Biogas Outlook 2024

Production and use of biogas in Denmark 2023-2045

Biogas Danmark

Preface

Biogas Outlook 2024 focuses on the effects of biogas production and use towards 2045 under three different scenarios

Biogas Outlook 2024 provides comprehensive insight into the development of biogas production and use based on available bioresources, including the potential of utilizing captured CO_2 from biogas for CO_2 storage (CCS) and Power-to-X (CCU).

Biogas Outlook is designed as a reference tool for finding critical facts about biogas. The publication provides a variety of data and factual information on the derived effects of biogas on climate, agriculture, nutrient recycling, aquatic environment, economy, market, and developments within the EU.

Biogas Outlook 2024 will be available in Danish and English under our website's "*fakta*" section. This site also provides access to Biogas Data Online, a platform containing historical and current data, as well as forecasts for biogas production, gas consumption, gas storage status, and the market value of biogas, among other things.

Biogas Outlook 2024 highlights how 2023 became a record-breaking year for biogas, as it covered 45 percent of the total gas consumption, including the biogas directly supplied from biogas plants to customers. Although bio-resources exist for more than doubling the biogas production, the development of biogas production stagnated in 2023 with limited opportunities for delivering more biogas to the gas grid in the future. This is due to declining conditions that will increase biogas producers' costs and simultaneously limit their earnings potential – unless the conditions change significantly. Currently, the development of biogas depends 100 percent on the market conditions in the export market, as the market conditions in Denmark are challenging.

This situation is reflected in the three scenarios presented in this edition of Biogas Outlook:

The Energy Agency scenario starts with the Agency's expectations for gas consumption and biogas production.

The Frozen Policy scenario adjusts the Energy Agency scenario with several new conditions that the Energy Agency has not included in the analysis assumptions in AF23 and the climate projection in KF24.

The Green Policy scenario builds on the Frozen Policy scenario, supplemented with Biogas Danmark's policy proposal to ensure market conditions for increased production and use of unsubsidized biogas in Denmark.

Best regards!

Henrik Høegh
Chairman

Frank Rosager
CEO

Biogas Danmark

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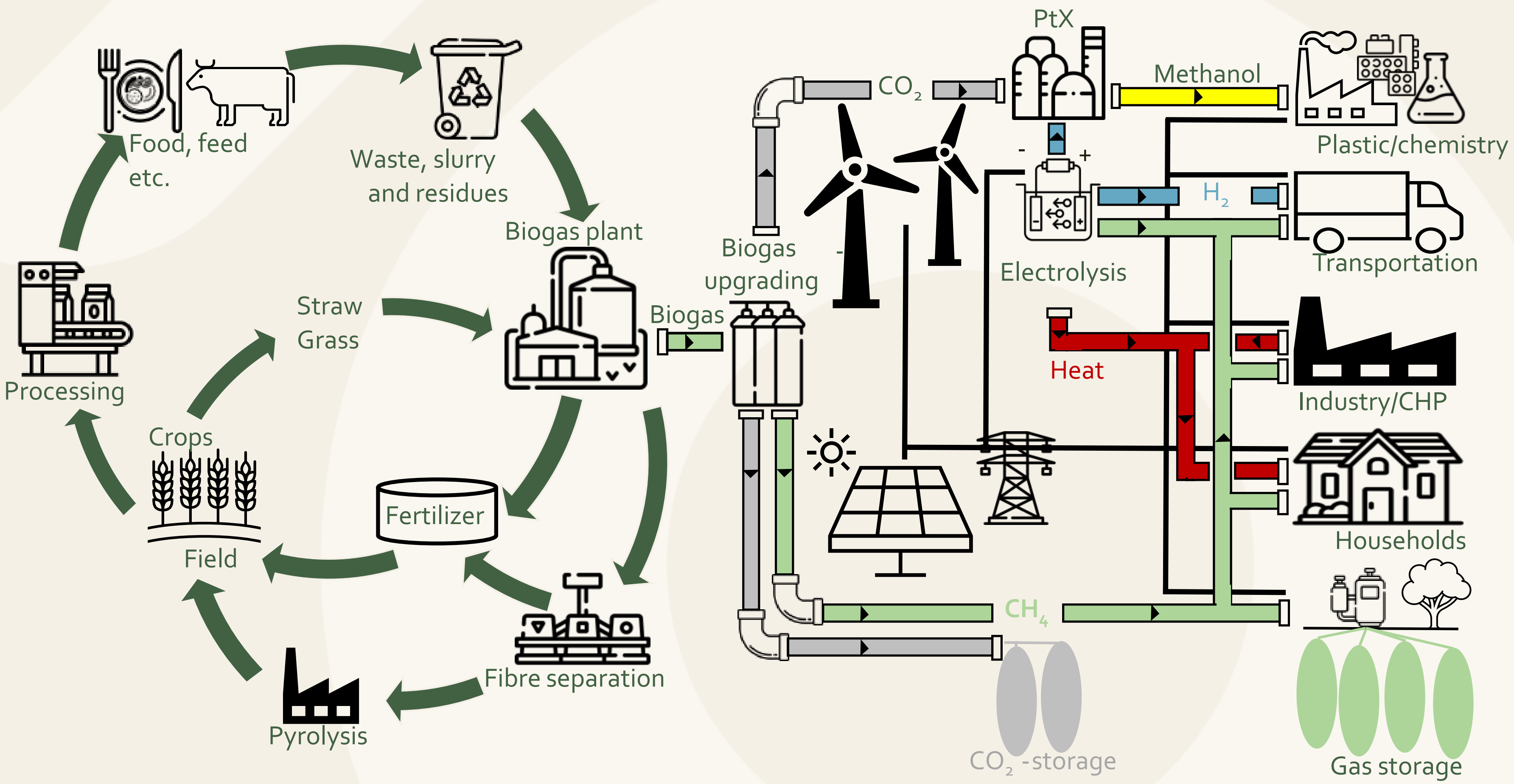
Biogas represents circular economy and sector integration

The Danish biogas plants are crucial in handling livestock manure and residues from households, industry and agriculture.
The biogas plants ensure that nutrients in waste and residues are recycled and reused as fertilizers in agriculture.

