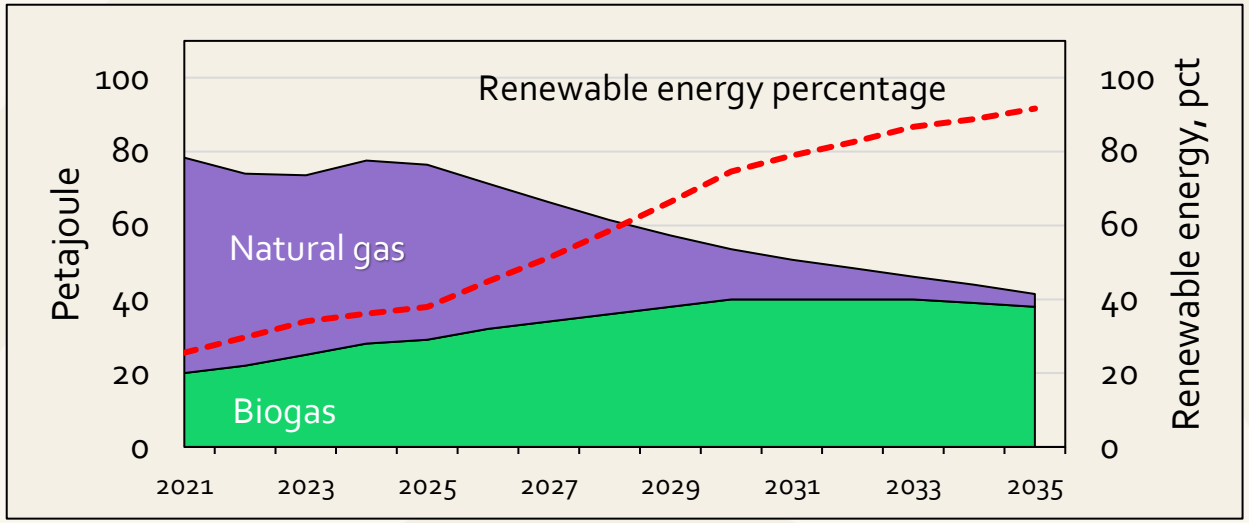
The effect of the Biogas Danmark scenario is that the RE percentage in the gas grid will reach 100 percent in 2027, 8-9 years earlier than the Danish Energy Agency's forecast.

In addition to contributing to Denmark reaching the 70 percent target in 2030, Biogas Danmark ensures the scenario of independence from Russian gas much earlier than the Danish Energy Agency expects.

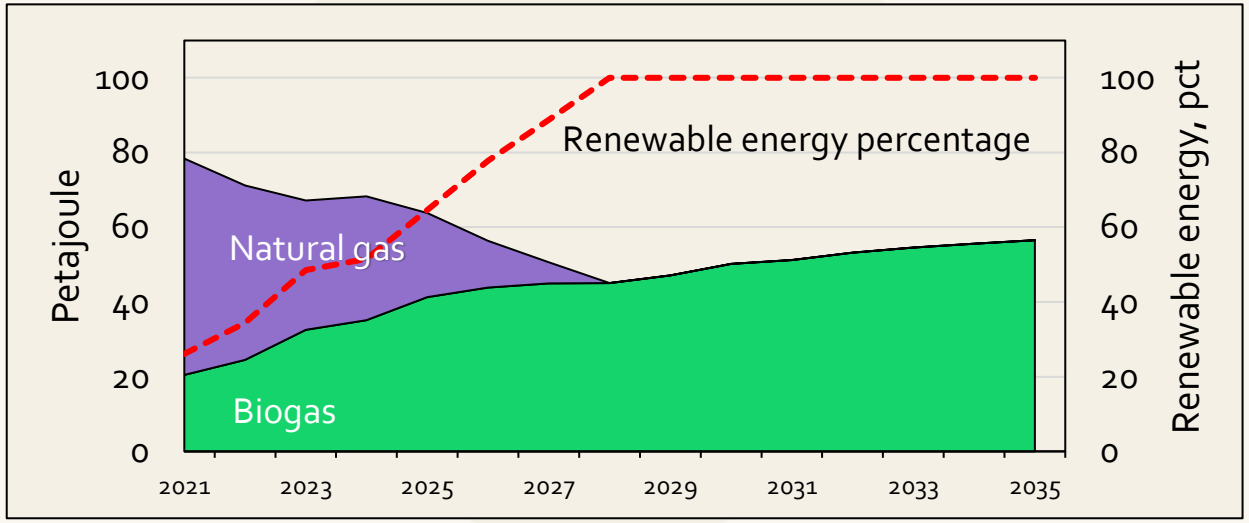
The consumption of natural gas and biogas in Denmark. The dashed curves show biogas' share of the total gas consumption.

Biogas Danmark

Development of gas grid consumption– Danish Energy Agency forecast



Development of gas grid consumption - Biogas Danmark's proporsal



Resume

Net climate effect of biogas

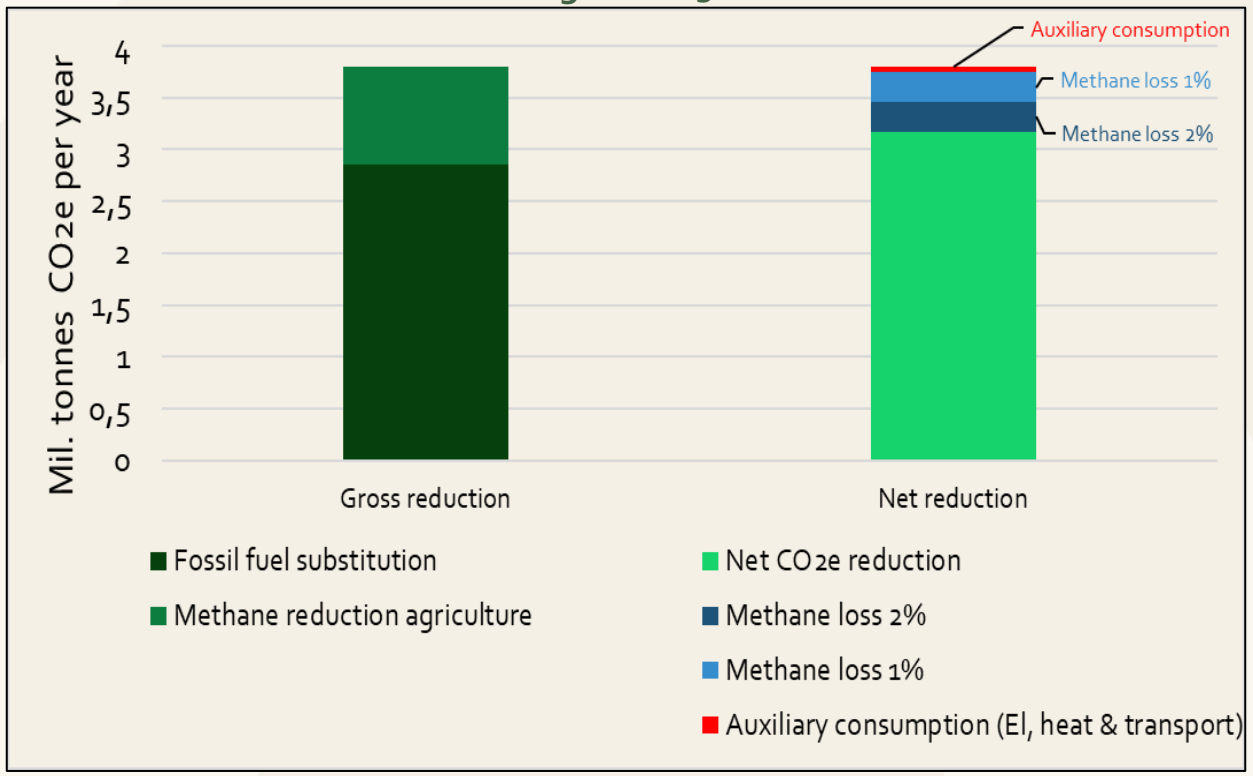
The net climate effect of biogas is greater than the CO_2 reduction by substituting fossil fuels.

Biogas not only substitutes fossil fuels but also reduces the climate footprint of methane from the storage of manure in agriculture when the manure is digested in biogas plants. Biogas production also has a climate footprint in the form of fugitive methane emissions and auxiliary consumption of energy, as well as the transport of biomass.

The net climate effect is calculated by subtracting the CO_2 emissions from the biogas auxiliary consumption and fugitive methane emissions from the gross climate effect. The figure shows the net climate effect by 1 and 2 percent fugitive methane emissions, respectively.
In the Energy Agency's scenario, a biogas production of 51 petajoules in 2030 means a substitution of fossil fuel of almost 3 million tonnes of CO_2, while the methane reduction in agriculture corresponds to approximately 1 million tonnes of CO_2.
The fossil energy consumption that is substituted is just under 3 million tonnes of CO_2 and is thus exceeded by the net reduction of 3.3 million tonnes of CO_2e for a fugitive methane emissions of 2 percent.
Therefore, the use of biogas is climate neutral.

Biogas Danmark

Gross and net climate effect of biogas in 2030 – DEA scenario



In 2020-21, the fugitive methane emissions was measured at around 2 percent at several agricultural-based facilities, and in 2022 a regulation was adopted that brings the fugitive methane emissions down to 1 percent. This regulation will come into force on 1 January 2023. Substitution of fossil natural gas is expected, as well as the inclusion of auxiliary consumption and biomass transport.

Net reduction with a fugitive methane emissions of 2 percent is in the Energy Agency's scenario calculated for 3.3 million tonnes of CO_2 equivalents and 3.6 million tonnes for a fugitive methane emissions of 1 percent.

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The climate footprint of gas and electricity consumption in Denmark

Gas and electricity consumption have approximately the same climate footprint

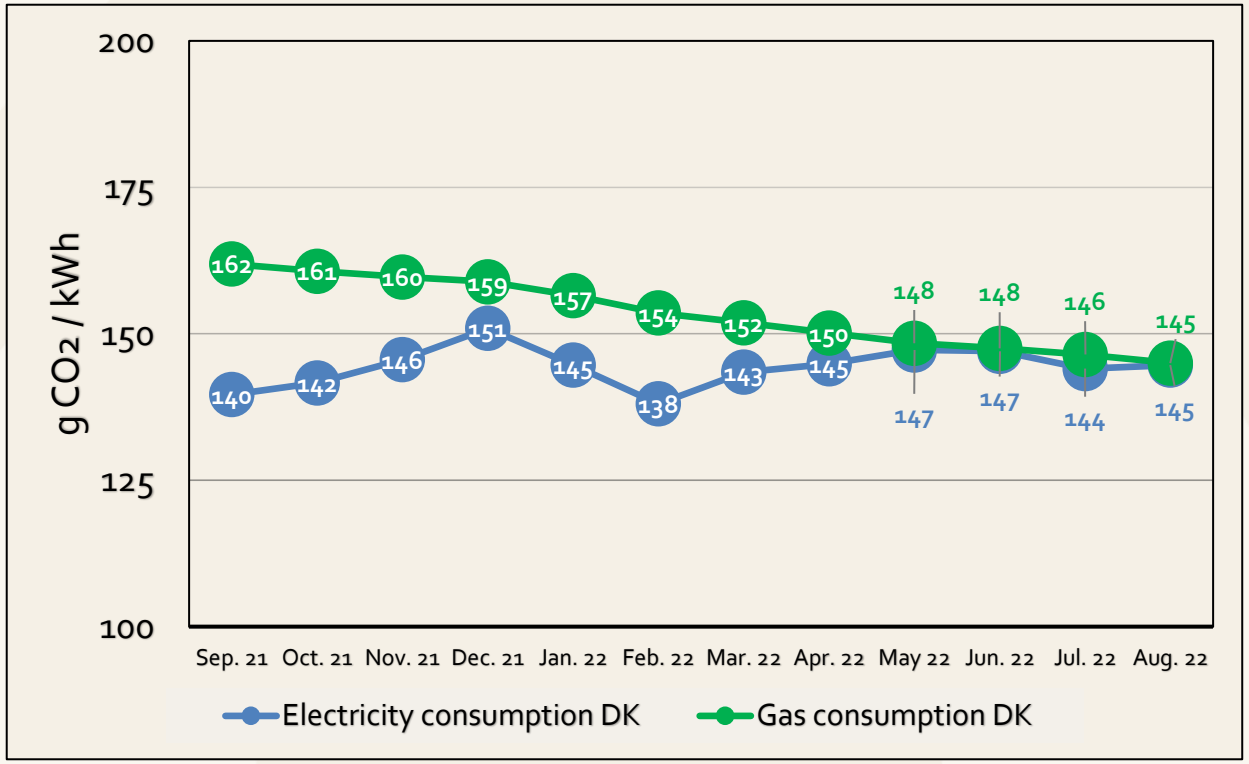
The CO_2 footprint of the Danish gas and electricity consumption, has approached each other in recent years and is now at the same level, just under 150 grams of CO_2/kWh. [7, 8]

The high gas prices and several political initiatives lead to decreasing gas consumption, and at the same time, biogas production is steadily increasing. This results in a constant decrease in the climate footprint of Danish gas consumption.

The climate footprint of electricity consumption is less constant, as it is affected by the water resources for the Norwegian hydropower plants, the wind resources in Northern Europe, and the gas, coal, and CO_2 quota prices.
The lack of northern European wind power and water in Norwegian hydropower led to an increase in the climate footprint of electricity consumption in the autumn of 2021. In the spring of 2022, it is mainly reduced production at gas power plants and the reopening of coal power plants that have led to increasing CO_2 emissions.

Biogas Danmark

Climate footprint in gas and electricity consumption 2021-2022



The climate footprint of gas and electricity consumption is shown as the average for the previous 12 months. The climate footprint for electricity consumption has been calculated and reported by Energinet [7, 8], while Biogas Danmark has calculated the climate footprint for gas consumption based on data for the gas grid reported by Energinet. [9]

Resume

The market value of biogas delivered via the gas grid

Development in market value and subsidy costs

Russia's reduction of gas supplies to Europe has given gas prices a significant jump on the stock exchanges.

The market value of biogas has increased considerably and looks set to remain high for the next few years. As gas prices rise, the subsidy is regulated down and looks set to stay low for the next few years.

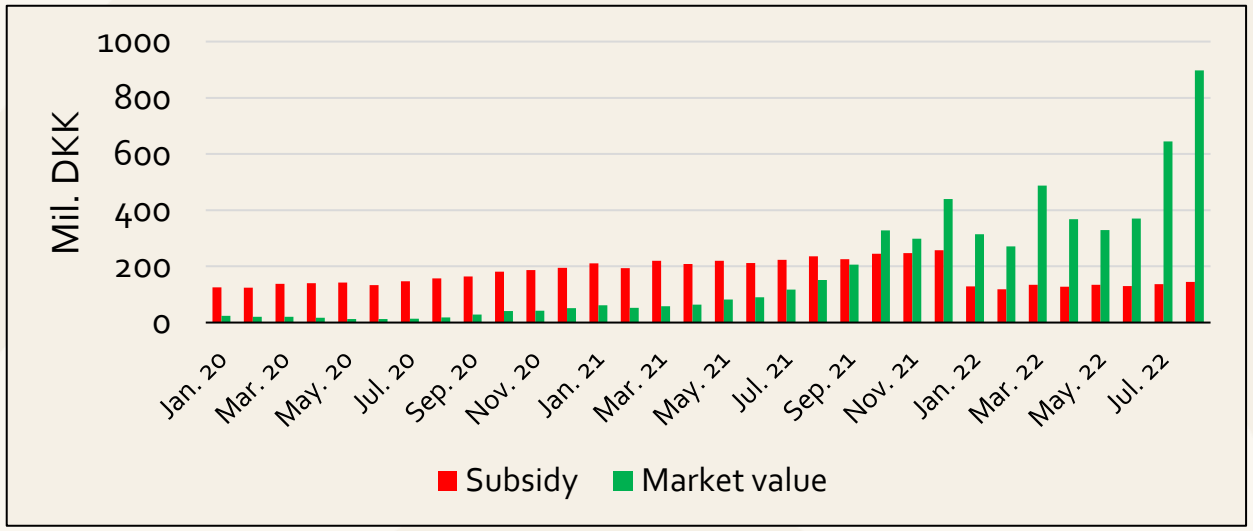
In the first eight months, Danish biogas production substituted fossil natural gas with a market value of approx. 3.5 billion DKK. Forward prices for the second half of 2022 indicate that the market value will exceed DKK 7 billion DKK for 2022.

As the gas would alternatively be delivered from Russia, it is money that has not been channelled out of Denmark and the EU to Russia. However, it has created value for the biogas producers and, not least, considerable savings for the many customers who have agreements on fixed prices from the biogas producers.

The development in gas prices has meant that the market value of the natural gas that the biogas substitutes now far exceeds the state's subsidy for the biogas.

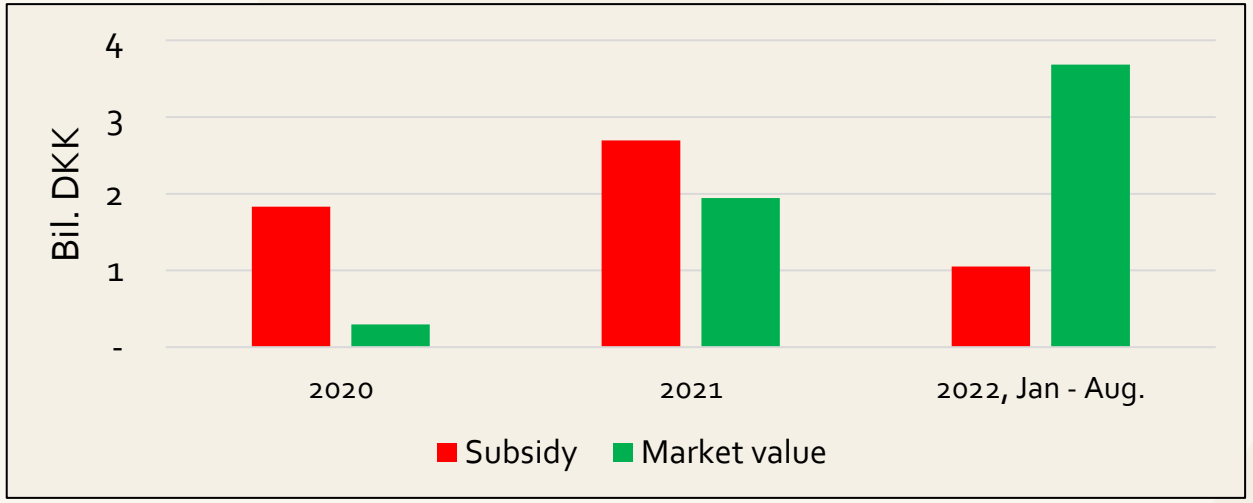
Biogas Danmark

The market value of natural gas substituted by upgraded biogas in Denmark



Since October 2021, the subsidy for biogas has been lower than the gas exchange value of the natural gas that the biogas substitutes from the gas grid. Sources: Energinet (biogas delivered to the gas grid) [9], Danish Energy Agency (subsidy) [10], and EEX Gas Market Data (market value) [11].

The market value of natural gas substituted by biogas since 2020 in Denmark



Gas consumption

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Gas consumption

Development in gas consumption

Gas consumption drops significantly

The Energy Agency scenario is based on the Energy Agency's forecast in KF22 [1] , which indicates that gas consumption will decrease by approximately 20 petajoules (PJ) towards 2030 and a further 18 PJ towards 2035. The Biogas Danmark scenario is based on the new focus on phasing out gas consumption more quickly in both heat supply and industry.