At the same time, the energy content in the biomasses is utilized to produce biogas, which substitutes for fossil fuels.

Before injecting the biomethane into the gas grid, the biogenic CO_2 is separated. The sector is actively developing the use of this CO_2 to produce Powerto-X fuels and CO_2 storage.



The Danish biogas sector is a strong example of circular economy in practice.

In the process of upgrading raw biogas, not only biomethane is produced, but also biogenic CO_2, which can efficiently store electricity in Power-to-X fuels.

Resumé

Three scenarios - Energy Agency, Frozen Policy and Green Policy

Key assumptions and main lines for the three scenarios

Common assumptions for the three scenarios

All three scenarios use the gas consumption in the Energy Agency's analysis assumptions AF22.[1] This is due to the recognition that AF23 is inaccurate following the chaotic development in 2022.

Energy Agency Scenario (AF22)

The Energy Agency scenario is based on AF23, which is the Energy Agency's forecast for the development of biogas production.

The Energy Agency scenario is based on AF23, which is the Energy Agency's forecast for the development of biogas production. The Energy Agency scenario involves a progression in biogas production based on the Energy Agency's predictions for both the existing subsidy scheme and the planned biogas subsidy tenders up to 2030.[1]

Since the Energy Agency's forecasts only include a detailed use of livestock manure [2], Biogas Danmark has assessed the use of the other available bioresources. Primarily, this is based on data from the latest biomass reports [3]

Biogas Danmark has conducted impact analyses of climate and environmental conditions, as well as potentials for CO_2 storage, Power-to-X, and pyrolysis, among other things, for the Energy Agency scenario. These are based on documented unit data from universities and similar institutions.

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Frozen Policy scenario

This scenario is Biogas Danmark's reevaluation of the Energy Agency scenario based on several new framework conditions that the Energy Agency has not considered.

This includes the combination of subsidy reduction for overcompensation, feed-in tariffs from Evida, lack of sales opportunities for origin guarantees in the new biogas tenders, an increased CO_2 e-tax on biogas in the gas grid, and a ban on using maize silage starting from 2025.

As a result, the existing subsidy scheme is projected to peak in 2024, with a total production of 26.2 PJ. However, due to the previously mentioned factors, production is expected to drop to 23.6 PJ in 2025 and 2026 before recovering to 26.2 PJ from 2027 onwards.

Even with full utilization of the maximum support ceiling in the new tender pools, the tenders will not be economically viable. As a result, the biogas production based on the tenders is expected to decrease from the anticipated 9.4 PJ to 6.5 PJ.

Green Policy scenario

This scenario is based on the Frozen Policy scenario. Still, it reflects Biogas Danmark's policy proposal to improve market conditions for unsubsidized biogas and reduce the tender scheme pools, which are further elaborated on page 9.

Comparison of the three scenarios

Page 7 shows how the three scenarios generally cover the need for gas in the future and how the Green Policy proposal can also significantly contribute to reducing greenhouse gases in the transport sector, construction industry, etc., after 2030.

Biogas Danmark believes that the realistic scenarios in the future are either the Frozen Policy or the Green Policy scenarios; these are the two scenarios described in Outlook 2024.

Page 8 illustrates the differences between these two scenarios regarding climate, environment, and other conditions.

Resumé

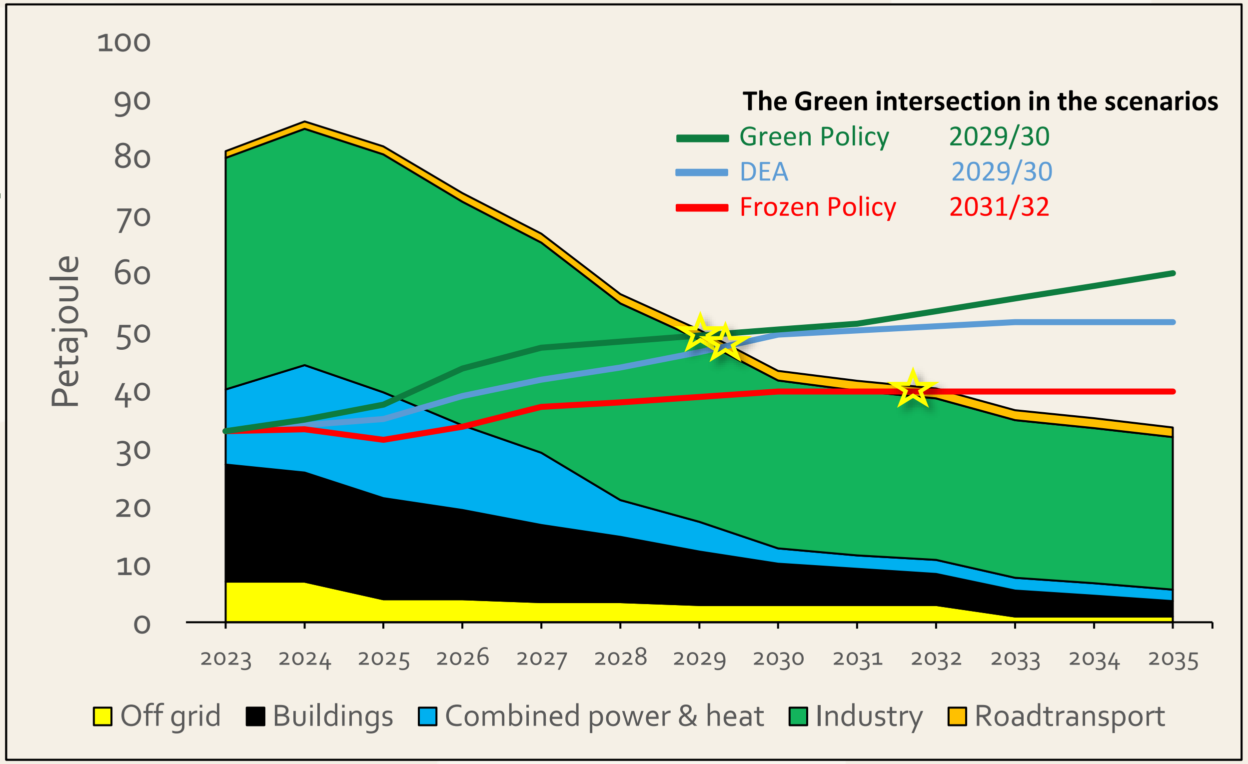
Development in biogas production and gas consumption

For the first time, biogas production is declining due to unexpectedly deteriorating framework conditions.

The Energy Agency's AF22 basis forecast in all three scenarios reveals that household gas usage will remain stable at 2.4 PJ in 2035. This forms the basis for NEKST, the national energy crisis staff, to recommend in spring 2024 that private gas consumers should purchase biogas at market conditions from 2030. Biogas Danmark recommends a CO_2 displacement requirement, following the Dutch model, to ensure this.

The projected biogas production in the Energy Agency scenario (blue line) indicates 100% coverage by 2030, a goal that Biogas Danmark finds unrealistic under the current conditions. The Frozen Policy scenario (red line) presents the consequences, showing that gas consumption will only be covered after 2032.

However, Biogas Danmark's Green Policy proposal (green line), which includes better conditions for unsubsidized biogas, can advance the point at which biogas production exceeds gas consumption in Denmark by 2029/30. Simultaneously, biogas production can significantly contribute to the fuel needs of the heavy road transport sector and later ships, aircraft, and green hydrocarbons for plastic production, for instance.



The figure illustrates the development of biogas production in the Energy Agency scenario and the Frozen Policy and Green Policy scenarios. The evolution of gas consumption is based on AF22, which is closest to the current trend in gas consumption, compared to AF23, which already showed a lower gas consumption than achieved in 2023.

Biogas Danmark

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Effects of biogas expansion

Significant climate and environmental gains from biogas expansion

The Green Policy scenario shows a significantly higher level of biogas production than the Frozen Policy, which is based on the anticipated prevailing conditions. Particularly in the Green Policy scenario, there are substantial benefits such as substituiton of fossil gas, reduction of Denmark's carbon footprint, less stress on the aquatic environment, and increased recycling of nutrients.

The Green Policy scenario assumes the same reduction in gas consumption towards 2035 as the Frozen Policy. However, it anticipates a faster growth in biogas production. From 2029/30, production exceeds the gas consumption of current gas customers, with the increased production intended for use in heavy land transport.

Simultaneously, the captured CO_2 from biogas can ensure the storage of large amounts of surplus electricity via Power-to-X. Alternatively, it can provide an additional climate effect of up to 2.2 million tons of CO_2 if this CO_2 is stored underground via Carbon Capture and Storage (CCS).

In terms of the environment, there is potential for reducing nitrogen discharge into the aquatic environment by 1,600 tons N and recycling an additional 8,000 tons of phosphorus on top of the 30,000 tons recycled with livestock manure, totaling 38,000 tons of phosphorus, a scarce and vital resource.

Effects of biogas expansion	Frozen Policy		Green Policy	
	2024	2030	2030	2035
Biogas production, PJ	**33**	**40**	**50**	**60**
Share of biogas in the gas grid, pct	33	89	100	100
Gas consumption, PJ	**86**	**44**	**50**	**60**
Of which from the gas grid	78	39	38	30
Of which outside the gas grid	7	3	3	1
Of which available for ships, plastic, etc.	1	2	9	29
PtX potential, PJ				
E-methane	18	25	32	40
E-methanol	9	13	17	21
Net climate effect (mil. tonnes of CO_2-eq)	**2,4**	**3,3**	**4,5**	**5,1**
Of which fossil substitution	2,1	2,4	3,1	3,8
Of which pyrolysis gas	0,2	0,3	0,4	0,4
Of which reduction in agriculture	0,3	0,7	1,1	1,1
Of which biochar	0,1	0,2	0,3	0,3
Of which methane emissions and own consumption	-0,4	-0,3	-0,4	-0,5
Reduction potential (mil tons of CO_2-eq)				
CCS potential	1,0	1,3	1,7	2,2
PtX e-methane potential (transport)	1,3	1,8	2,4	2,9
PtX e-methanol potential (transport)	0,7	1,0	1,3	1,6
Circular economy				
Reduced nitrogen emissions, tonnes N	750	1.200	1.525	1.575
Phosphorus content in digested biomass, tonnes P	21.825	29.375	37.625	38.100

Biogas Danmark

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Biogas Denmark's Green Policy proposal

A comprehensive package with several initiatives

In a policy proposal, Biogas Danmark suggests several initiatives [4] aimed at transitioning biogas production from subsidy-dependent to market-driven:

1. Refund CO_2 levy for biogas, verified by origin guarantees.
2. Tighten CO_2 requirements for the transport sector beyond the ETS2 quota, like Germany.
3. Enforce CO_2 displacement requirements for gas suppliers for heating, inspired by the Dutch model.
4. Implement climate footprint rules for transport infrastructure, akin to building regulations.
5. A minimum 50 percent basic deduction in CO_2 emissions for livestock manure digested in biogas facilities before the CO_2e levy is determined (corresponds to Model 2+3).
6. Stop Evida's proposal for injection tariffs and propose a green tariff model.
7. Cut biogas tender funds by half to 10 years, with potential origin guarantees reducing subsidy requirements and advancing the last tenders to expire in 2026.

Agreed tenders and Biogas Danmarks proposals for acceleration

New tenders, 2024 prices	2024	2025	2026	2027	2028	2029	2030	2031-2050	Total
Planned biogas tenders, mill. DKK	347	0	0	88	88	106	104	**0**	733
Accumulated subsidy, mill. DKK/year	347	347	347	435	523	629	733	10 556	13 927
Annual new production, PJ	**4.4**	**4.4**	**4.4**	**5.6**	**6.7**	**8.1**	**9.4**	**188**	**231**
Frozen Policy, mill. DKK/year	0	87	260	88	88	106	104	**0**	733
Accumulated subsidy, mill. DKK/year	0	87	347	435	523	629	733	11 173	13 927
Annual new production, PJ	**0.0**	**0.8**	**3.1**	**3.8**	**4.6**	**5.6**	**6.5**	**130**	**130**
Green Policy, mill. DKK/year	**0**	87	453	193	0	0	0	0	733
Accumulated subsidy, mill. DKK/year	0	87	540	733	733	733	733	3 038	6 597
Annual new production, PJ	**0.0**	**0.8**	**5.5**	**8.0**	**8.0**	**8.0**	**8.0**	**162**	**200**
Change in subsidy, mill. DKK/year	0	0	193	105	-88	-106	-104	0	0
Accumulated subsidy, mill. DKK/year	0	0	193	298	210	104	0	-8 135	-7 330
Annual new production, PJ	**0.0**	**0.0**	**2.5**	**4.2**	**3.4**	**2.5**	**1.5**	**32**	**46**