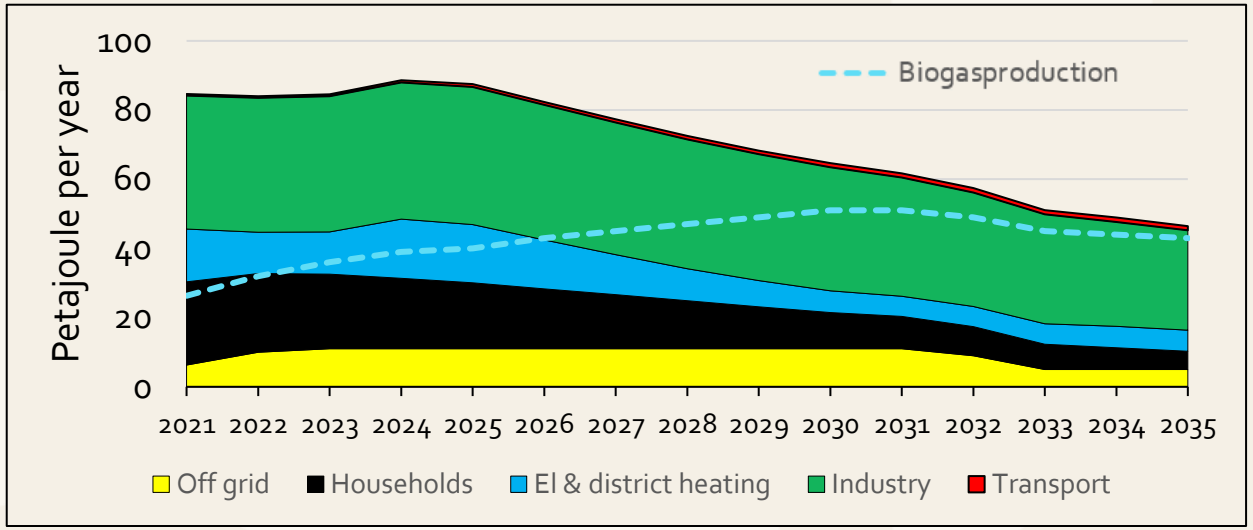
In the Climate Agreement on green electricity and heat, it has been agreed to phase out gas consumption in private households so that only biogas may be used from 2030 and that the goal is a ban on gas stoves in 2035. [5] Biogas Danmark's scenario implies that the number of gas stoves will decrease by 300,000 by 2028 and be entirely gone by 2035.

High gas prices and the Danish Energy Agency's warnings to cut off the gas supply to companies make them switch to fossil oil and coal. It is therefore expected in Biogas Danmark's scenario that gas consumption for business will fall by approximately 30 percent in 2028 compared to 2021.

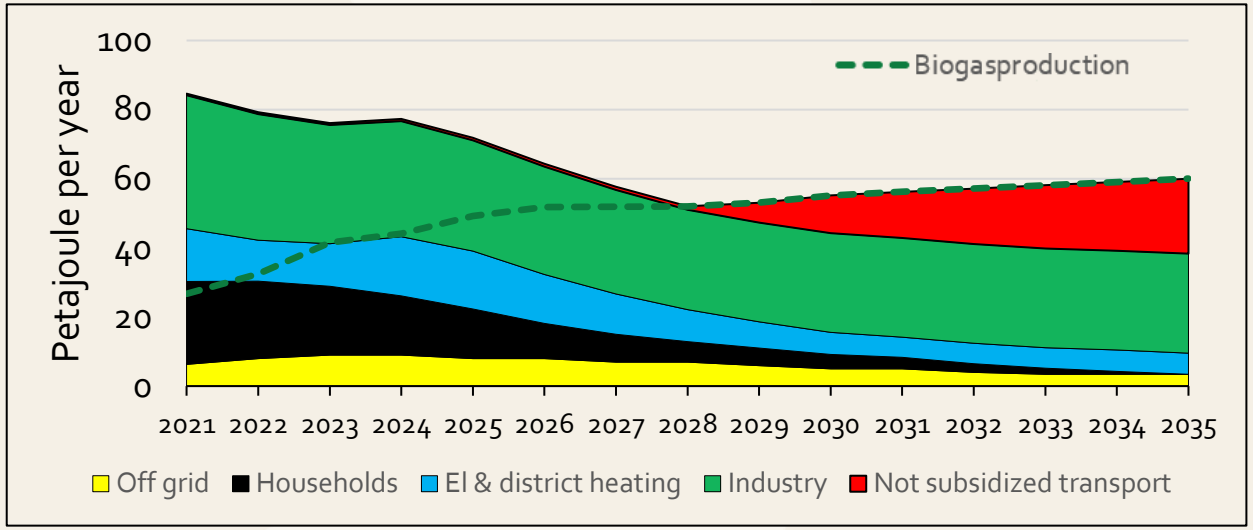
From 2027, this releases up an increasing amount of biogas available for the green conversion of heavy transport. In Sweden and Germany, the use of biogas in heavy trucks and ships is under intense development. In Denmark, biogas will be able to cover a large part of the energy consumption in trucks that cannot switch to electricity before 2035. In the long term, there is also great potential so that biogas can be used to produce green jet fuel.

Biogas Danmark

Development in gas consumption – Danish Energy Agency , KF22



Development in gas consumption – Biogas Danmark



Gas consumption

Biogas for heavy transport

Biogas can provide a quick green transition

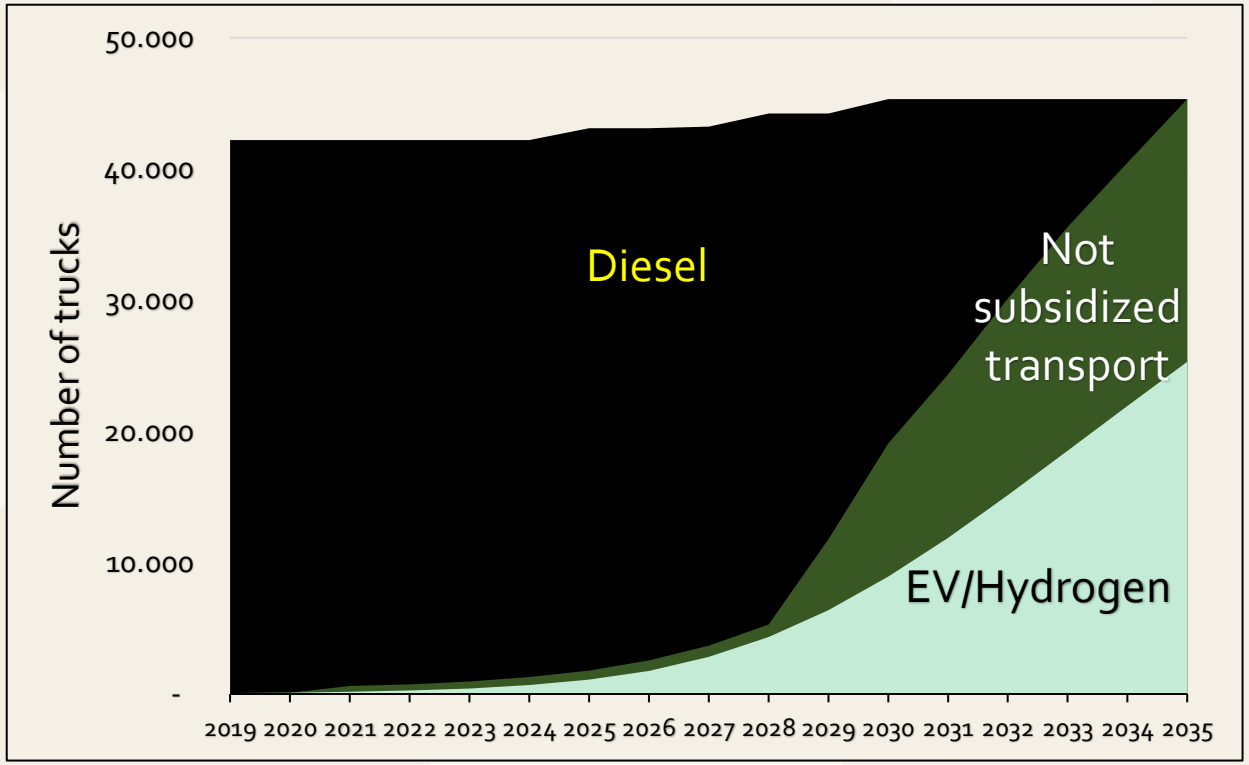
In recent years, there has been a gradually increasing interest in converting trucks to biogas in Denmark. From 1 January 2022, this biogas will be supplied without subsidy, which is the consequence of an amendment to the Biofuels Act and introduction of a new CO_2 substitution requirement in the Danish transport sector.

An analysis of the transport area by Green Power Denmark (formerly Dansk Energi) from the spring of 2022 shows that electric and hydrogen trucks will only begin to cover half of the heavy transport in the years around 2035[12]. There is, therefore, a need for an extra effort to the green conversion of heavy transport, especially in the heavyweight classes.

Biogas Danmark's potential estimate shows the potential for the Danish biogas producers to supply 10 PJ of unsubsidized biogas to the transport sector in 2030 and 22 PJ in 2035. This means that biogas can cover the energy needs of, for example, 10,000 trucks in the heaviest weight classes from 2030 and 20,000 in 2035.

Such a development will require an increase in the CO_2 substitution requirement, as well as Denmark making it possible for a CO_2 tax refund when purchasing biogas from the gas grid, as is the case in our neighboring countries.

Potential for biogas for road freight transport in Denmark



The figure is based on Green Power Denmark's forecast for developing the number of electric and hydrogen trucks (BEV/hydrogen). The growth in biogas trucks has been calculated by Biogas Danmark It is based on using 10 petajoules of unsubsidized biogas for heavy transport in 2030, increasing to 22 petajoules in 2035, which will be available in the Biogas Danmark scenario. According to the Danish Energy Agency's Climate Status and Projection 2022, diesel trucks are expected to still make up 79 percent of the truck fleet in 2035.

Biogas Danmark

Biomass utilization

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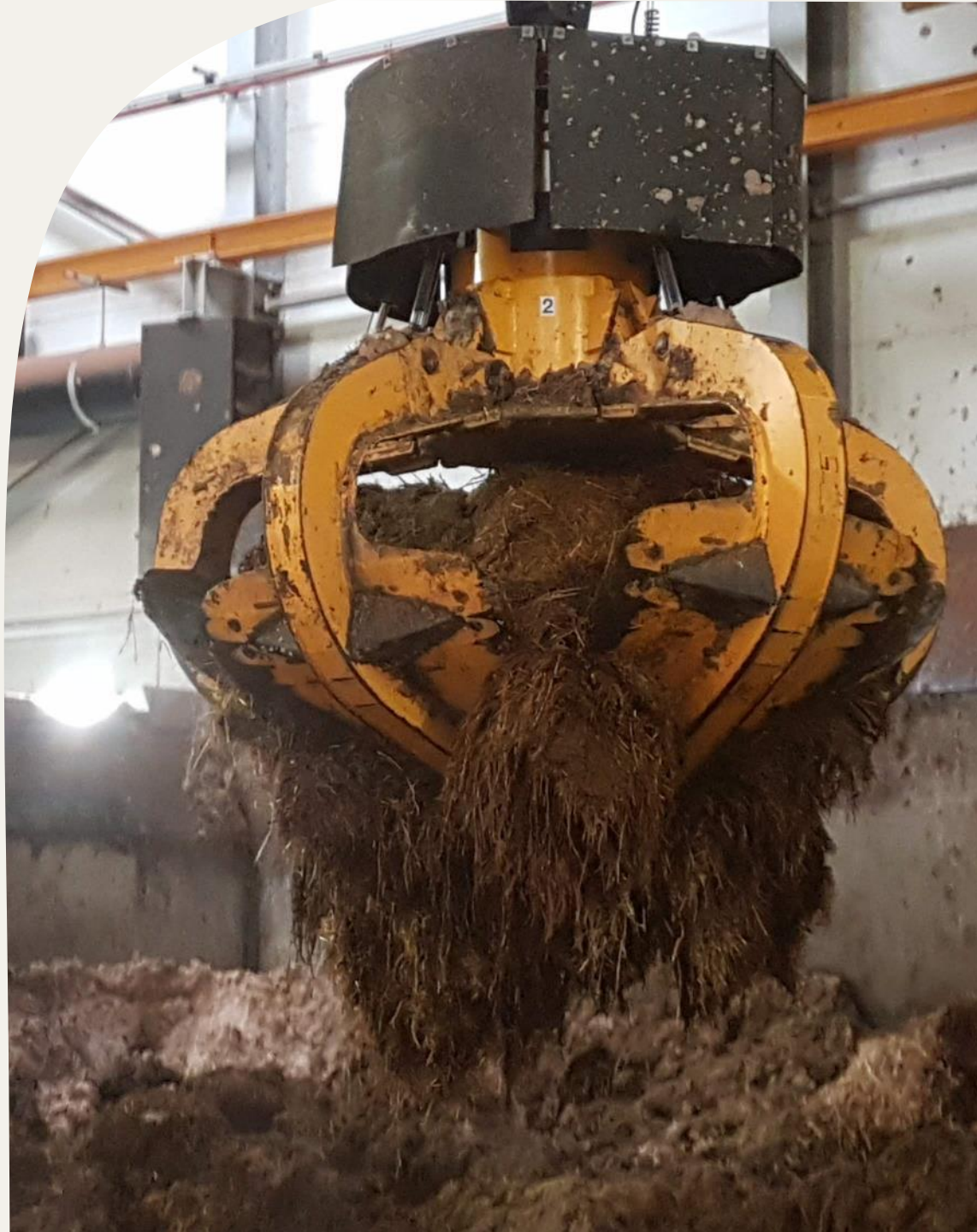


Biogas Danmark

Biomass utilization

The development of biogas production

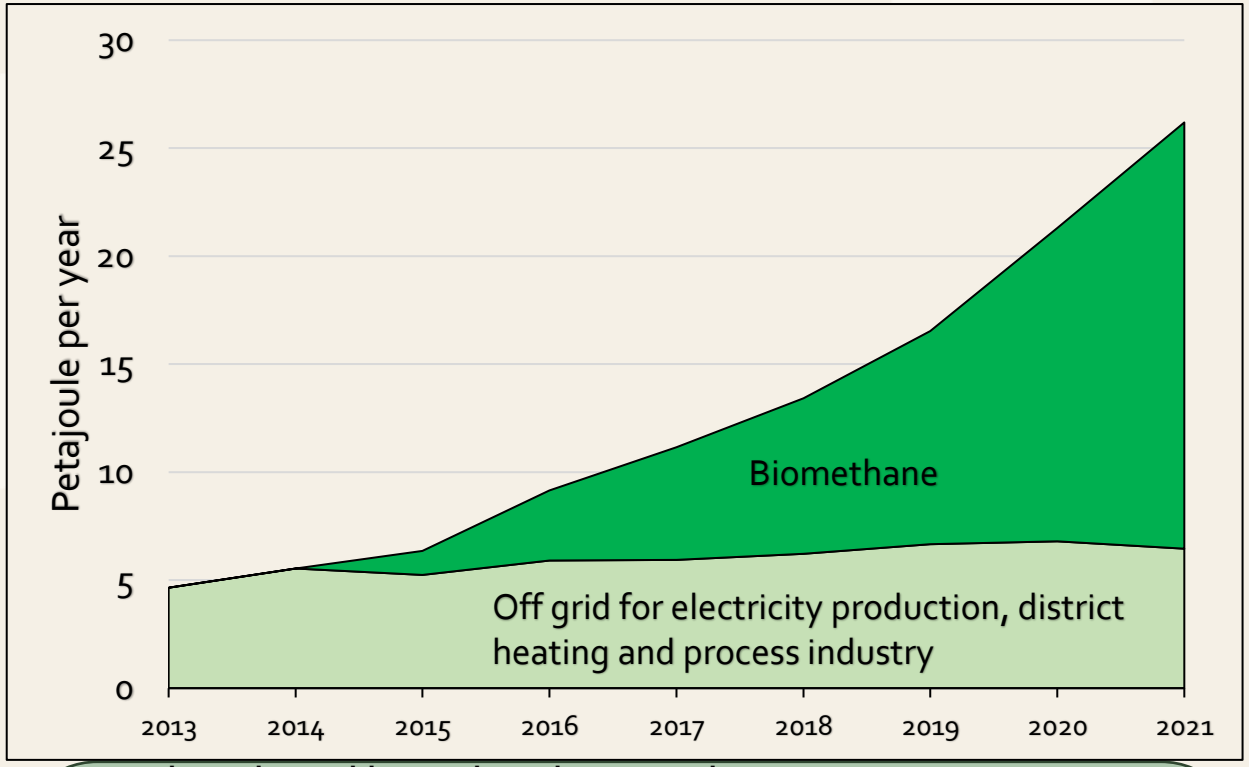
Danish biogas production has in been strong growth since 2012.

In 2012, a new tender scheme allowed biogas producers to supply upgraded biogas to the gas grid.[13]

Two years later, the first Danish biogas entered the gas grid. Since then, biogas production has increased from approximately 5 petajoules in 2014 to 26 petajoules in 2021, where biogas made up roughly 25 percent of total gas consumption.

In 2022, a production of upgraded biogas for the gas grid was expected in the order of 22-24 petajoules, corresponding to approximately 30 percent of gas consumption. At the same time, about 6-7 petajoules of biogas are expected to be used directly for cogeneration and process energy in industry.

The development of biogas production in Denmark since 2013



Approximately 200 biogas plants in Denmark

Plants that do not upgrade biogas to the gas grid typically produce electricity and heat.

- Agricultural-based biogas plants have 100 units, of which 55 with upgrading.
- Wastewater plant 60 units, of which 2 units with upgrading.
- Industrial biogas plants 7 units.
- Plants that recover biogas from landfills 25 units.

The Danish Energy Agency's overview of biogas plants in 2022 can be downloaded here:
https://ens.dk/sites/ens.dk/files/Bioenergi/liste_over_biogasanlaeg_i_dk.pdf [14]

Biogas Danmark

Biomass utilization

Biogas production split by bioresources - Danish Energy Agency

Manure supplies 35 percent of the biogas

While manure makes up roughly three-quarters of the total tonnage of biomass for biogas plants, manure only provides approximately one-third of the gas.

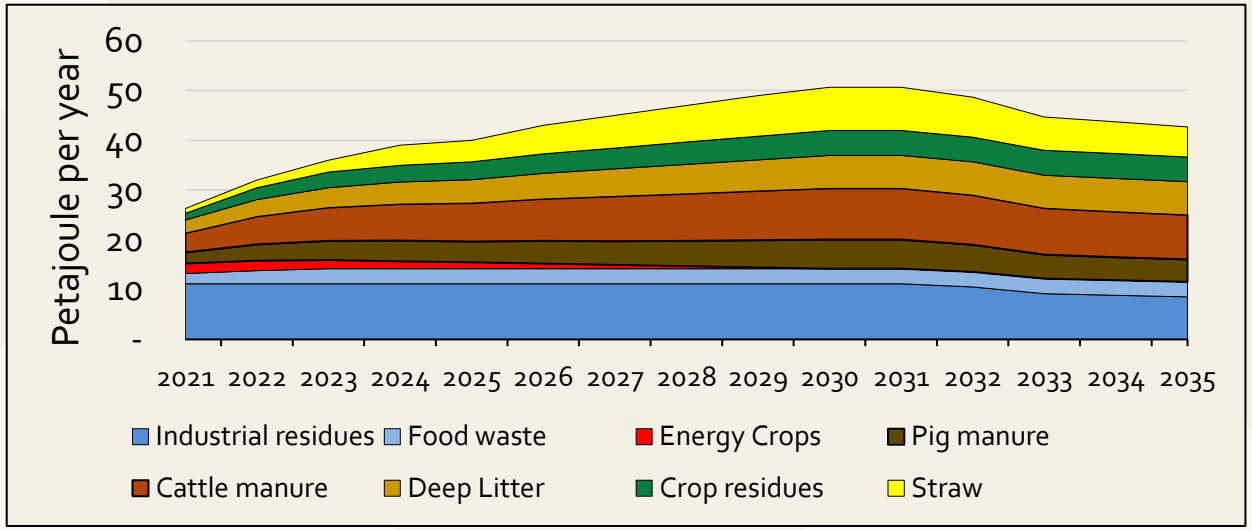
The reason is that manure has a relatively low dry matter content. Since dry matter is the raw material for biogas production, manure yields less biogas than drier biomasses such as deep litter, straw, industrial residues, and household waste.

Pig manure supplies approximately 10 percent of biogas production, while energy crops will be completely phased out by 2030 at the latest.