The row "Planned Biogas Tenders" shows when the subsidy is expected to be paid out for the first time from the pools according to the Energy Agency's forecast. The subsidy runs for 20 years from the year the subsidy is first paid out. "Frozen Policy" shows the revised course, as the tenders are now delayed. "Green Policy" shows how Biogas Danmark intends to consolidate and advance biogas tenders and halve the support period. Biogas Danmark's proposal would result in significantly faster growth in biogas production and a saving of DKK 7.5 billion in total subsidy in the tenders.

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RE-shares in the gas system

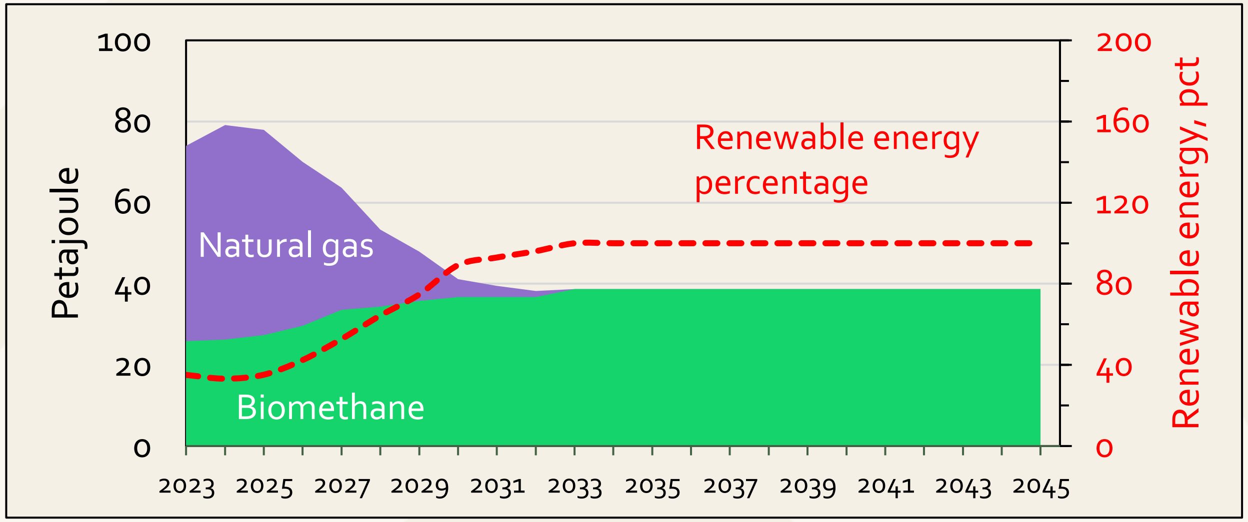
The Green Policy scenario provides 100 percent RE in the gas system from 2030.

In both scenarios, the development of gas consumption is based on the Danish Energy Agency's AF22. However, the Green Policy provides incentives for increased production and demand.

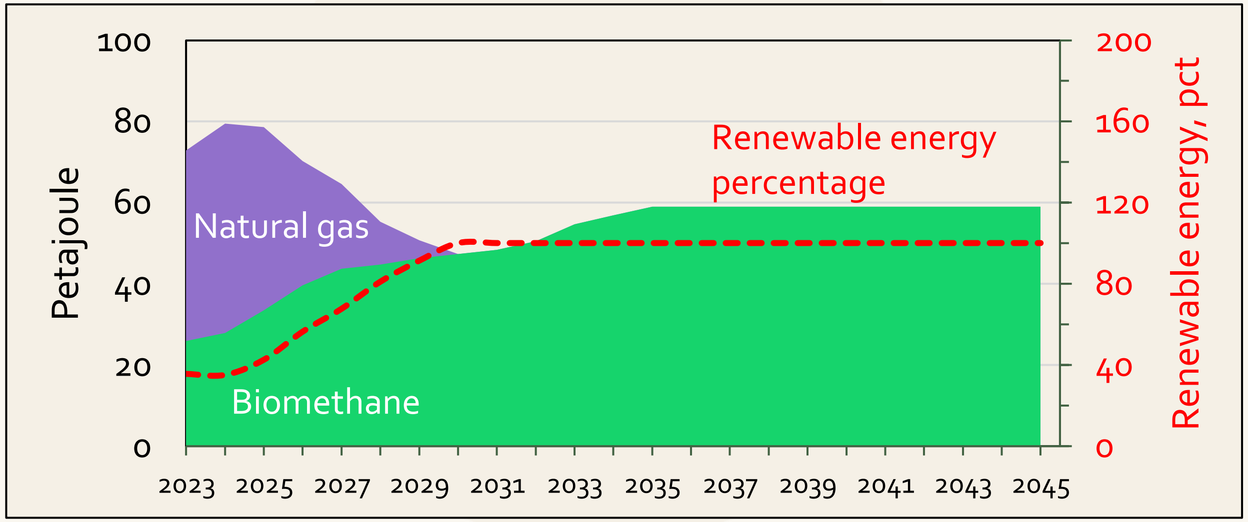
The Biogas Denmark policy proposal to increase the use of unsubsidized biogas in transportation, industry, construction, and private households results in biogas contributing significantly more than the gas consumption in the AF22 forecast. In the Frozen Policy scenario, the expected gas consumption in AF22 cannot be covered until 2033.

With the adoption of the EU's new Renewable Energy Directive III, it has been decided that renewable energy shares should follow the export of origin guarantees. This gives Denmark an interest in stimulating an increased consumption of biogas with origin guarantees, as this ensures that biogas production contributes to meeting the EU's renewable energy requirements for Denmark of approximately 60 percent by 2030.

Future gas consumption and biomethane in grid – Frozen Policy



Future gas consumption and biomethane in grid – Green Policy



Resumé

Development in biogas production and bioresource utilization

Biogas Denmark's bid on biomass utilization

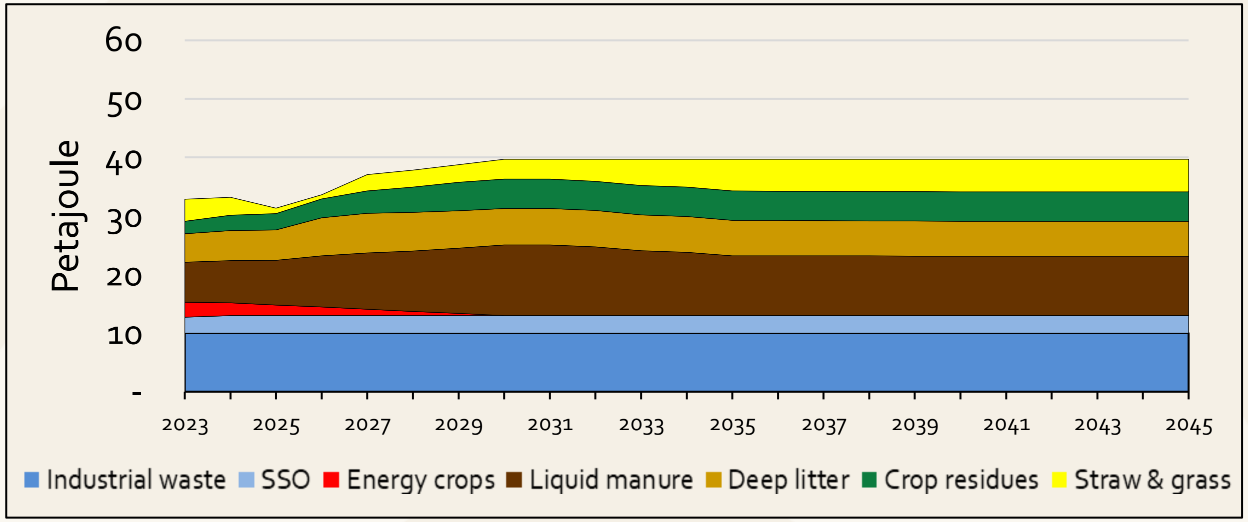
Under the current policy conditions for biogas, as outlined in the Frozen Policy scenario, Danish biogas plants are projected to produce 40 petajoules (PJ) of biogas by 2030, with the growth in biogas production plateauing after that.

Biogas Danmark, however, assumes that production will reach 60 PJ by 2035 due to a more ambitious green policy as envisioned in the Green Policy scenario.

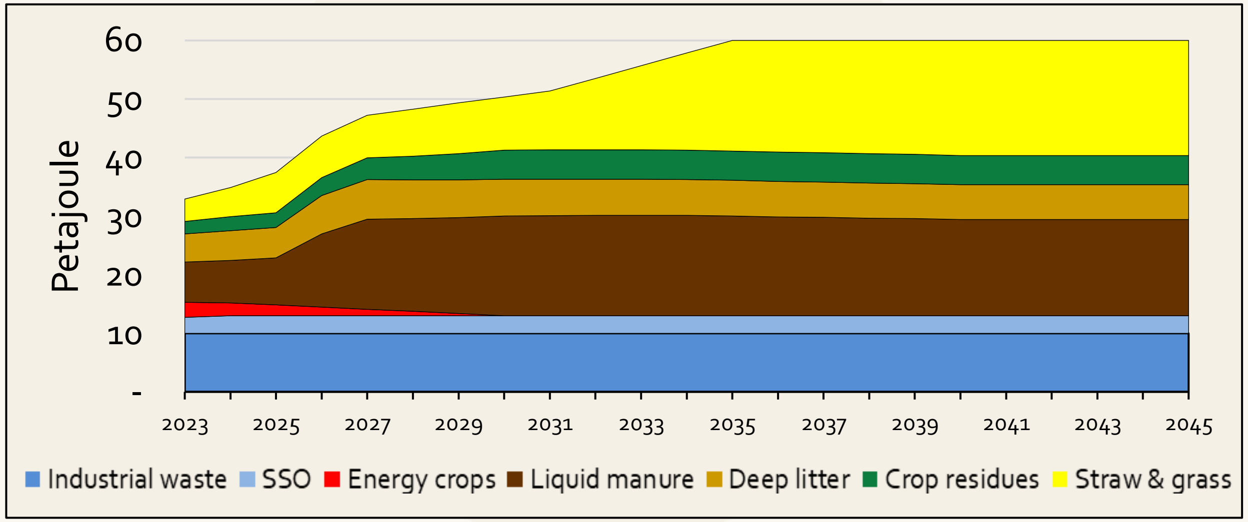
Both scenarios anticipate a rising trend in the methanation of livestock manure and the use of crop residues for biogas production. Notably, the Green Policy scenario also highlights an increased usage of straw for biogas production.

Food waste from households, the service sector, and retail (SSO) and industrial waste are expected to be fully utilized by 2025, while energy crops are expected to be phased out by 2030.

Biogas production distributed by bioresources in PJ – Frozen Policy scenario



Biogas production distributed by bioresources in PJ – Green Policy scenario



Biogas Danmark

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Future gas consumption and biogas production

Gas consumption is significantly decreasing.