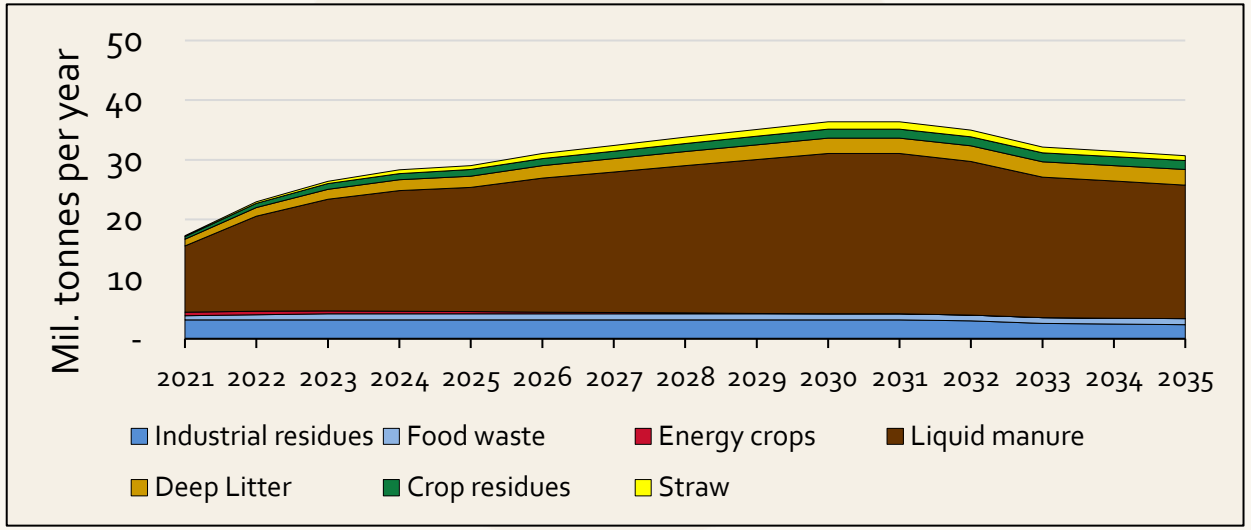
Two-thirds of biogas production comes directly from agriculture. Since industrial residues and food waste through the food chain also have their origin in agriculture, agriculture accounts for the total biogas production.

Biogas Danmark

Biogas production split by bioresources in PJ – DEA scenario



Biogas production split by bioresources in tonnes – DEA scenario



Biomass utilization

Biogas production divided by bioresources – Biogas Danmark

Larger quantities of animal manure and straw are digested

The Biogas Danmark scenario indicates a significant increase in biogas production. The resources available for this production growth are primarily straw, and animal manure, as household waste and industrial residues, are assumed to be fully utilized after 2025.

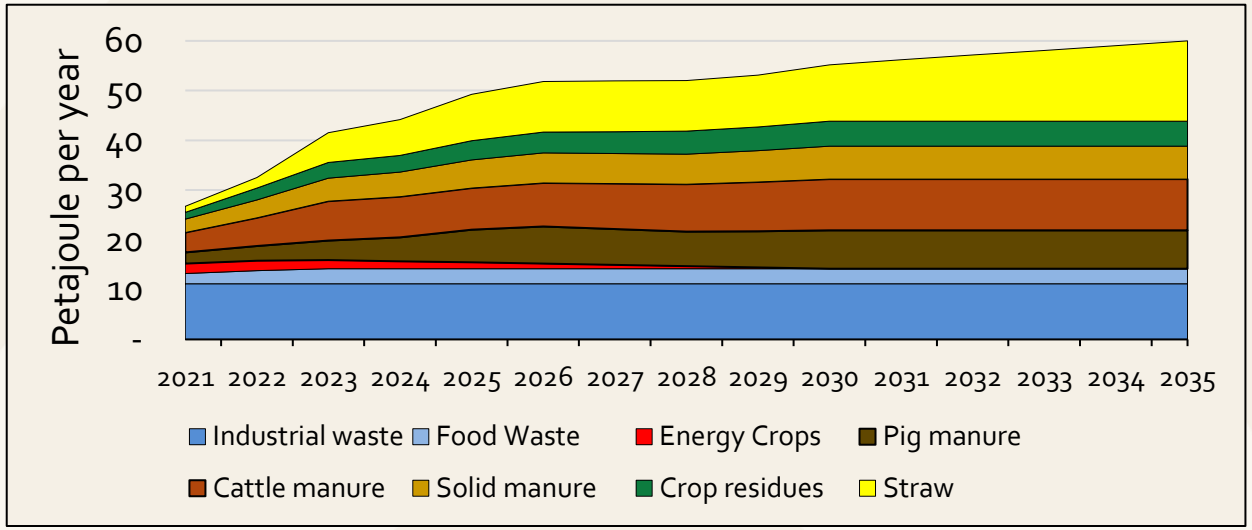
In 2035, manure makes up 75 percent of the input and supplies 33 percent of the biogas in the Biogas Danmark scenario. Straw makes up approximately 6 percent of the input biomass but delivers roughly 30 percent of the biogas.

Pig manure supplies 12 percent of biogas production in 2035.

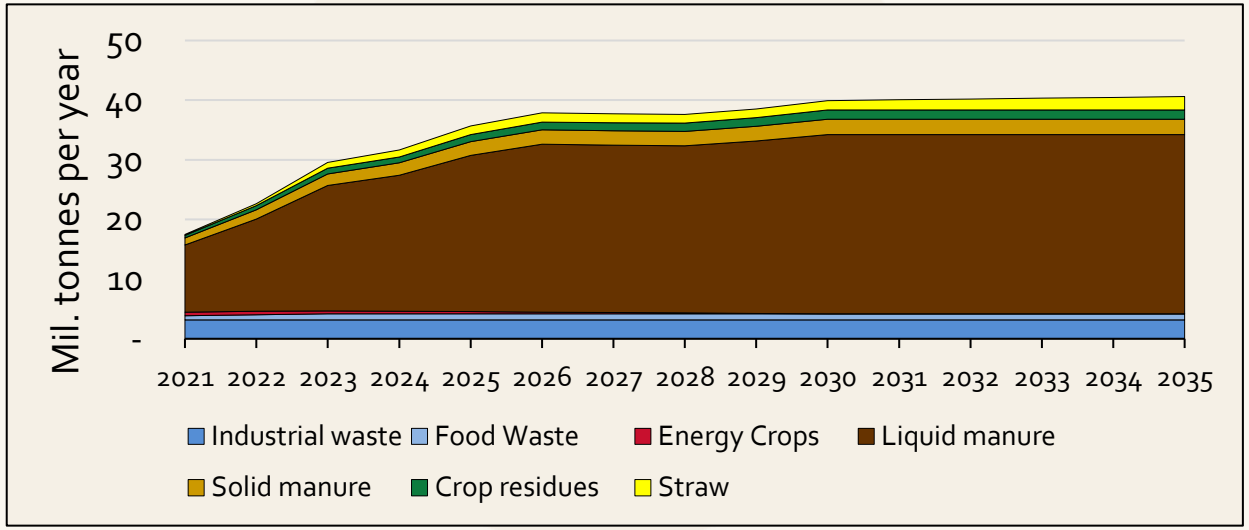
The substantial increase in the digestion of straw presupposes further development of methods and technologies for efficient degassing of straw. At the same time, it will result in higher fibre content in the digestate, which is expected to promote development in the direction of separating the degassed biomass and, thus, the production of designer fertilizer adapted to the recipients' needs.

Biogas Danmark

Biogas production split by bioresources in PJ – Biogas Danmark scenario



Biogas production split by bioresources in tonnes – Biogas Danmark scenario



Biomass utilization

Digesting of animal manure and straw

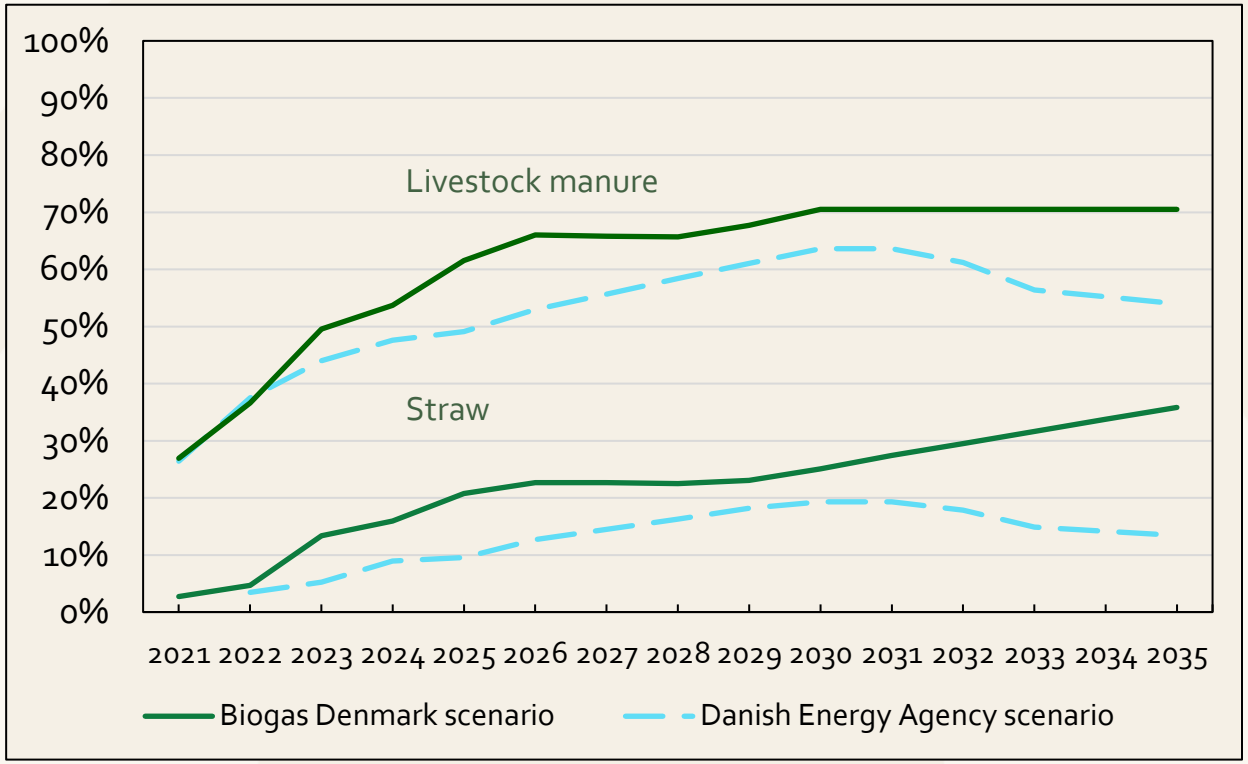
Significant surplus of straw

Although in the Biogas Danmark scenario, higher proportions of livestock manure and straw are used in the biogas plants compared to the Energy Agency scenario, there will still be a large surplus of straw.

The Energy Agency's scenario assumes that 64 percent of the livestock manure will be digested in biogas plants in 2030, corresponding to the agency's forecast in KF22, while the Biogas Danmark scenario includes degassing of 70 percent of the livestock manure, as this scenario increases the total biogas production to 60 petajoules.

For straw, the Energy Agency scenario will require that approximately 20 percent of the straw resource be used for biogas in 2030, while the Biogas Danmark scenario requires that 25 percent of the straw be used for biogas in 2030, increasing to 36 percent in 2035.

Utilization of the potential from livestock manure and straw.



The figure shows what proportion of the total resources of livestock manure and straw is used for biogas production in the two scenarios.

Research shows that when straw and deep litter are digested in biogas plants, most of the slowly convertible carbon is returned to the agricultural soil. This way, the same amount of carbon is stored long-term as if the straw were crushed directly into the ground.

Biogas Danmark

Biomass utilization

Consequences of halving livestock production.

The full potential for biogas production remains after halving.

Part of the climate debate concerns whether it is possible to maintain the same high biogas production if livestock production in Denmark is significantly reduced.

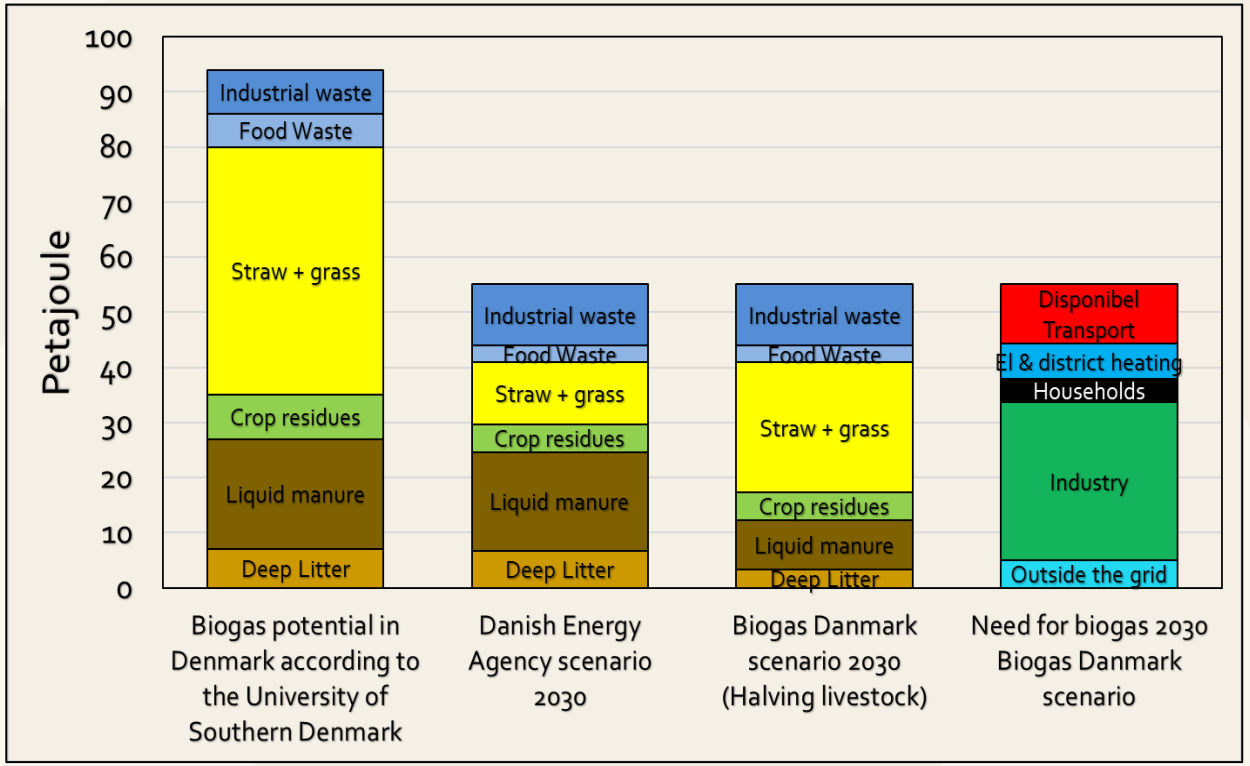
The figure shows the consequences if the supply of livestock manure to biogas plants is halved in 2030. The consequence will not be reduced biogas production but primarily an increased utilization of straw for biogas. Straw utilization will increase from 25 percent to approximately 52 percent in 2030.

Smaller livestock can also reduce grain production for feed and instead increase the production of, for example, grass for plant-based protein production. Residual products from this will be recirculated through the biogas plants and reduce the need to increase the use of straws.

With the University of Southern Denmark's study of the biogas potential, there will therefore continue to be a significant potential for further biogas production beyond the 60 petajoules in 2035, which is included in the Biogas Danmark scenario.

Biogas Danmark

Biogas potential, bioresources and demand for biogas in 2030.



According to the University of Southern Denmark, the total biomass potential for biogas production appears in the column on the left [3]. Pillar 2 shows the biogas production divided by different bioresources in the Biogas Danmark scenario. Pillar 3 shows the distribution of bioresources by halving the supply of livestock manure to the biogas plants in the Biogas Danmark scenario. The right column shows the use of biogas in different sectors in 2030 in the Biogas Danmark scenario.

Climate effect

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Biogas Danmark

Climate effect

Net climate effect of biogas

The net climate effect of biogas is greater than the CO_2 reduction by substituting fossil fuels

Biogas not only substitutes fossil fuels but also reduces the climate footprint of methane from the storage of manure in agriculture when the manure is digested in biogas plants. But biogas production also has a climate footprint in the form of fugitive methane emissions, auxiliary consumption of energy, as well as the transport of biomass.

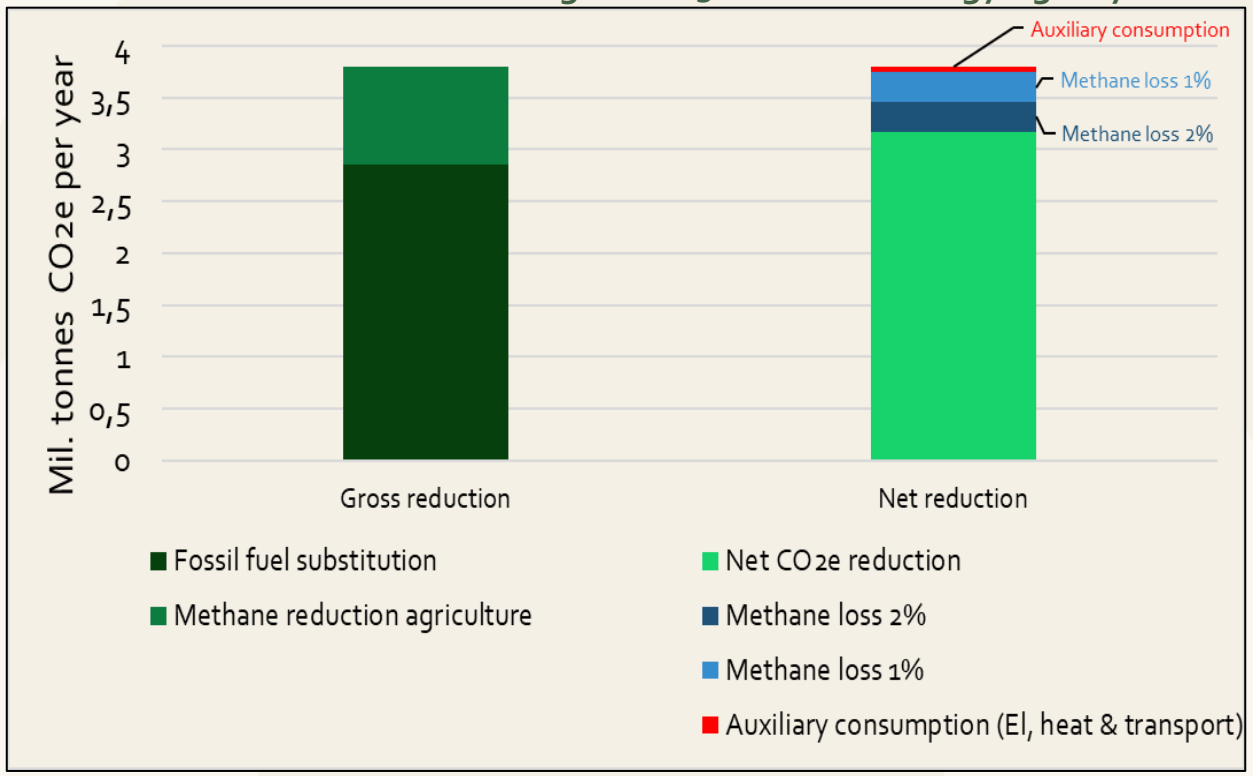
The net climate effect is calculated by subtracting the CO_2 emissions from the biogas plants' auxiliary consumption and fugitive methane emissions from the gross climate effect. The figure shows the net climate effect for a fugitive methane emissions of 1 and 2 percent, respectively.

In the Energy Agency's scenario, a biogas production of 51 petajoules in 2030 means a substitution of fossil fuel of almost 3 million tonnes of CO_2, while the methane reduction in agriculture corresponds to approximately 1 million tonnes of CO_2.

The fossil energy consumption that is substituted is just under 3 million tonnes of CO_2e and thus exceeding the net reduction of 3.3 million tonnes of CO_2e at a fugitive methane emissions of 2 percent. Therefore, the use of biogas is climate neutral.

Biogas Danmark

Gross and net climate effect of biogas in 2030 – Danish Energy Agency scenario



In 2020-21, the fugitive methane emissions was measured at approximately 2 percent at some agricultural-based facilities, and in 2022 a regulation was adopted that brings the fugitive methane emissions down to 1 percent. This regulation comes into force on 1 January 2023. The substitution of fossil natural gas is expected, as well as the inclusion of auxiliary consumption and biomass transport. In the Energy Agency's scenario, the net reduction for a fugitive methane emissions of 2 percent is calculated at 3.3 million tons of CO_2 equivalents and 3.6 million tons for a fugitive methane emissions of 1 percent.

Climate effect

Biogas' contribution to Danish climate targets in 2025 and 2030

Biogas will make a significant contribution

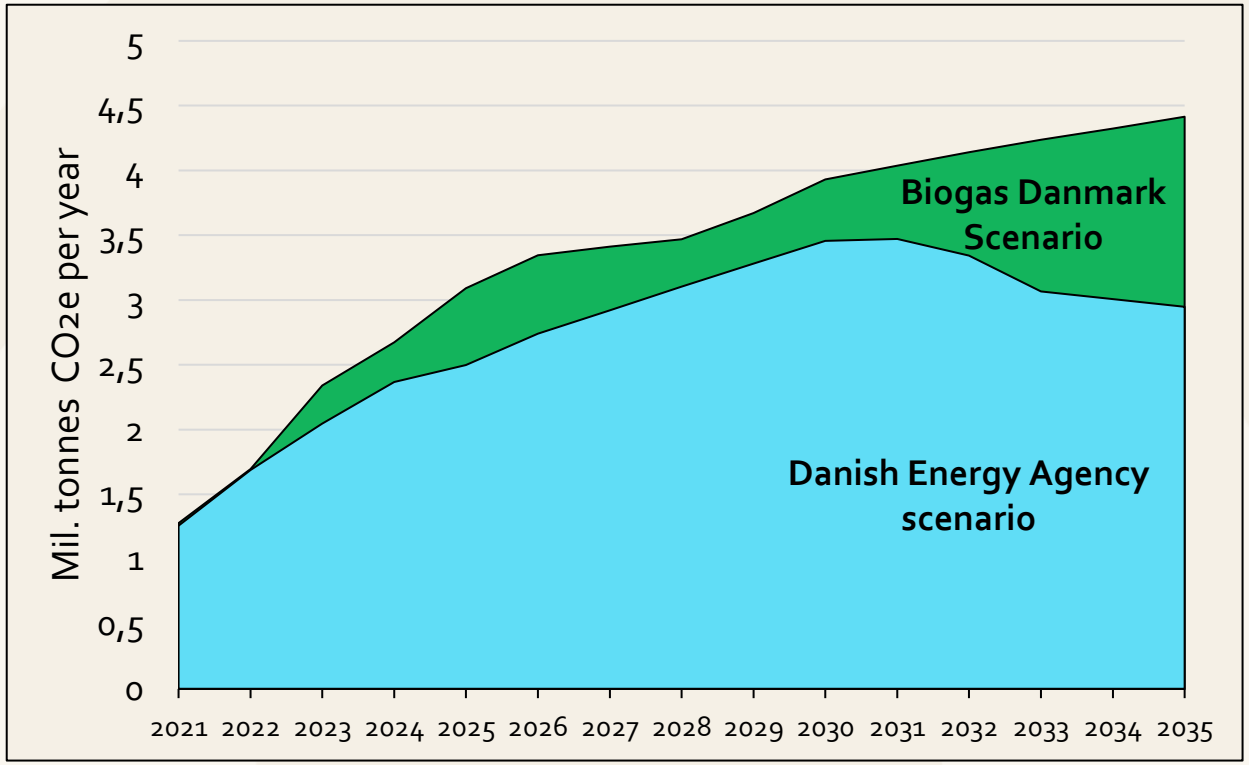
The increasing biogas production significantly contributes to Denmark reaching the 70 percent climate target for 2030. [1]

The Energy Agency scenario shows that biogas contributes to a net CO_2 reduction of 2.3 million tonnes in 2025 and 3.6 million tonnes in 2030.

Biogas Danmark's scenario with Biogas Danmark's recommendations gives corresponding reductions of net 3.2 million tonnes in 2025 and 4.3 million tonnes of CO_2 in 2030.

According to Climate Status and Projection 2022, Denmark needs to reduce by 2.4-5.5 million tonnes of CO_2 to reach the partial target in 2025 and 10 million tonnes of CO_2 to reach the 70 percent target in 2030.

Two scenarios for annual net CO_2 reduction in biogas production.



Biogas Danmark

Climate effect

Climate effect when producing and using biogas

Significant greenhouse gas reduction from biogas production.

The Danish Energy Agency scenario provides a net CO2 reduction in 2030of 3.6 million tonnes falling to 3.1 million tonnes in 2035. The Biogas Danmark scenario entails a reduction of 4.3 million tonnes of CO2 equivalents in 2030, increasing to 5.5 million tonnes in 2035.

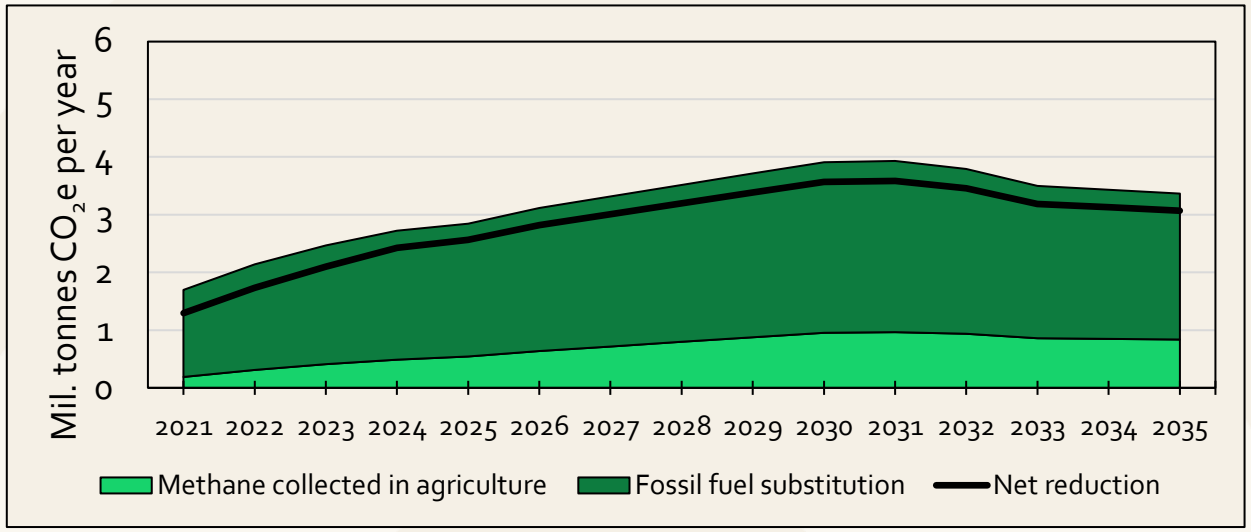
The calculation of the net climate effect is based on the reduction of methane emissions from livestock manure in agriculture and the substitution of fossil fuel consumption. In addition, CO2 emissions from biomass transport, the biogas plants' energy consumption, and fugitive methane emissions from the plants are deducted.

The CO2 emissions from the biogas plants' energy consumption are assumed to reduce by phasing in heat pumps.

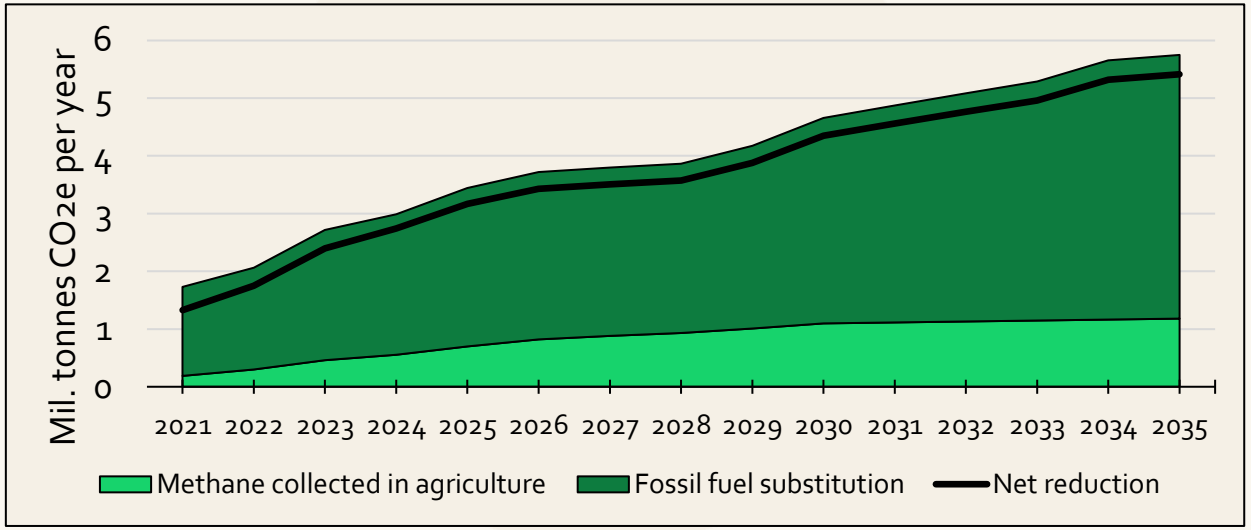
A fugitive methane emissions of 2.1 percent has been factored in from 2021. The Danish government will introduce regulation of fugitive methane emissions from 1 January 2023. It is assumed that the biogas plants will gradually reduce the fugitive methane emissions to 1 percent from 2025.

Biogas Danmark

Danish Energy Agency scenario



Biogas Danmark scenario



Net CO2 reduction is after deducting fugitive methane emissionsand the biogas plants' energy consumption for process and transport.

Climate effect

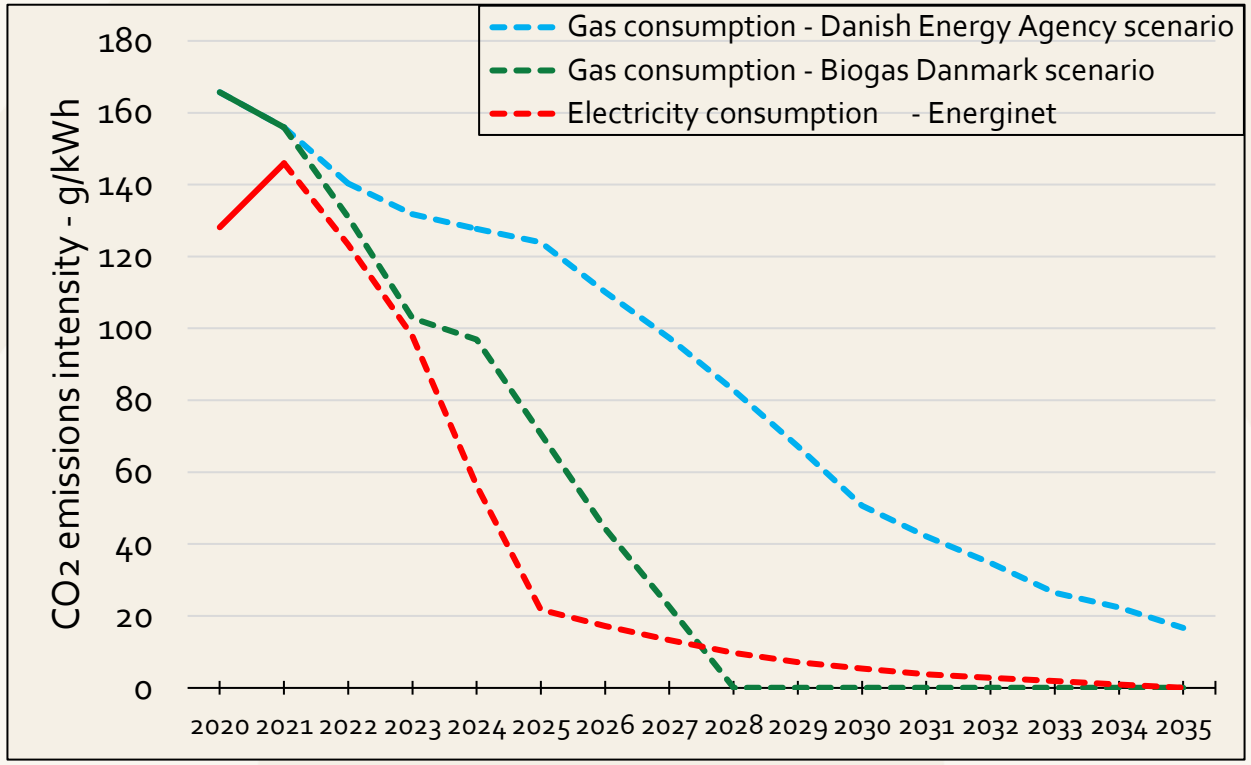
Future climate effect of gas and electricity consumption

The climate footprint from gas consumption can be reduced at the same rate as the climate footprint of electricity consumption.

Danish gas and electricity consumption currently has almost the same climate footprint. The climate footprint from gas consumption will also be able to follow the green conversion of electricity consumption in the future if Biogas Danmark's recommendations are realized.

If the Danish Energy Agency's forecast for biogas production and gas consumption turns out to be the outcome, the climate footprint of gas consumption will also decrease, but with a delay of a few years, and Denmark will not achieve climate-neutral gas consumption before 2035.

Projection of the climate footprint of gas and electricity consumption.



Energinet has carried out the projection of the CO_2 intensity in electricity consumption.
[15] Biogas Danmark has calculated the CO_2 intensity in gas consumption, partly based on the Danish Energy Agency's expectations for developing biogas production, partly based on the Biogas Danmark scenario.

Biogas Danmark

Climate effect

The life cycle analyzes of the climate effect of pyrolysis and biogas

Marked CO_2 reduction by pyrolysis and biogas.

A certified life cycle analysis of the potential of using straw for pyrolysis and biogas shows that it makes good climatic sense to use straw together with manure for biogas production.

Pyrolysis plants convert straw into fuel and biochar deposited in agricultural land. Biogas plants convert straw and manure into upgraded biogas and CO_2, which is deposited. The analyzes include the effect of auxiliary consumption, transport of biomass etc.

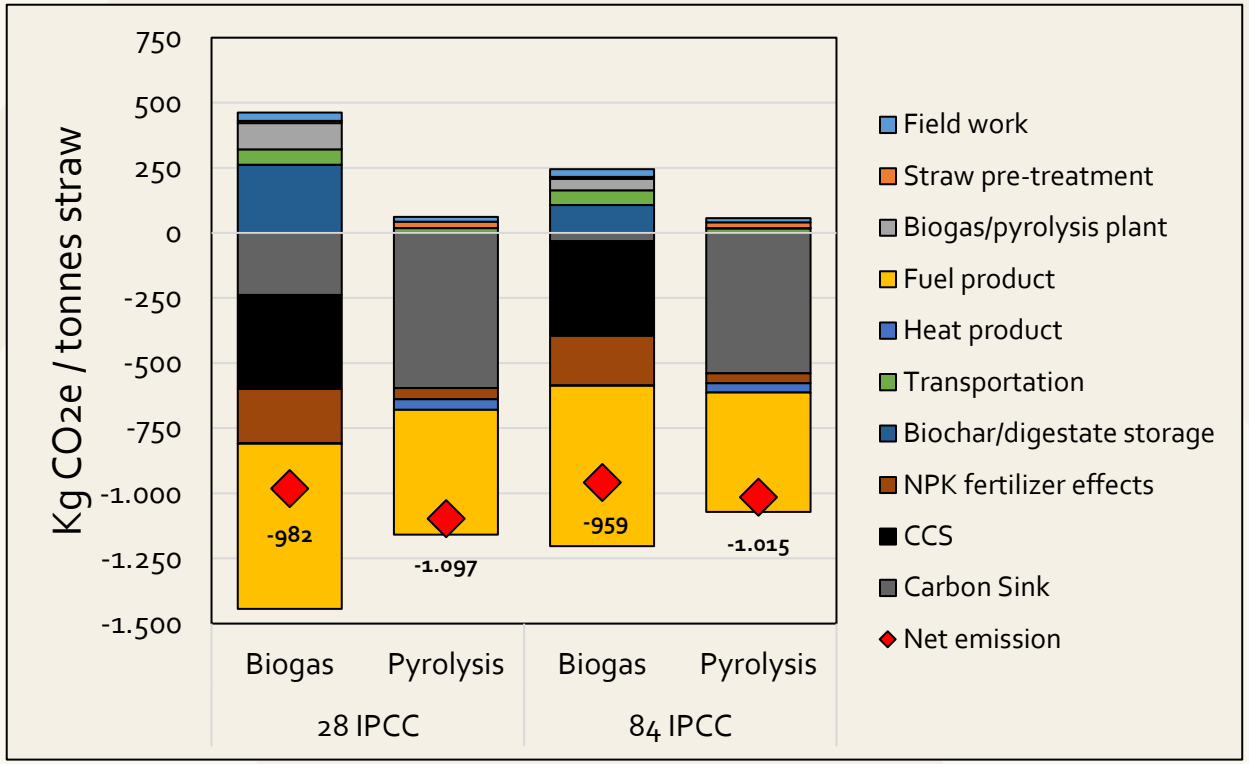
The analysis concludes there is a significant climate effect with both technologies and that the technologies are on par with each other.

The results indicate that the most optimal solution may be that the straw is first degassed in a biogas plant, after which a separated fibre fraction goes to the pyrolysis plant.

The first full-scale plant is being built at a biogas plant in Jutland.

Biogas Danmark

Climate footprint of pyrolysis of straw and biogas with CCS.



Life cycle analysis compares the use of straw for biogas and manure (including CO_2 storage) with the pyrolysis of straw. The red markings show the total greenhouse gas reduction in kg CO_2 equivalents per tonne of straw at a methane emission factor of 28 (100-year period) and 84 (20-year period), respectively. [16]

Effects in agriculture

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Biogas Danmark

Effects in agriculture

Climate effect on the farm

Digesting the livestock manure reduces the climate impact

When livestock manure is stored in the manure channels in the stables, a natural turnover occurs, forming the greenhouse gas methane. When the manure is digested in a biogas plant, this methane is collected and thus, the climate impact of agriculture is reduced. At the same time, the biogas produced can substitute fossil energy and thus reduce CO2 emissions.

The climate benefit can be optimized by moving the manure more quickly from the stables to the biogas plant. Either by frequently flushing the slurry once a week or through a so-called line winch daily.

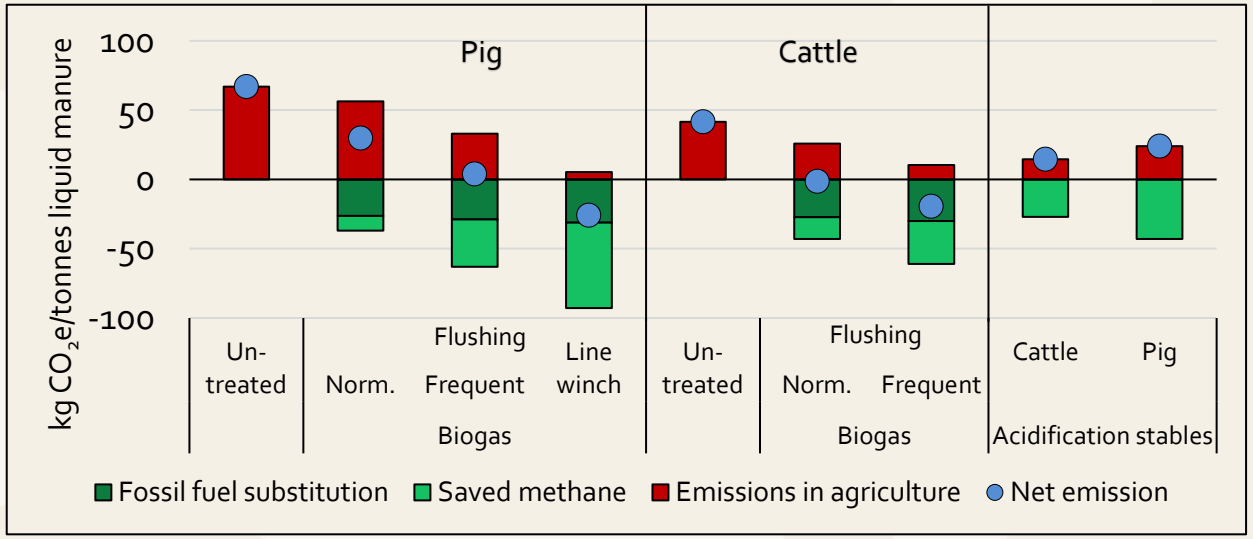
Optimum manure handling in the stables combined with biogas can thus make livestock manure climate neutral.

Agriculture can also reduce methane emissions by adding sulfuric acid to the slurry. However, if the manure is acidified in the barn, it cannot be used to the same extent in biogas plants.