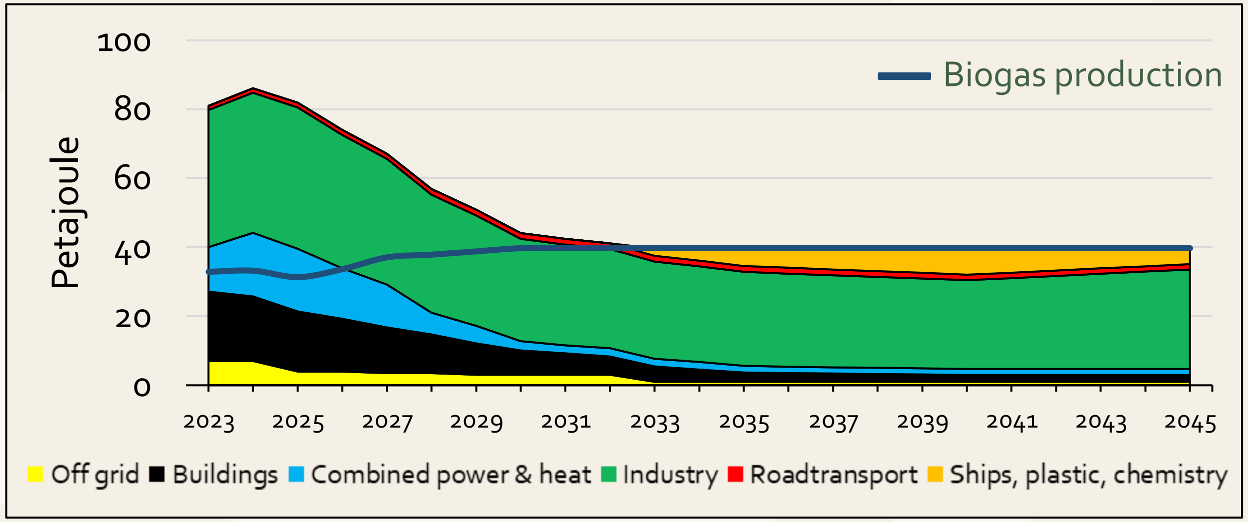
In both scenarios, the gas consumption, as projected by the Danish Energy Agency's forecast in AF22 (1), is expected to decrease by approximately 30 petajoules (PJ) by 2030 and a further 10 PJ by 2035.

The decrease in gas consumption is due to political measures, especially subsidy schemes for phasing out gas in private homes and district heating.

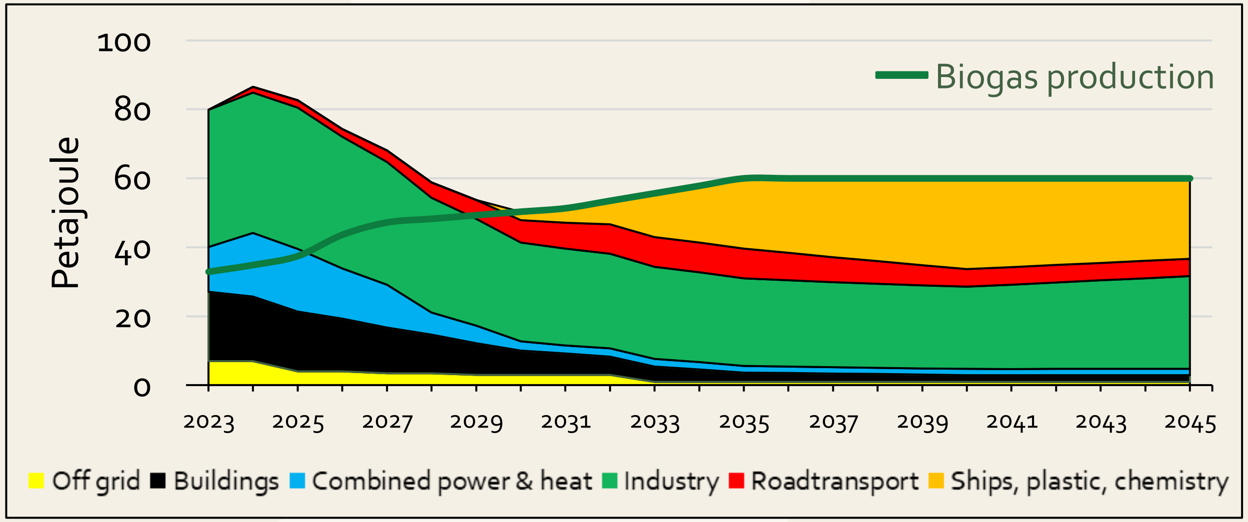
Given the upcoming worsened conditions for new biogas tender schemes and the use of biogas delivered via the gas grid, the Frozen Policy scenario shows that biogas will not cover gas consumption until at least 2033.

The Green Policy proposal involves new incentives to increase demand for unsubsidized biogas delivered through the gas grid. This is reflected in an increasing biogas production that surpasses the forecast for gas consumption in AF22 by 2030. The increased unsubsidized biogas production also reflects an increased biogas consumption - beyond the forecast in AF22. This consumption occurs in heavy goods transport and later in ships, airplanes and production of, for example, plastic, which is seen as a rise in consumption from 2030 (marked in red and orange in the lower figure).

Future gas consumption and biogas production – Frozen Policy



Future gas consumption and biogas production – Green Policy



Biogas Danmark

Resumé

Market value of biogas delivered through the gas grid

Development of market value and subsidy costs

Due to the reduced gas supply from Russia to Europe in 2022, the gas prices on the European stock exchanges increased significantly. As a result, the value of the biogas delivered to the gas grid in 2022 substituting fossil natural gas had a value of DKK 5.7 billion. When the biogas production value used off the grid is included, the value increases to almost DKK 8 billion.

The market value of biogas is volatile, but stock exchange prices remain significantly higher than before, and forward prices are expected to remain high in the coming years. Gas prices are expected to remain high for some time, and subsidies will likely stay low.

Since the delivery of natural gas from Russia has diminished, money has not been channelled out of Denmark or the EU to Russia. Instead, it has created value for biogas producers and, most importantly, for the many customers who have contracted with biogas producers for a fixed price.