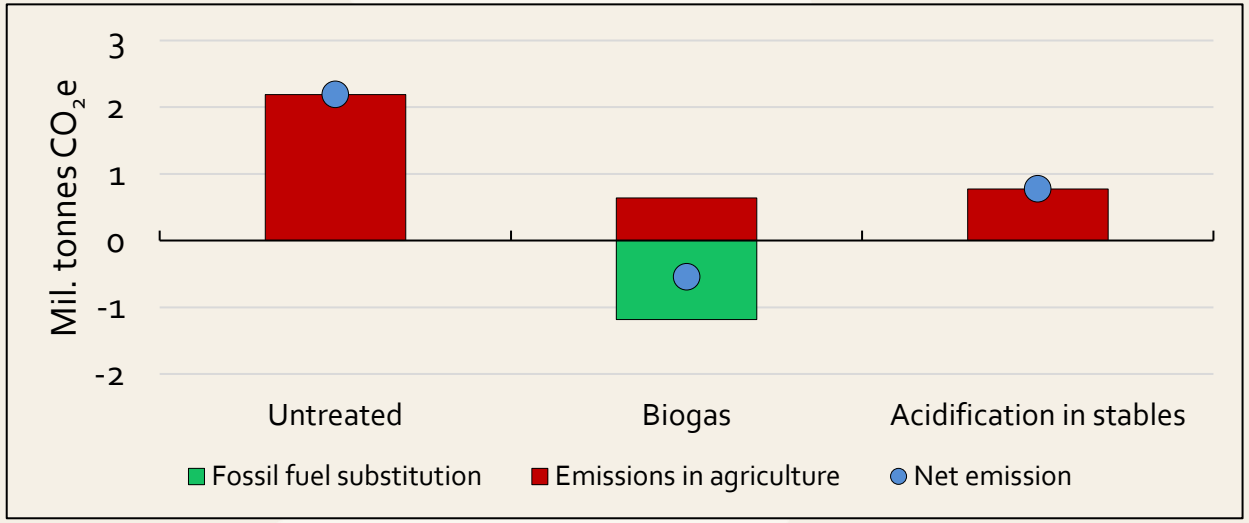
Acidification, thus, does not have double the climate effect of biogas. As can be seen from the lower figure, both the climate effect in agriculture and the overall net CO2 reduction is smaller with acidification than with biogas.

Biogas Danmark

Climate benefit can be increased through optimal manure management (17, 18)



Climate benefit from degassing or stable acidification of all Danish manure



Effects in agriculture

Climate effect in agriculture

Great synergy with frequent flushing and cooling.

Like the rest of society, agriculture faces a significant climate challenge and is the only sector with a binding climate target. With the climate agreement for agriculture from 2021, frequent flushing of manure from existing slaughter pig barns and all new pig barns is required from 1 January 2023.[19]

The Danish Agency for Agriculture has previously financed an advisory project with the participation of several biogas plants and approx. Four hundred suppliers of pig manure, where effects in existing stables have been documented.

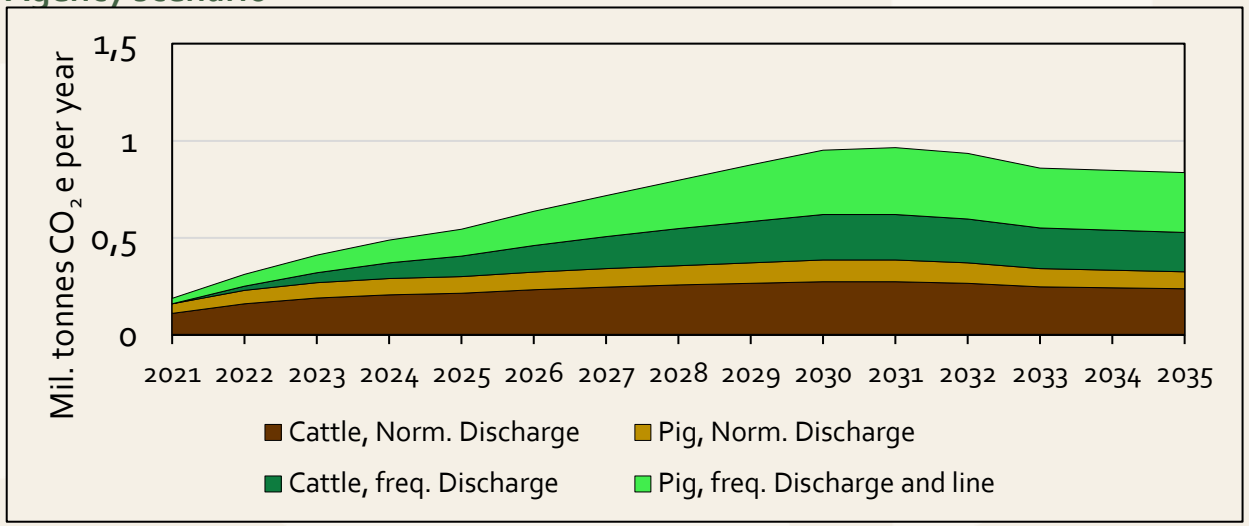
The effect will be even higher in new barns, where frequent flushing is established with weekly pumping out of the slurry or daily in barns with line winches.

Digesting of livestock manure thus has an additional climate effect as methane emission from barns and manure storage is reduced. At the same time, producing biogas replaces fossil gas and thus reduces the release of CO2 from this.

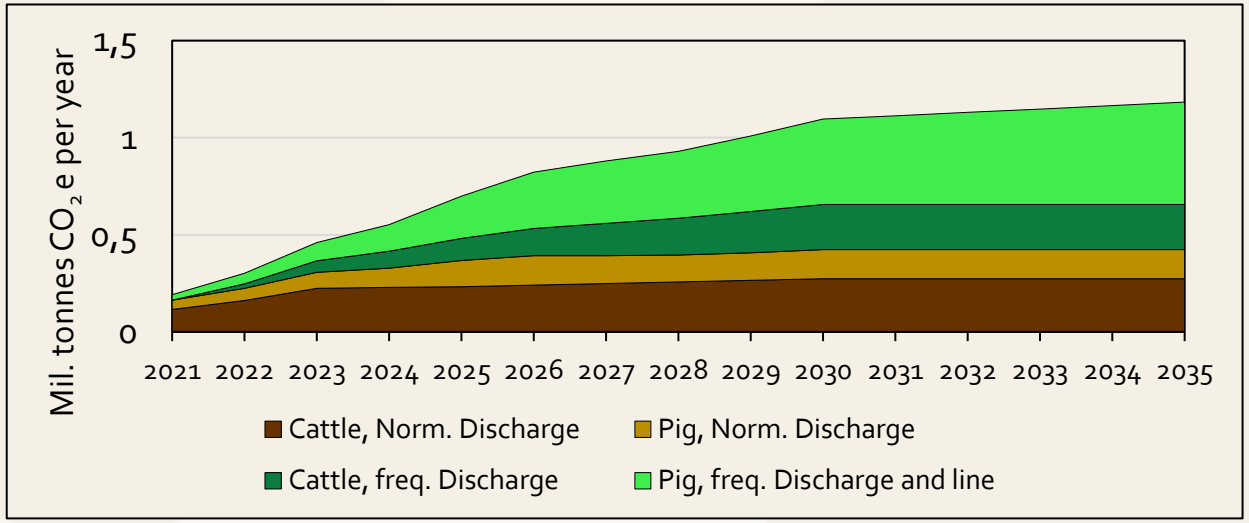
The total climate gain is approximately 4 million tonnes CO2e in the Energy Agency scenario and almost 6 million tonnes in the Biogas Danmark scenario. Approximately one million tonnes are from agriculture.

Biogas Danmark

Climate effect due to frequent flushing/slurry cooling– Danish Energy Agency scenario



Climate effect due to frequent flushing/slurry cooling – Biogas Danmark scenario



Effects in agriculture

Reduced nitrogen loss to the aquatic environment

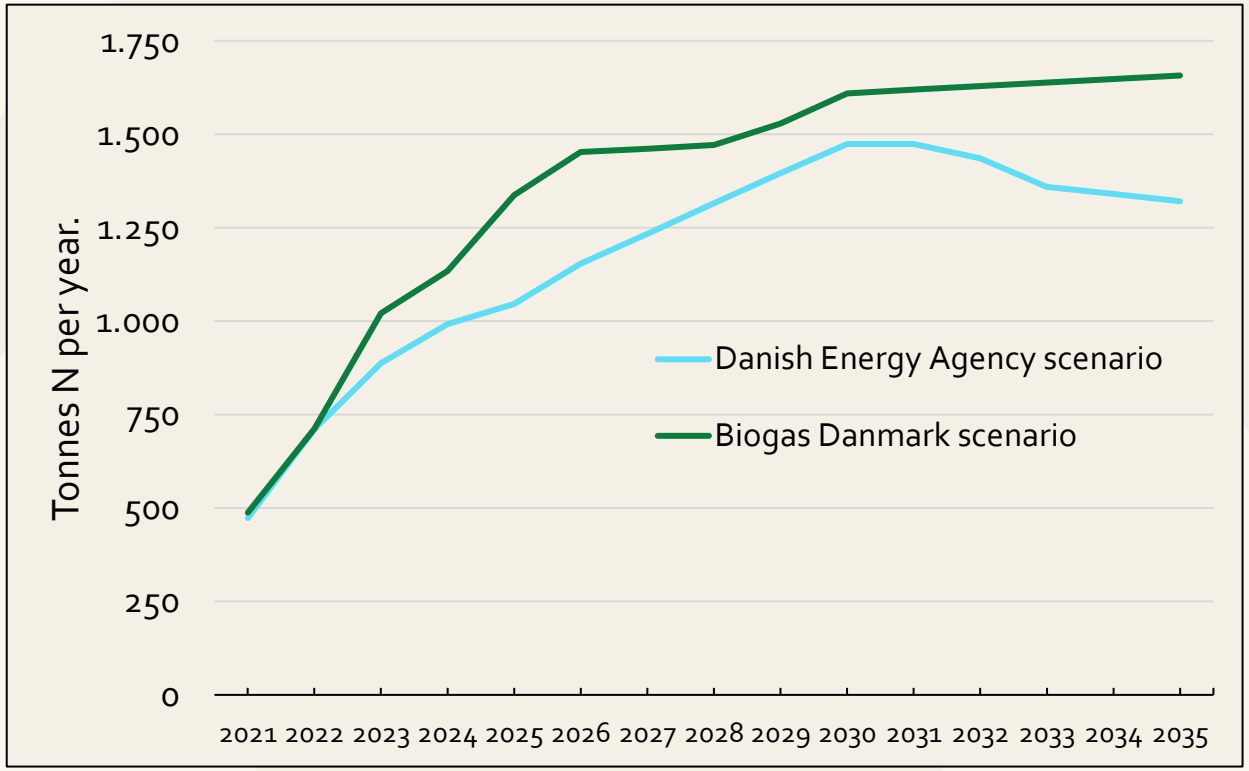
The biogas plants can contribute significantly to the Agricultural Agreement's goal of lower nitrogen emissions.

When digesting livestock manure in a biogas plant, the nitrogen will convert so that it can be used as fertilizer taken up directly by the crops when the digested biomass is applied to the field. Therefore, the plants grow better and produce a higher harvest yield, and at the same time, the risk of the nitrogen being washed into the aquatic environment is reduced.

In the Agricultural Agreement from 2021, it is agreed that nitrogen emissions must be reduced by 10,400 tonnes towards 2027[19] for Denmark to meet the EU's water quality targets. A biogas production of 51 petajoules, according to the Danish Energy Agency's scenario, enables the degassing of 65 percent of livestock manure in 2030. This reduces nitrogen flushing into the aquatic environment by roughly 1,200 tonnes per year in 2027.
If the subsidy schemes are brought forward to 2024-2026, the increased and earlier digesting of the livestock manure will reduce nitrogen emissions by 1,500 tonnes per year in 2027. With a continued biogas expansion cf. the Biogas Danmark scenario, nitrogen emissions can be reduced by up to 1,600 tonnes annually in 2030.

Biogas Danmark

Annual reduction of nitrogen emissions by digesting livestock manure.



Digesting 65 percent of the livestock manure in 2027, cf. The Danish Energy Agency scenario can reduce nitrogen emissions by almost 1,300 tonnes in 2030. An advance in biogas production cf. the Biogas Danmark scenario can increase the reduction in nitrogen emissions to nearly 1,600 tonnes per year from 2030.[20]

Effects in agriculture

Recycling of phosphorus

Biogas plants recycle scarce resources.

Biogas plants utilize large quantities of residual products from agriculture, households and industry and ensure the recirculation and recycling of the nutrients as fertilizer.

The most considerable amounts of phosphorus are found in livestock manure. Still, significant amounts of phosphorus are also recycled as residual products from industry and food waste from households.[21]

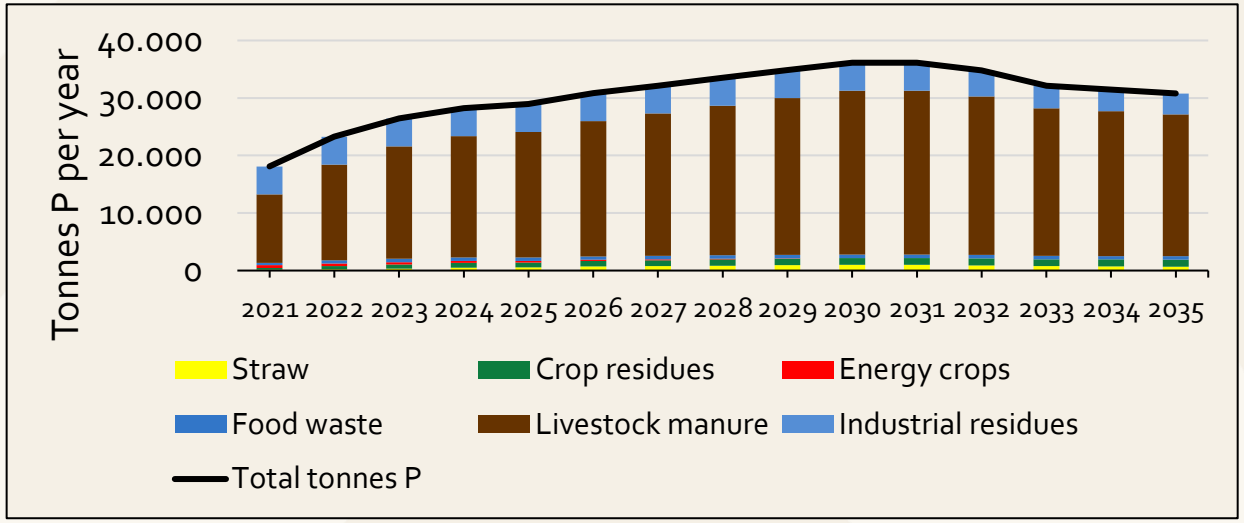
In total, biogas plants will handle around 36,000 tonnes of phosphorus in 2030 in the Danish Energy Agency's scenario, of which almost 5,500 tonnes come from industrial residues and food waste. Furthermore, around 2,200 tonnes of phosphorus from straw and crop residues from agriculture.

In comparison, Danish crops are supplied with around 13,500 tonnes of phosphorus with commercial fertilizer. [22]

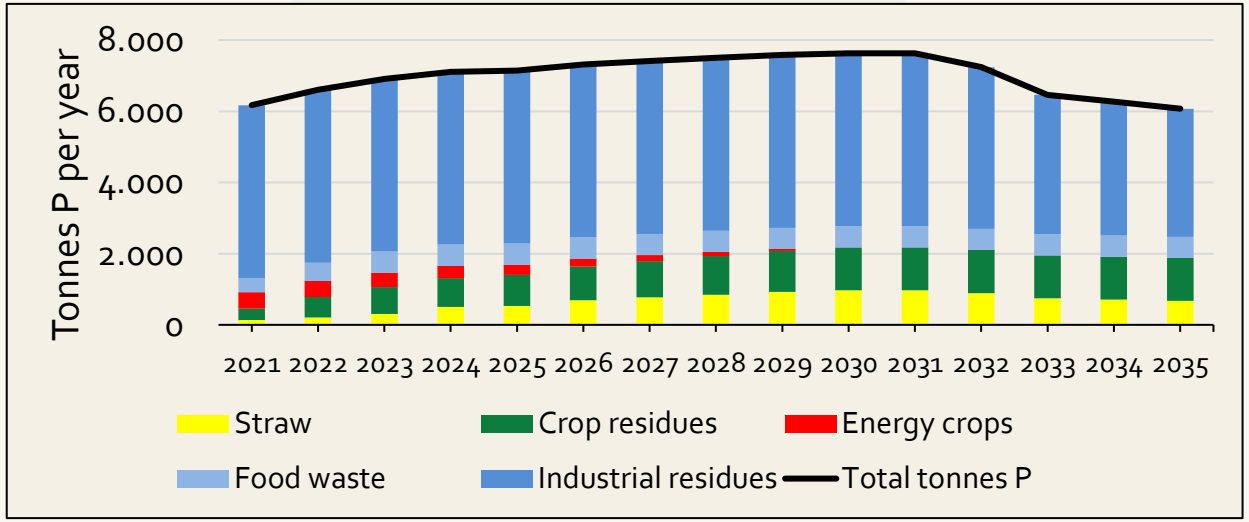
Both figures relate to the Energy Agency scenario.

Biogas Danmark

Livestock manure and industrial residues contribute the most considerable phosphorus resources



Biogas plants recirculate significant amounts of phosphorus.



Effects in agriculture

The synergy between biogas and ecology

Biogas plants can contribute to increased ecology.

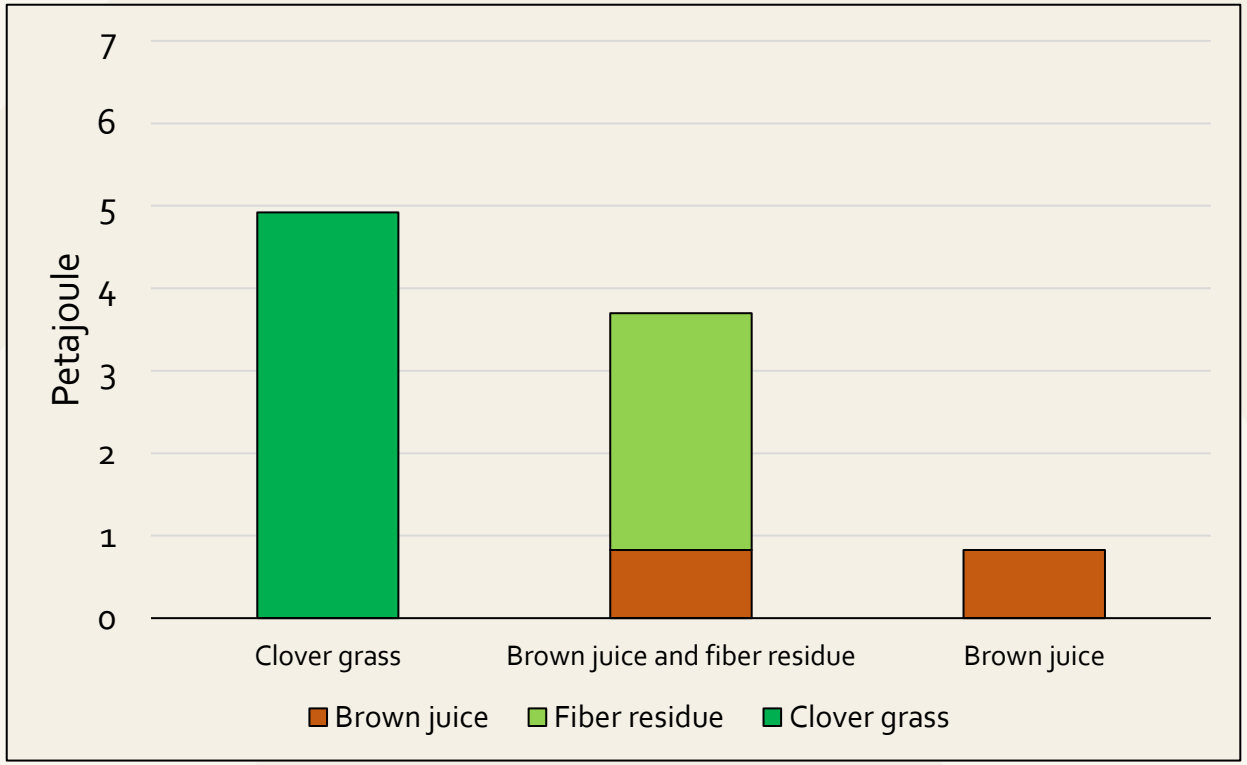
There is a political goal of doubling the ecological area. Biogas plants can support this by recirculating nutrients from food waste and residual products from agriculture.

Seges Innovation has estimated that an increase in the ecological area by 300,000 ha will require 60,000 ha of clover grass, which collects nitrogen from the atmosphere. [23] If there is no market for clover grass for fodder, the biogas plants can use it for energy and fertilizer. If it is digested in biogas plants rather than being ploughed down directly, the risk of both nitrogen and greenhouse gas emissions is reduced.

1.4 million tonnes of clover grass silage from 60,000 ha can yield just under 5 PJ of biogas. An expansion with biorefineries is expected in the coming years, which can extract the protein for feed and food. This will produce large amounts of residual products used for fodder or biogas. If the fibre fraction is used as cattle feed, there will be approximately a biogas potential. 0.9 PJ in the afternoon. If both the fibre fraction and the brown juice are used in a biogas plant, it gives approx. 3.8 PJ biogas.

Biogas Danmark

Biogas production at around 60,000 ha of organic clover grass



In ecology, clover grass is essential to supply crops with nitrogen. The biogas plant can advantageously digest the clover grass if it cannot be used as feed for ruminants. In the future, it can also go to biorefineries that extract the protein and the residual products, fibre and brown juice can be used for biogas and feed. Source: Seges Innovation. [23]

Effects in agriculture

Biogas and biorefining

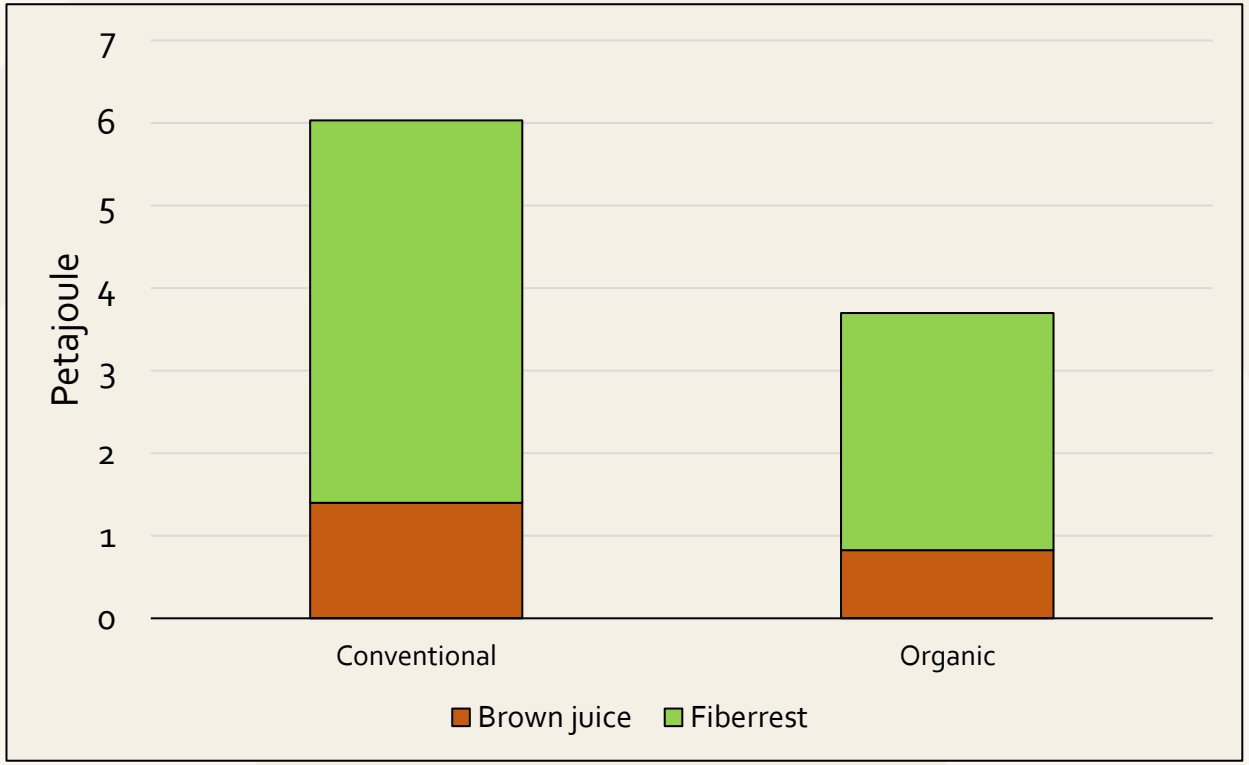
Biogas supports green biorefining.

There is a focus on replacing imports of protein through the increased establishment of biorefineries that can extract protein from green crops. In the coming years, the Ministry of Food will offer a subsidy scheme for feasibility studies and the establishment of biorefineries. Here, the focus is on the synergies between biorefining and biogas, where biogas plants can ensure the utilization of the residual products for energy and fertilizer.

Seges Innovation has assessed the biogas potential in the biorefineries' residual products, which produce 50,000 tonnes of conventional and 30,000 tonnes of organic protein. This requires 56,500 ha of organic clover grass and 74,000 ha of traditional grass, respectively.

If the brown juice and the fibre fraction go to biogas, the total biogas potential is approx. 9.7 PJ. If only the brown juice goes to biogas, the biogas potential is 2.2 PJ.

Biogas yield from biorefining at 74,000 ha of conventional clover grass and 56,500 ha of organic clover grass



Kilde: Seges Innovation. [23]

The total Danish protein import is in the order of 700,000 tonnes of protein per year. Thirty thousand tonnes of protein are imported for organic feed annually, which Danish grass protein can replace.[24]

Biogas Danmark

Economy and market

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Biogas Danmark

Economy and market

The market value of biogas delivered through the gas grid

Development in market value and subsidy costs

Russia's reduction of gas supplies to Europe has given gas prices a significant jump on the stock exchanges.

The market value of biogas has therefore increased considerably and looks set to remain high for the next few years. As gas prices rise, the subsidy is regulated down and looks set to stay low for the next few years.

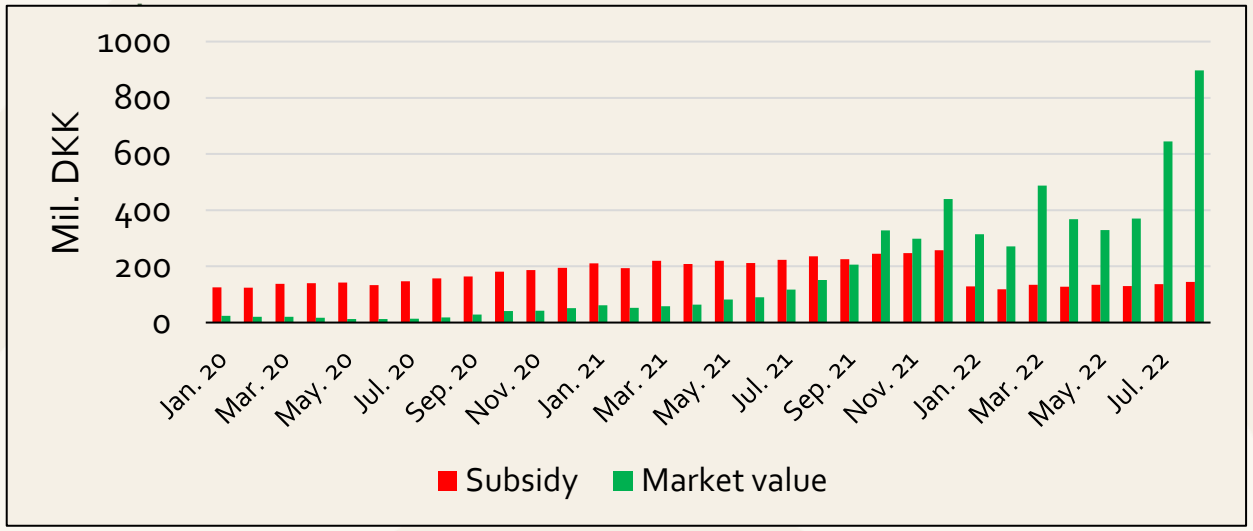
In the first eight months, Danish biogas production subsidized fossil natural gas with a market value of approx. 3.5 billion Forward prices for the second half of 2022 indicate that the market value will exceed DKK 7 billion. DKK for the whole of 2022.

As the gas would alternatively have been delivered from Russia, it is money that has not been channelled out of Denmark and the EU to Russia. Still, it has created value for the biogas producers and, not least, significant savings for the many customers who have agreements on fixed prices from the biogas producers.

The development in gas prices has meant that the market value of the natural gas that the biogas substitutes now far exceeds the state's subsidy for the biogas.

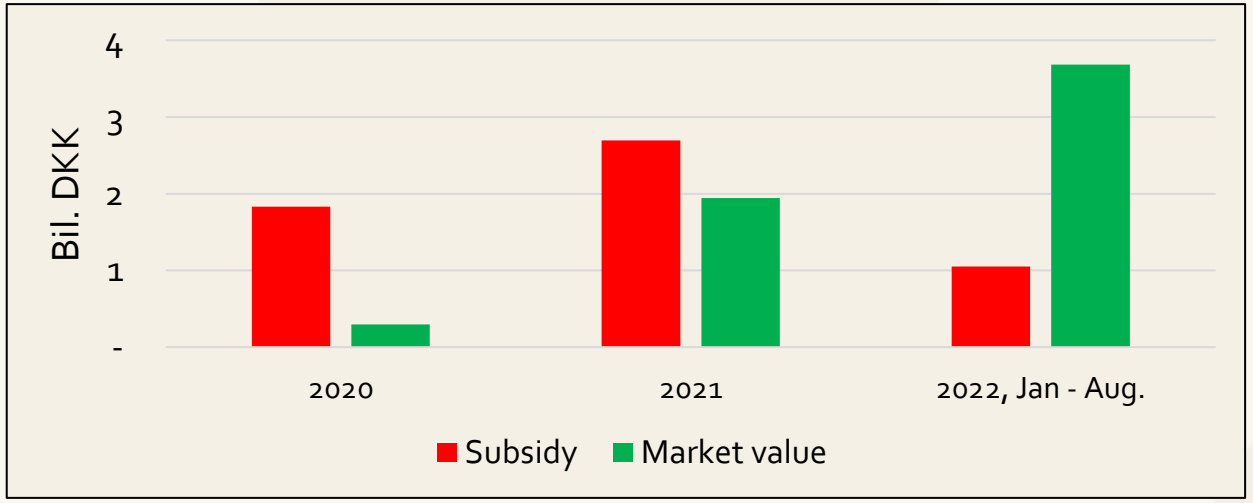
Biogas Danmark

The market value of natural gas substituted by upgraded biogas in



Since October 2021, the subsidy for biogas has been lower than the gas exchange value of the natural gas that the biogas substitutes from the gas grid. Sources: Energinet (biogas delivered to the gas grid) [9], Danish Energy Agency (subsidy) [10], and EEX Gas Market Data (market value) [11].

The market value of natural gas substituted by biogas since 2020 in Denmark



Economy and market

Guarantees of origin

Guarantees of origin document the supply of biogas through the gas grid.

The biogas producers sell biogas delivered through the gas grid to gas customers in Denmark and abroad.

The guarantees of origin are stamped with the name of the biogas plant, and the amount of biogas delivered to the grid is issued by the state-owned Energinet.

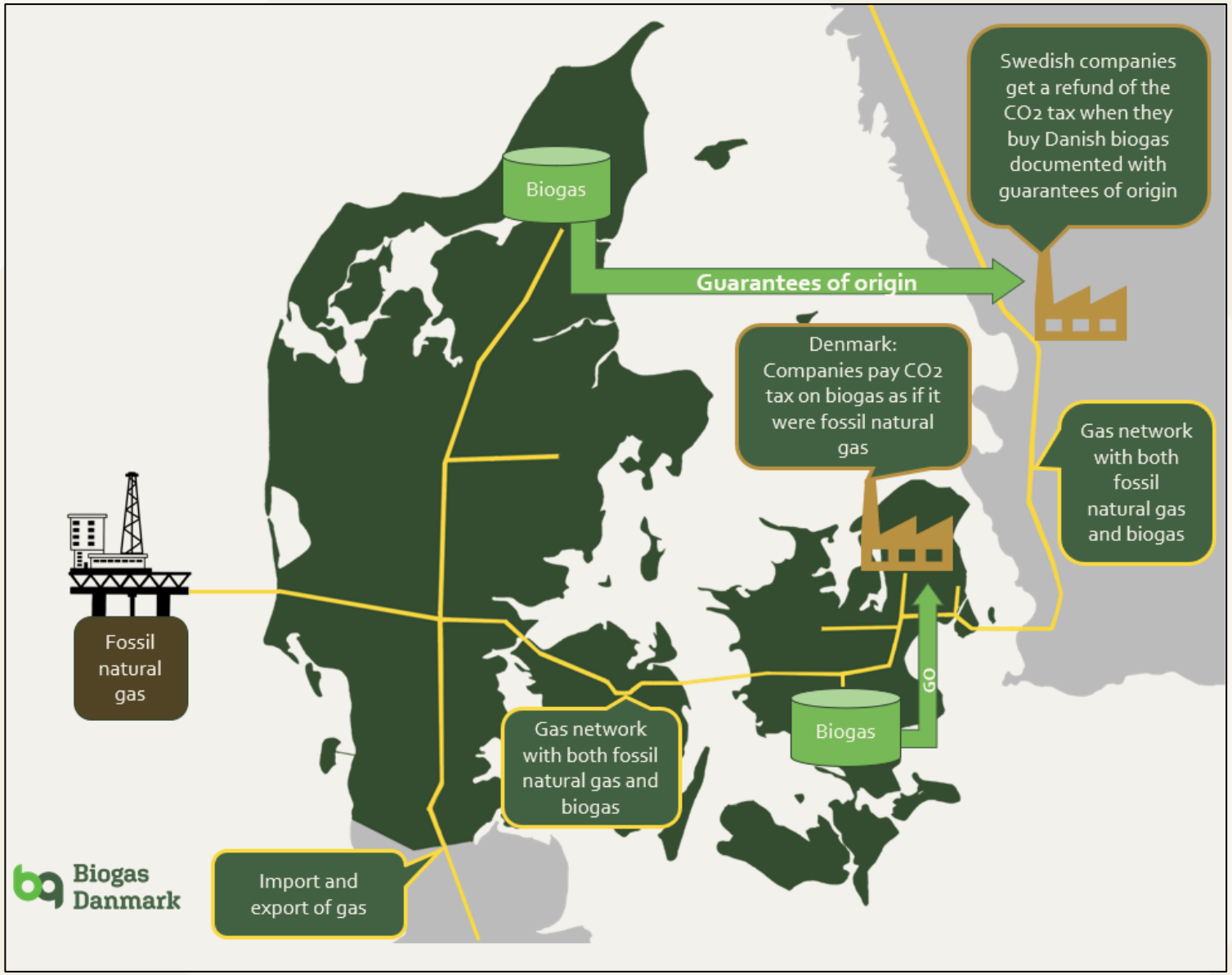
Gas customers can acquire this biogas by paying the producer for both the gas and the guarantee of origin, which Energinet must delete from their register to document that the gas has been used and cannot be sold again.

In other countries, such as Sweden and Germany, the tax authorities accept the guarantees of origin as documentation so that the buyer can obtain a CO_2 tax refund.

This is yet to be the case in Denmark.

Biogas Danmark

The flow of biogas, associated guarantees of origin, and differences in possible CO_2 tax refunds.



Economy and market

Market-driven subsidy needs

High gas prices and demand for biogas delivered through the gas grid lowers the need for subsidy

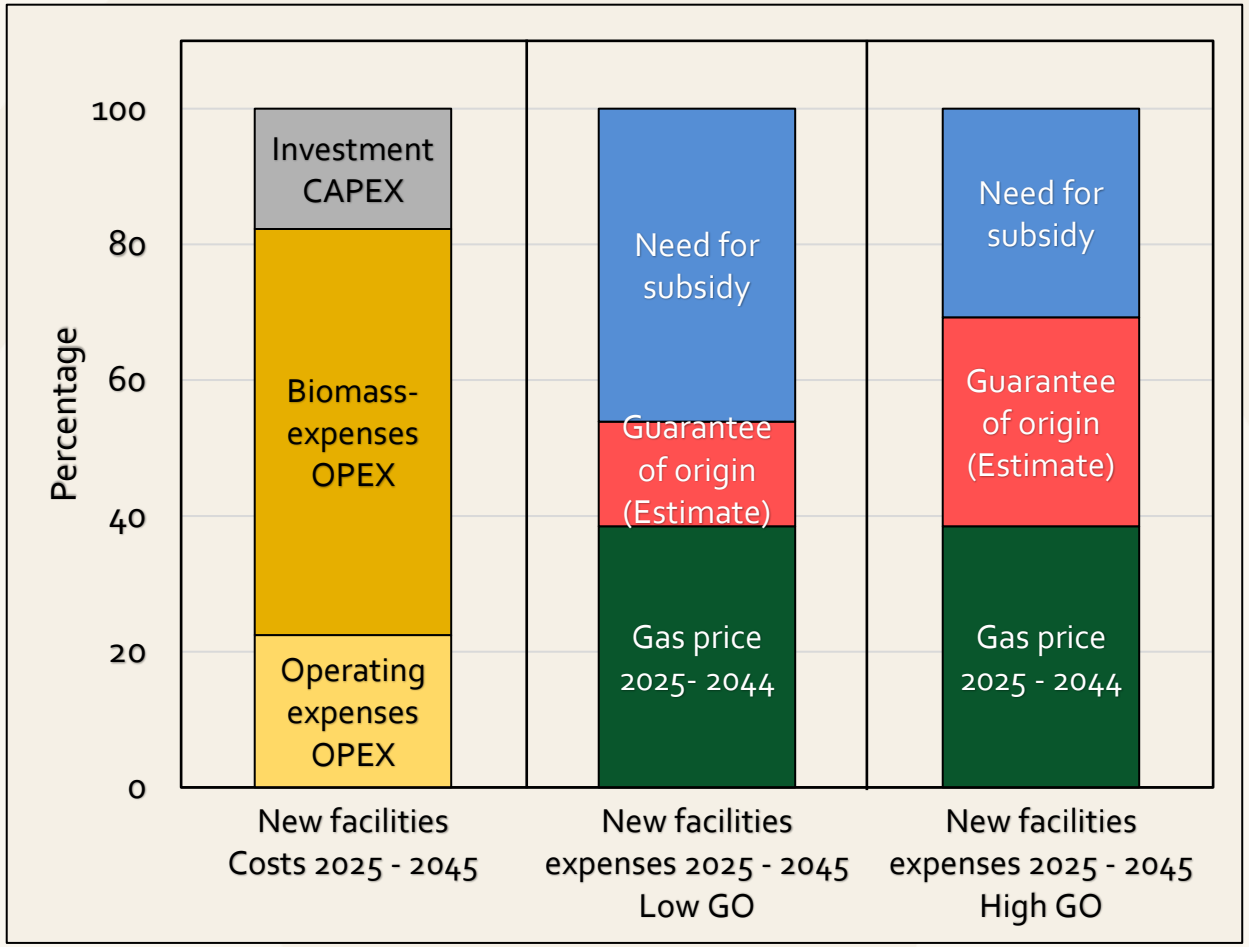
In contrast to wind power and solar cell plants, the production expenses of larger biogas plants are not dominated by investment costs but by operating costs, where the expenses for acquiring and handling biomass are dominant.

Economies of scale have already driven investment and operating costs down.

Therefore, the need for subsidy is primarily driven by market sales revenue. The natural gas prices on the stock exchange are consequently of decisive importance, and there is increasingly a willingness to pay extra for biogas delivered through the gas grid, which is documented by purchasing guarantees of origin.

The prices for guarantees of origin for unsupported biogas are so high that they can cover the production costs without subsidy due to CO_2 substitution requirements in the EU transport market.

Costs, income and subsidy for biogas plants



The figure illustrates the relationship between production costs, market income and subsidy needs for biogas delivered to the gas grid for plants with a production of 30 million cubic meters and above, with prices for guarantees of origin in 2021 and expectations for the future.[25]

Biogas Danmark

Economy and market

Export of Danish biogas

84 percent of the biogas exported in 2021

Over several years, most Danish biogas has been purchased by foreign companies, with Sweden and Germany as the dominant markets. An estimate for 2021 shows that foreign companies bought 84 percent of the biogas.[27)]

The background for the high export of Danish biogas is that Sweden and Germany, in particular, have significantly higher CO_2 substitution requirements and acceptance that biogas can be delivered through the gas grid.