The development in gas prices has led to a situation where, for a period, the exchange value of the natural gas substituted by biogas has exceeded the state's subsidy costs for biogas.[8]

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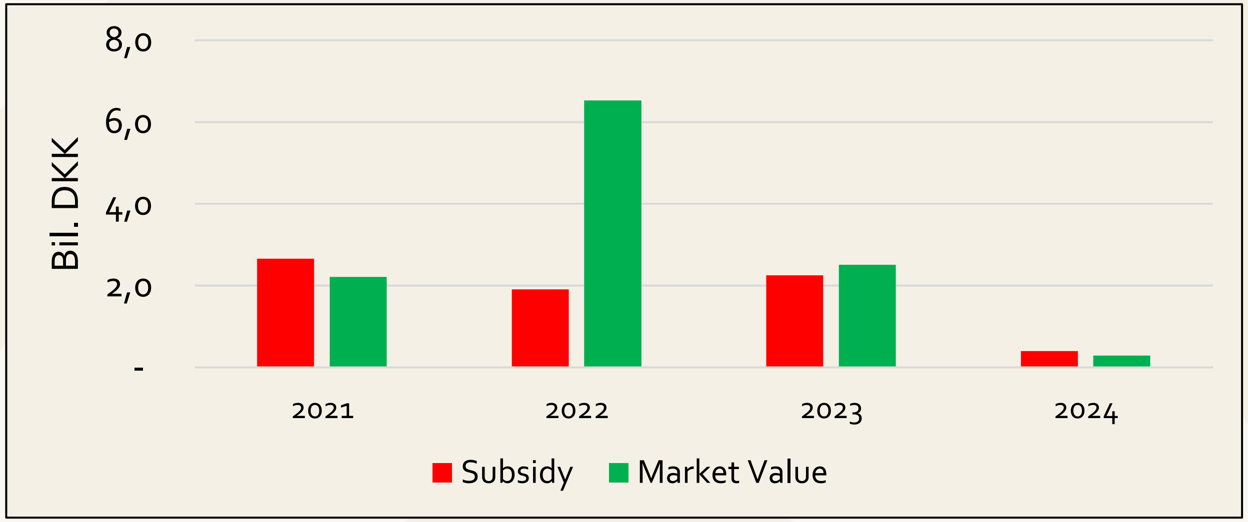
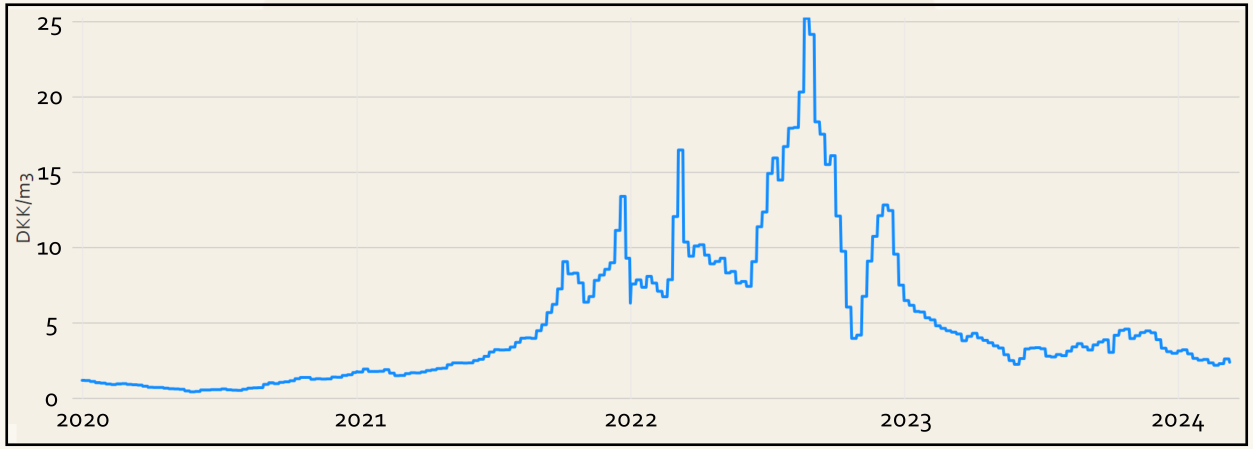
Market value of natural gas substituted by biogas in Denmark since 2021.



Subsidy for biogas compared to the market value of the natural gas that the biogas substitutes. Sources: Energinet (biogas delivered to the gas grid)[5], the Danish Energy Agency (subsidy)[6] and EEX Gas Market Data (market value)[7].

Nordic exchange (ETF) natural gas prices since 2020



Resumé

CO_2e taxes on livestock manure

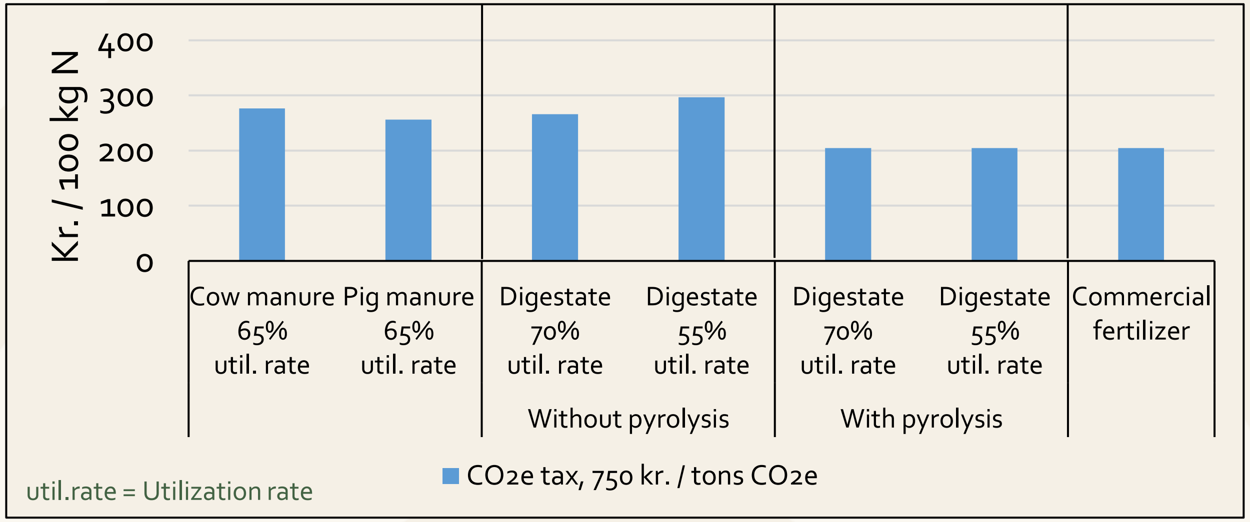
A calculating of the consequences

The government's expert committee on the green tax reform - the "Svarer" Committee - has now provided recommendations with several models for a CO_2e tax on the agricultural sector's biological emissions.[9] These models are designed to achieve the necessary reductions in greenhouse gas emissions from agriculture. Biogas Danmark has analyzed the operational and economic consequences of imposing a CO_2e tax on different types of farms.