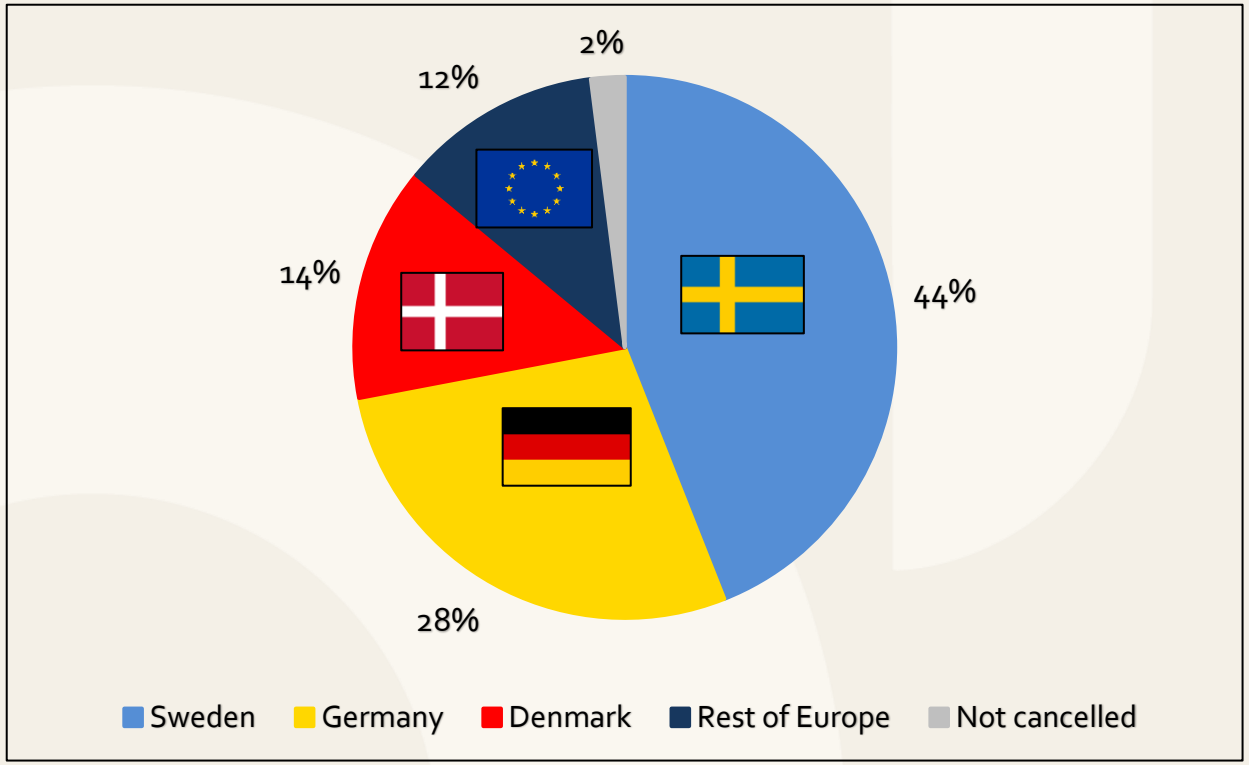
Since Denmark has not had high CO_2 taxes or the possibility of getting a tax refund for biogas delivered via the gas grid, companies in Denmark have yet to have the same incentives to choose climate-neutral biogas over fossil natural gas.

With the politically agreed green tax reform in Denmark, there is a recognition that unsubsidized biogas delivered through the gas grid and documented with guarantees of origin can obtain a tax refund, which increases the demand for unsubsidized biogas.

Suppose the full potential for unsubsidized biogas is to be utilized in Denmark. In that case, it will further require that the CO_2 substitution requirement comes on a par with Germany or that advanced biofuels are necessary.

Biogas Danmark

Export of Danish biogas in 2021



The figure shows the distribution of guarantees of origin from Danish-produced biogas in the countries where the guarantees of origin were purchased in 2021.[(26)]

The climate effect will be in Denmark.
Guarantees of origin give companies abroad the opportunity for tax refunds and to market green energy consumption. Even if the guarantees of origin and thus the biogas are exported, the climate effect of biogas production is still included in the national Danish climate accounts. The income from the sale of guarantees of origin helps to reduce the support for biogas production.

Economy and market

CO2 tax refund on biogas – Sweden and Denmark

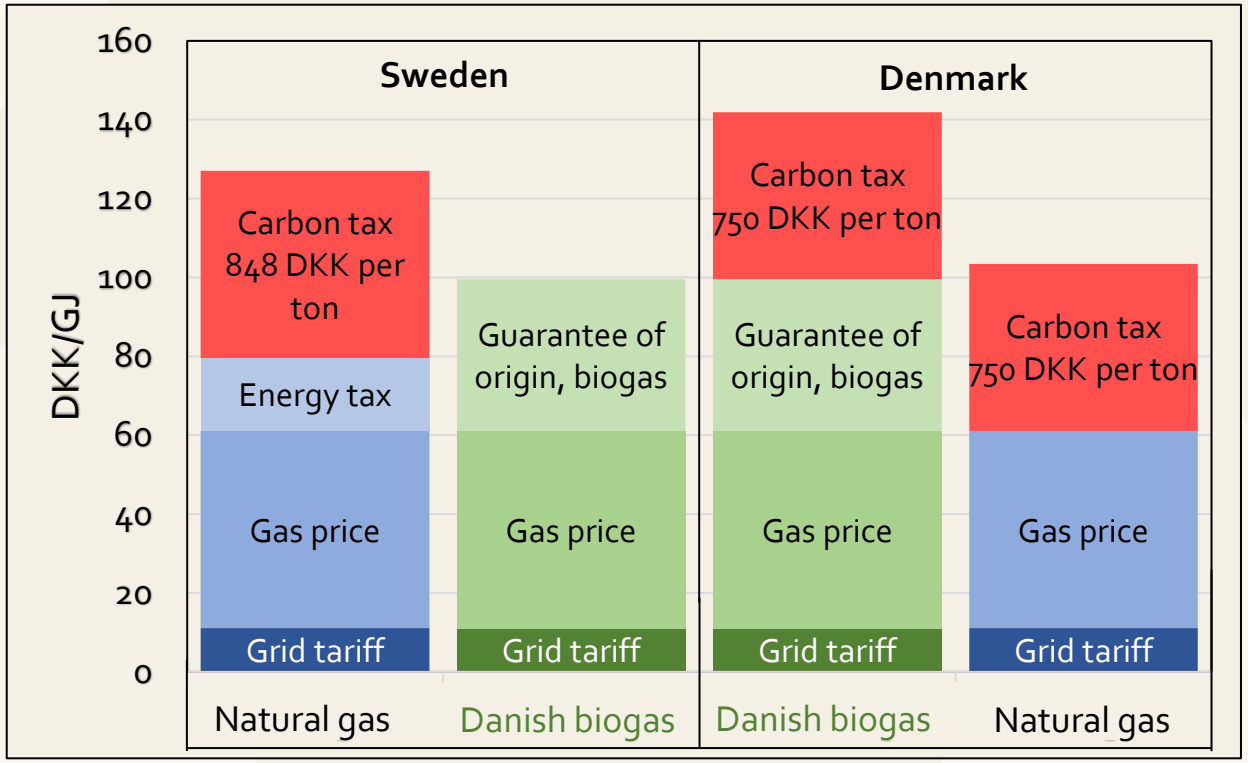
Reimbursement gives Swedish companies an advantage

There are significant differences in the tax systems in Denmark and Sweden, which is why Danish-produced biogas is primarily exported to Sweden.

Denmark has the same CO2 tax on fossil natural gas and climate-neutral biogas delivered through the national gas grid. In Sweden, the ordinary process industry pays significantly higher taxes on natural gas than the Danish companies. In return, they get a full tax refund when they buy biogas documented with guarantees of origin. This also applies to Danish-produced biogas.

The agreement on green tax reform from June 2022 agreed to analyze the possibilities of introducing a CO2 tax refund for biogas, which is purchased with guarantees of origin as documentation.

Gas costs for the non-quota covered industry 2030



This is how the tax differences will affect the opportunities to buy Danish biogas in the quota-covered industry in Sweden and Denmark, respectively, if Denmark maintains the current practice of charging CO2 tax on biogas, even though it is climate neutral.

Standard Swedish process industries have strong tax incentives to choose climate-neutral biogas over natural gas. In Denmark, the process industry has no tax incentives to choose biogas over natural gas unless there is an opportunity for a CO2 tax refund for the biogas. The figure shows the difference in expected gas costs and taxes for Danish and Swedish industrial companies outside the quota sector in 2030.

Biogas Danmark

Economy and market

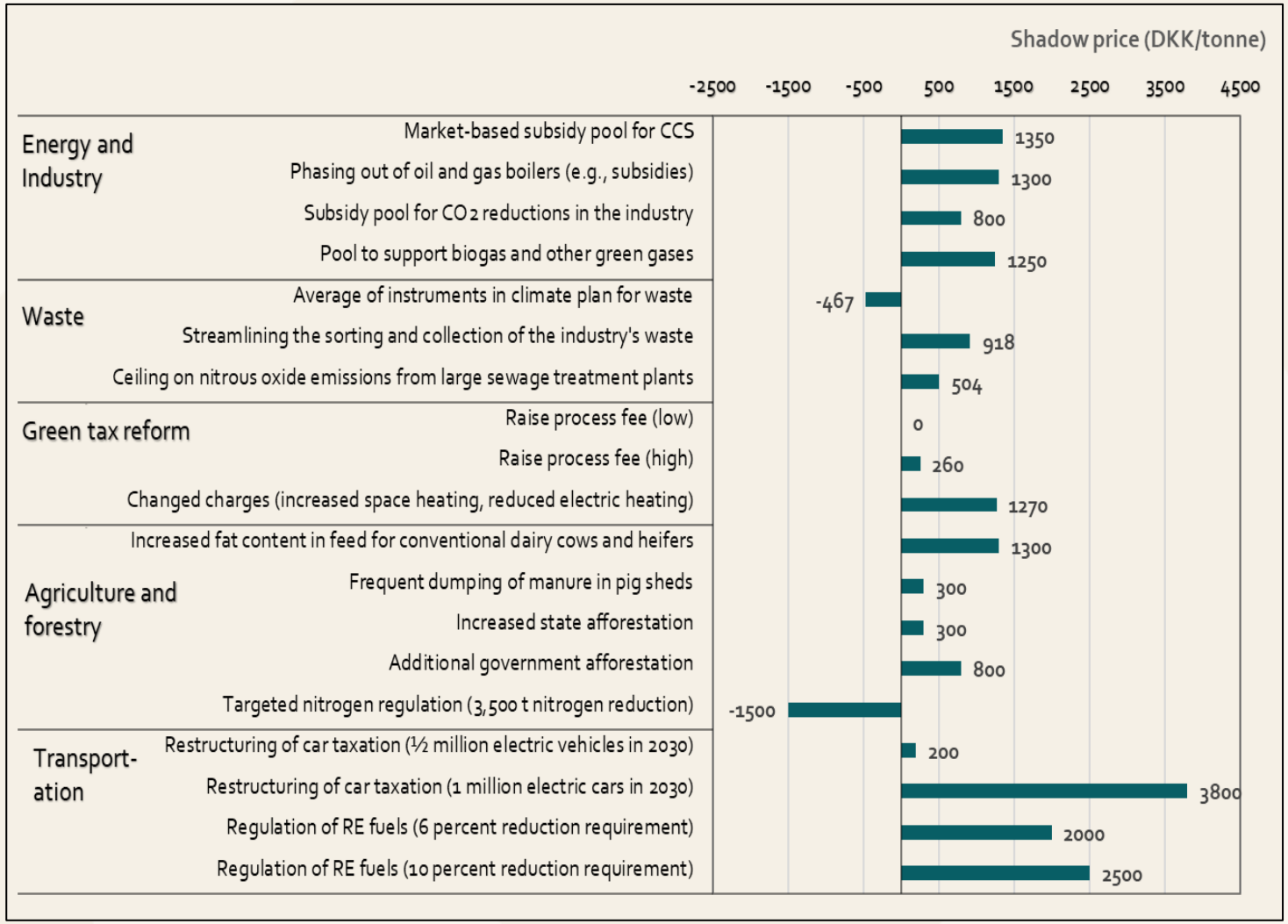
CO2 shadow cost of biogas

Low shadow cost of biogas compared to other initiatives to reach the 70 percent target.

According to the government's Climate Program 2020, the future biogas pools have a CO2 shadow cost of DKK 1,250/tonne CO2. [27]

Biogas thus has a CO2 shadow cost, which is relatively low compared to a number of the other initiatives that have been adopted so far.

CO2 shadow costs according to the Government's Climate Program 2020 [27]



Biogas Danmark

Economy and market

Employment in biogas production

Biogas production can contribute to more than 6,000 permanent jobs

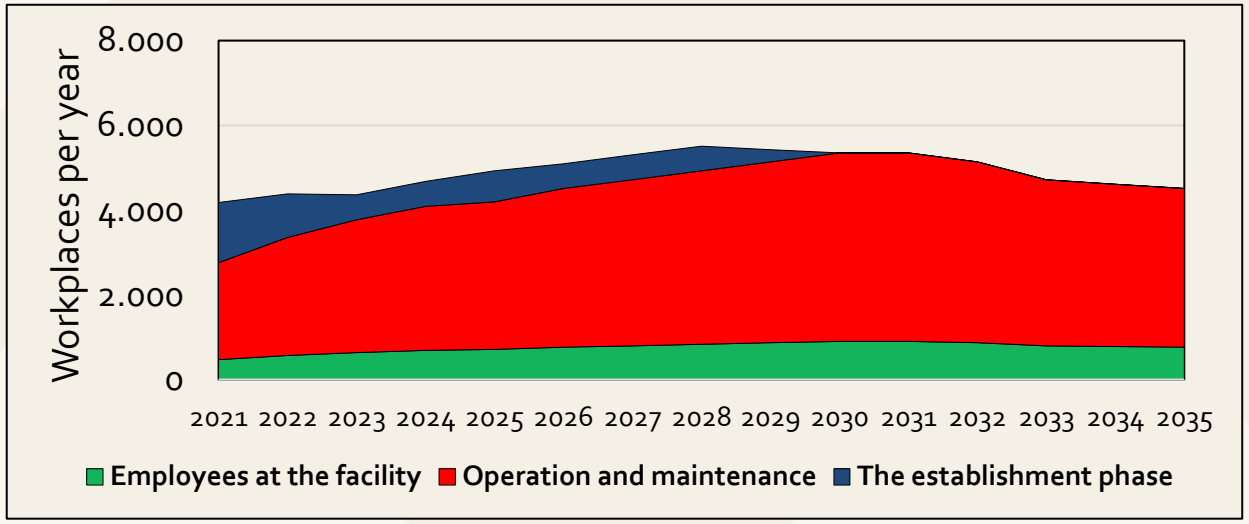
The biogas expansion creates many jobs - both in the construction phase and in many permanent jobs for the operation, service and maintenance of the biogas plants. [28]

The biogas plants can thus play a vital role in both maintaining and creating new jobs and contributing to a more balanced Denmark, as most job creation occurs in rural areas.

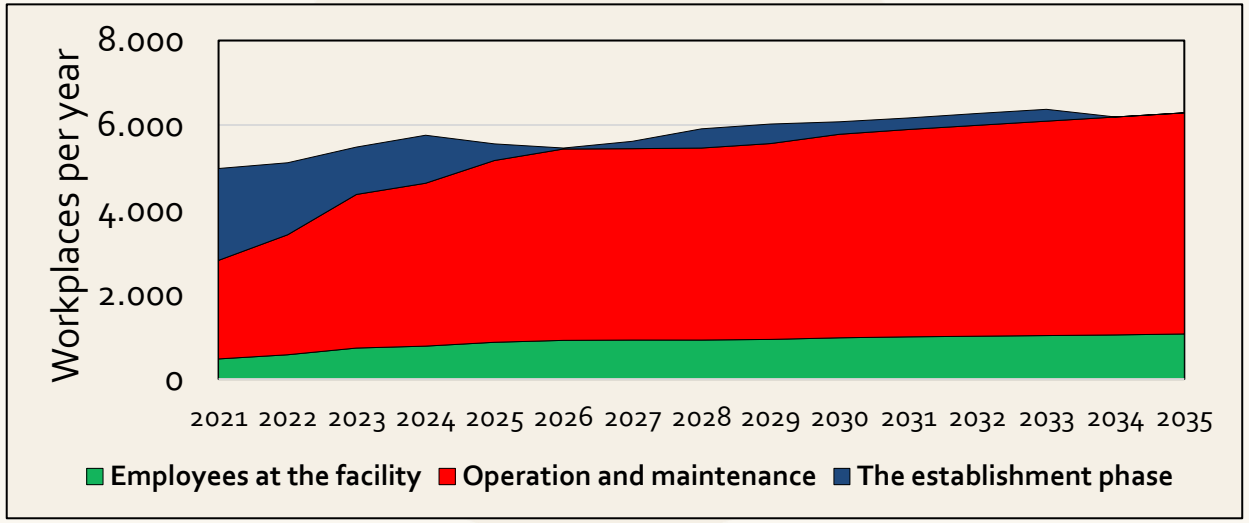
In just a few years, the Biogas Danmark scenario will contribute up to 1,000 more jobs in rural areas than the Danish Energy Agency's projection of biogas production entails.

Degassing of livestock manure and residual products from agriculture thus contributes to reducing agriculture's climate impact without affecting production, exports and employment.

Employment – Danish Energy Agency scenario



Beskæftigelse - Biogas Danmark scenario



Biogas Danmark

CCS and Power-to-X

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Biogas Danmark

CCS and Power-to-X

Biogen CO2 for CCS and Power-to-X

Potential in the use of CO2 from biogas

CO2 from biogas is referred to as biogenic CO2, as it originates in plant material that has extracted the CO2 from the air by photosynthesis and which would, in any case, be emitted again by the natural decomposition of the plant material.

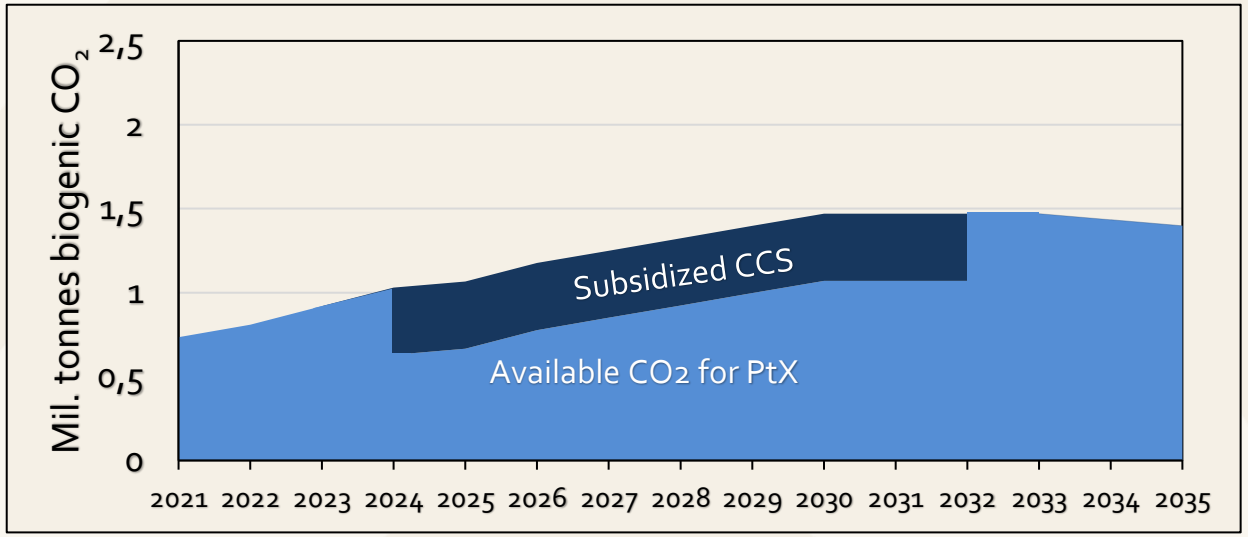
Biogas typically contains 60-65 percent methane and 35-40 percent biogenic CO2. When upgrading the biogas to the quality required in the gas grid, the CO2 is released, and there is great potential in using this CO2 for either CO2 storage (CCS), Power-to-X (PtX) or industrial use of CO2, which today is fossil-based.

While the Energy Agency scenario gives an available CO2 potential of just under 1.5 million tonnes per year, the Biogas Danmark scenario gives an available potential of over 2 million tonnes per year in 2030.

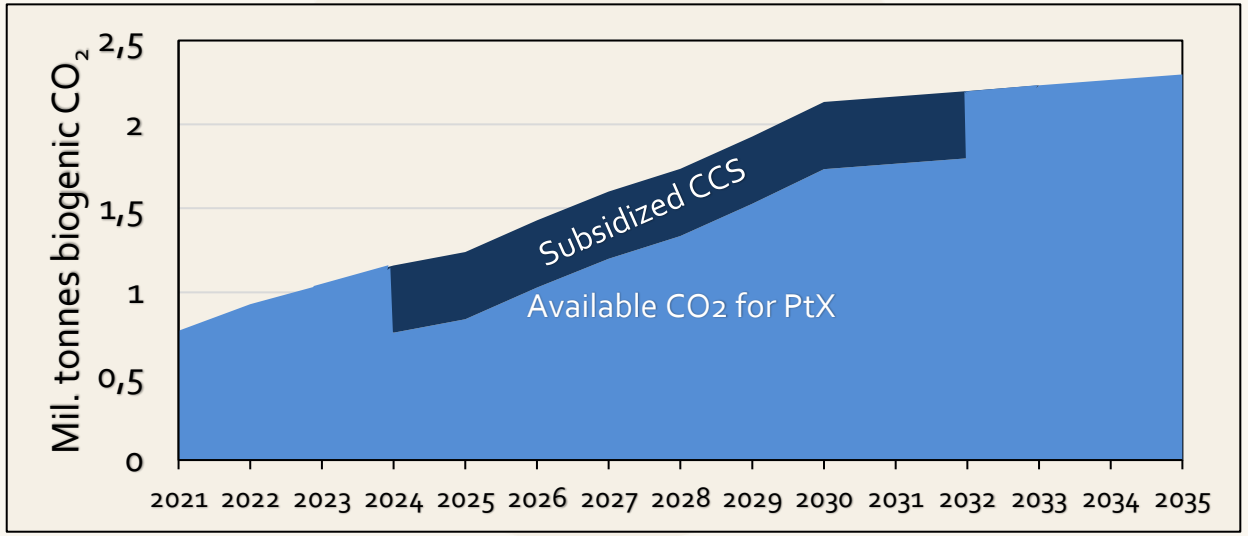
A tender scheme has been adopted which allows storing CO2 from biogas over eight years, as shown in the figure. The support scheme will allow a total of 3.2 million tonnes of biogenic CO2 to be stored.[29)]

Biogas Danmark

Available CO2 for PtX and CCS – Danish Energy Agency scenario



Available CO2 for PtX and CCS – Biogas Danmark scenario



CCS and Power-to-X

Climate effect when using CO2 for e-methane and e-methanol

CO2 from biogas can store 2 GW of electricity from solar cells and wind power in the Danish gas storages or as methanol

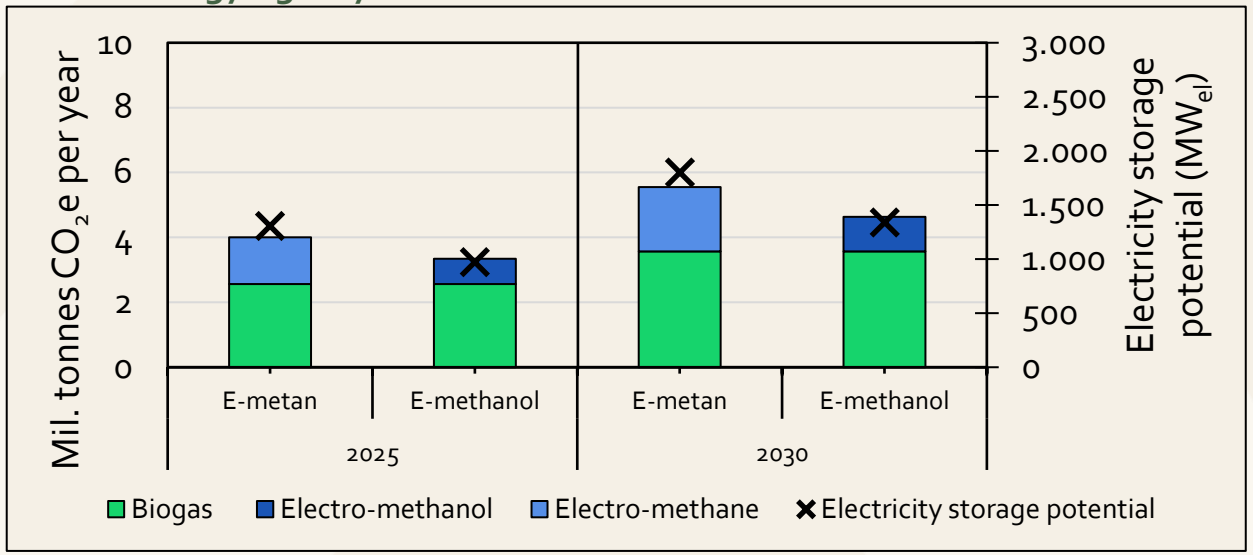
The biogenic CO2 from biogas can be used to produce Power-to-X fuels. These are created by using electricity from wind and sun to produce hydrogen by electrolysis. The hydrogen is combined with CO2, producing methane or methanol.

Calculations show that in 2030, for both scenarios, it is possible to store around 2,000 MW (2 GW) of electricity through the production of e-methane or around 1,500 MW (1.5 GW) electricity from the production of methanol every single hour all year round. Methane (CH4) provides more significant electricity storage than methanol, as more hydrogen atoms are bound per carbon atom in methane.[30]

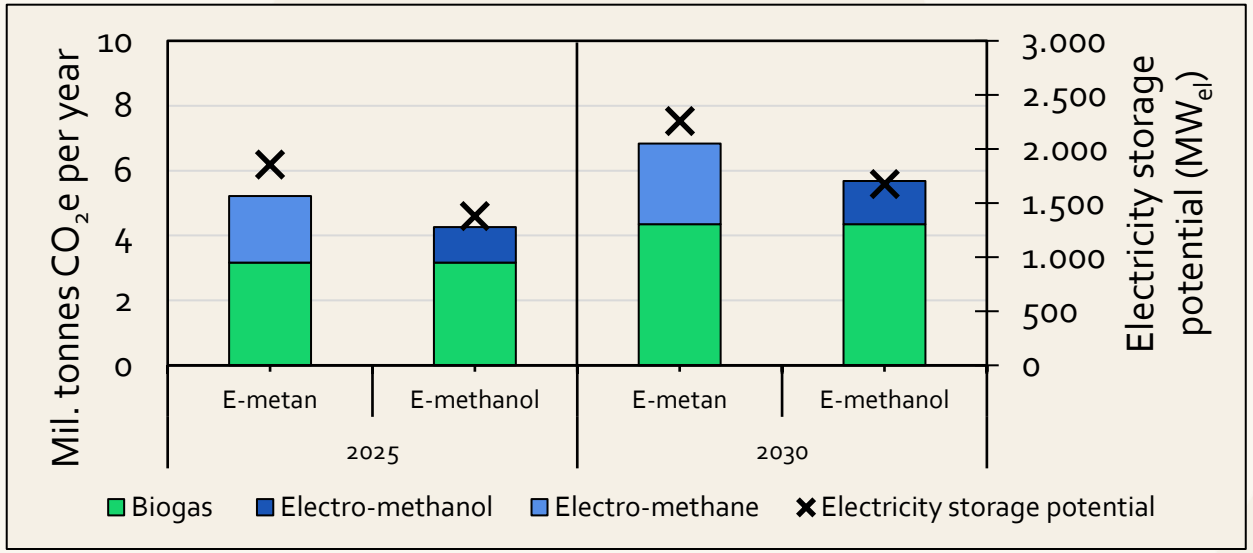
This corresponds to collecting 30 to 70 percent of the electricity capacity from an energy island during the hours when it is maximally windy. Actual capacity utilization depends on the amount of excess electricity, which is minimal at low wind speeds. Since PtX fuels are primarily used in the transport sector, it is assumed in the climate calculations that they substitute diesel.

Biogas Danmark

Greenhouse gas reduction potential in 2025 and 2030
Danish Energy Agency scenario



Greenhouse gas reduction potential in 2025 and 2030
Biogas Danmark scenario



CCS and Power-to-X

Most significant climate effect when utilizing captured CO2

The biogenic CO2 that is captured at the biogas plant's upgrading plant can be used in at least five different ways:

1. Deposit as CCS.
2. Bonding with hydrogen from renewable energy to electro-methane (e-methane) [30]
3. Bonding with hydrogen from renewable energy to electro-methanol (e-methanol) [30]
4. Replacement of industrial CO2 that is currently produced from natural gas.
5. Replacement of oil for industrial plastic production

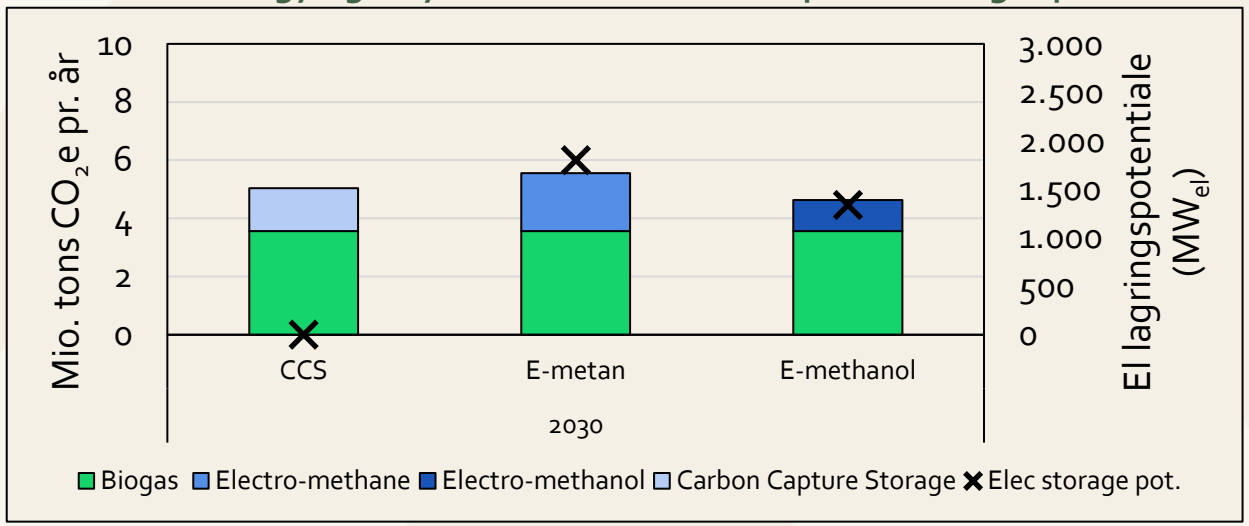
Solution 4 will be the most obvious and with the highest climate effect. It has yet to be possible to obtain data for this. In 2022, there will be significant industrial demand and high prices due to a lack of natural gas.

The figures compare CCS and two PtX solutions, their immediate climate value, and the possibility of balancing electricity from renewable energy plants.

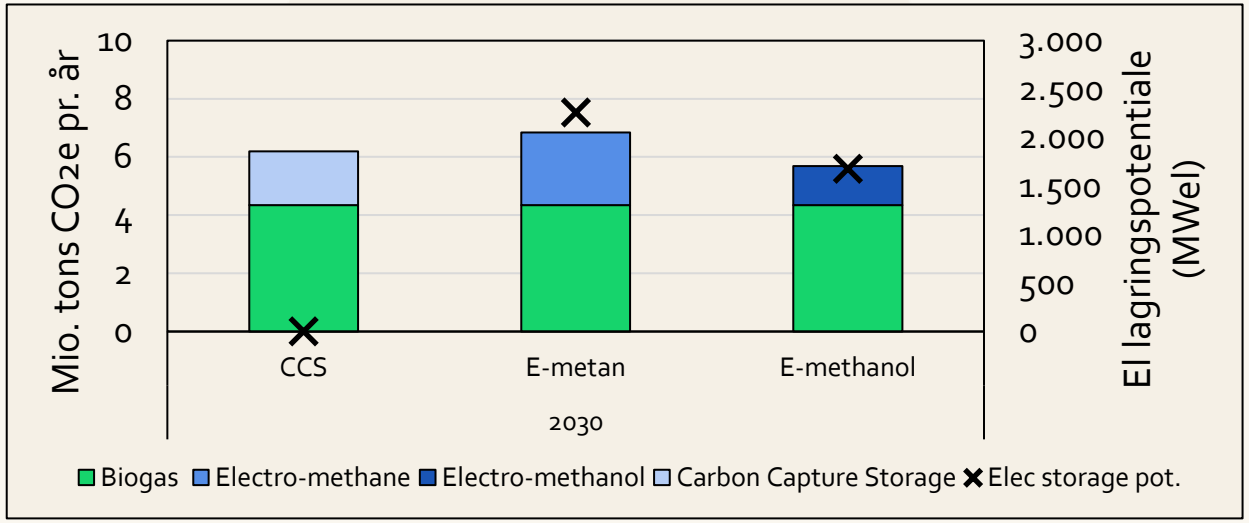
E-methane substitutes the most, but only because it can bind more energy from RE electricity.

Biogas Danmark

Greenhouse gas reduction potential in 2030
The Danish Energy Agency's scenario with CO2 capture at biogas plants



Greenhouse gas reduction potential in 2030
Biogas Danmark scenario with CO2 capture at biogas plants



This is how we have done it

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Biogas Danmark

This is how we have done it

Database and prerequisites

Biogas Outlook 2022 is based on the Danish Energy Agency's forecast for biogas production in Climate status and projection 2022 (KF22) [1]. The Danish Energy Agency indicates the development in biogas production and the quantities of manure that are digested but has no further information on which biomasses are expected to be used in biogas production. Therefore, Biogas Danmark has assumed the biomass distribution, partly based on the annual biomass reports to the Danish Energy Agency[31], and partly on the University of Southern Denmark's calculation of the biomass potential [3]. KF22 includes an expected distribution of cattle manure and pig manure.

KF22 also does not include a detailed forecast for the phasing of frequent flushing of manure from barns to biogas plants. At the same time, the Danish Energy Agency still needs to incorporate the decision of the agricultural agreement [19] that pig barns must phase frequent flushing from 2023. For the period up to 2030, Biogas Danmark has made its assumptions based on data on frequent flushing from Aarhus University.

In addition, it is assumed that the fugitive methane emissions will fall from the measured approximately 2 percent to 1 percent from 2025, based on the Climate Agreement on green electricity and heat from June 2022 [5], where it has been decided to introduce regulation of the fugitive methane emissions from 1 January 2023.

While the Energy Agency's scenario follows the biogas forecast in KF22, Biogas Danmark's scenario shows how biogas production develops by advancing the planned tender schemes and by creating framework conditions for increased sales of unsubsidized biogas to the transport sector. Based on this, Biogas Danmark has prepared assumptions for biomass distribution at a higher biogas production.

This increases biogas production and a more significant methane reduction in agriculture.

Reductions in nitrogen leaching are calculated based on research from Aarhus University [20]. Recirculation of phosphorus is calculated based on standard values from Seges. [21]

The market value of biogas is calculated on data from the Danish Energy Agency [8], EEX Gas Market Data [9] and Energinet [10]. The employment figures for both scenarios are calculated based on a study of the job effects of establishing and operating biogas plants from Damvad Analytics.

Calculations for CO_2 storage and Power-to-X are primarily based on the Danish Energy Agency's technology catalogues.[31, 30] The CO_2 content is calculated based on the distribution of CO_2 and methane in biogas.

This is how we have done it

Key figures and standard values

The tables on this page show the central values for gas yield for different biomasses [31, 32] and the values used for energy content in density, climate effects, fugitive methane emissions, projection of frequent flushing, etc.

Biomass	Dry matter [%]	Volatile soil (VS) [%]	Gas yield Nm3 CH4/ kg VS	Gas yield Nm3 CH4/ tonne biomass
Cattle manure	8	6	0,25	15
Pig manure	5	4	0,35	15
Deep Litter	30	24	0,27	65
Energy Crops	31	29	0,33	96
Crop residues	30	29	0,32	92
Straw	84	80	0,29	228
Industrial residues	22	20	0,45	90
Food waste	23	20	0,43	84

Explanation		Unit
Calorific value and density		
Methane Lower calorific value	35,9	MJ/Nm^3
Natural gas Lower calorific value	39,6	MJ/Nm^3
Density, methane	0,72	kg/Nm^3
Density, Carbon dioxide	1,98	kg/Nm^3
CO_2e emissions		
CO2 emission, natural gas	55,5	kg CO_2/GJ
CO2 emission, diesel	74,1	kg CO_2/GJ
CO2 emission, diesel RED II	94	kg CO_2/GJ
CO2 emission, electricity production	Energinet projection	
Auxiliary consumption		
Pretreatment and biogas production	36	kWh/tonne biomass
Upgrading	0,6	kWh/Nm_3 CH_4
CO2, transport of biomass	1.080	tonnes CO_2 / PJ biogas
Upstream emission, natural gas	3.600	tonnes CO_2 / PJ biogas
Fugitive methane emission	2,1 → 1	%
Projection of frequent flushing	7	%, new stable
	9	%, old stable
PtX		
CH4/CO2 ration in biogas	60 / 40	%
PtX, elektromethane	35	%, Efficiency
PtX, methanol	48	%, Efficiency

Biogas Danmark

References

Note no.	Subject	Reference
1	Climate status and projection 2022	Klimastatus og -fremskrivning 2022
2	Climate status and -projection 2022 (KF22): Biogas production	Klimastatus og -fremskrivning 2022 (KF22): Biogasproduktion
3	Danish energy crop analysis	Energiafgrødeanalysen
4	Climate agreement for energy and industry etc. 2020	Klimaaftale for energi og industri mv. 2020
5	Climate agreement on green electricity and heat 2022	Klimaaftale om grøn strøm og varme 2022
6	Fugitive methane emissions at Danish biogas plants 2021	Metantab på danske biogasanlæg 2021
7	Energinet, CO_2 in the electricity grid	Energinet, CO_2 i elnettet
8	Energinet, CO_2 in the electricity grid	Energinet, CO_2 i elnettet
9	Energinet, CO_2 in the gas grid, note	
10	The Danish Energy Agency, Subsidy rates 2022	Energistyrelsen, Støttesatser 2022
11	Spot market data	Spot market data
12	Green Power Denmark	Green Power Denmark
13	Subsidy scheme 2012	Støtteordning 2012
14	List of biogas plants in Denmark, 2021	Liste over biogasanlæg i Danmark, 2021
15	Energinet, Environmental report 2021	Energinet, Miljøredegørelse 2021
16	LCA Biogas and pyrolysis	LCA Biogas og pyrolyse
17	Effects of regular and frequent flushing	Effekter af normal og hyppig udslusning
18	Seges Gris, note	
19	Agreement on the green transformation of Danish agriculture	Aftale om grøn omstilling af dansk landbrug
20	Climate and environmental effects + nitrogen leaching	Klima og miljøeffekter + kvælstofudvaskning

Biogas Danmark

References

Note no.	Subject	Reference
21	Phosphorus regulation	Fosforregulering
22	Phosphorus in Danish agriculture	Fosfor i dansk landbrug
23	Seges Innovation, notates	
24	Aarhus University on protein	Aarhus Universitet om protein
25	Production prices and auxiliary consumption	Produktionspriser og eget forbrug
26	Energinet regarding guarantees of origin	Energinet vedr. oprindelsesgarantier
27	Climate program 2020	Klimaprogram 2020
28	Employment effects	Beskæftigelseseffekter
29	Agreement for CO_2 capture	Aftale for CO_2-fangst
30	Technology catalog, renewable fuels	Teknologikatalog, fornybare brændstoffer
31	BiB analysis, 2021	BiB-analyse, 2021
32	Article on gas yield from biomass	Artikel om gasudbytte af biomasser

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E: biogas@biogas.dk

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Fremtiden er cirkulær