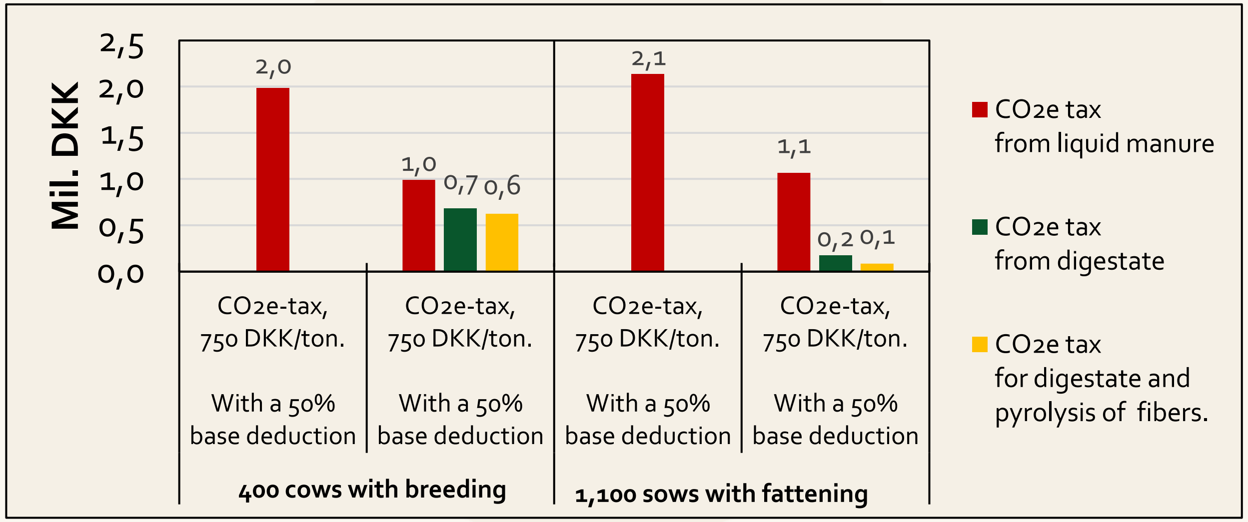
The top figure focuses on the consequences of the specific nitrous oxide tax on nitrogen fertilizer. It shows that crop farmers can significantly lower their tax burden by opting for commercial fertilizer instead of digested biomass. Separating the digested biomass and performing pyrolysis or combustion of the dry matter can balance this out.

The bottom figure presents the tax burden with a tax of 750 DKK/ton CO_2e without a basic allowance and with a 50 percent basic allowance. It can be seen digestion in biogas plants (shown in green) provides a significant tax relief compared to untreated slurry (shown in red).

Implications of nitrous oxide tax on nitrogen fertilizer



Calculation of CO_2e taxes for two model livestock farms



Biogas Denmark's calculations for two typical livestock farms encompass emissions from the stable, storage, animal digestion, and intestinal system, as well as nitrous oxide from the field.

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Gas consumption

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Gas consumption

Need for biogas storage

Temperature fluctuations and continuous biogas production require storage in large tanks.

There is a close correlation between temperature fluctuations (degree days) and annual gas consumption. The top figure shows this clear relation, particularly in winter. The temperature-independent and more constant consumption, which is attributed to industrial use, can be read from the summer consumption.

Since biogas is constantly produced throughout the year, storage is needed to align production with demand. However, the phasing out of gas for space heating gradually reduces this storage need.

The low gas uptake during the summer, combined with an increasing delivery of biogas to the gas grid, necessitates adjustments to the gas grid. This ensures the gas can be compressed from Evida's distribution network to Energinet's transmission network, where the gas storage facilities are connected.

Degree days measure how cold it has been and how much energy is used for heating. A degree day is defined as a difference of 1°C between the indoor temperature set at 17°C and the daily average outdoor temperature. For more details, visit Biogas Data Online at biogas.dk/biogas-data-online.

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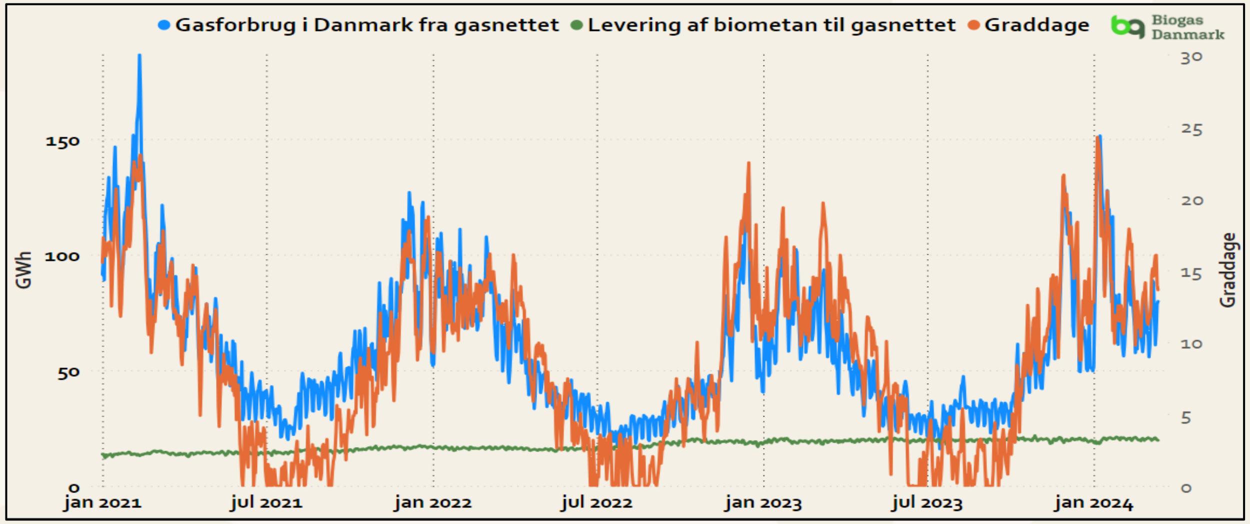
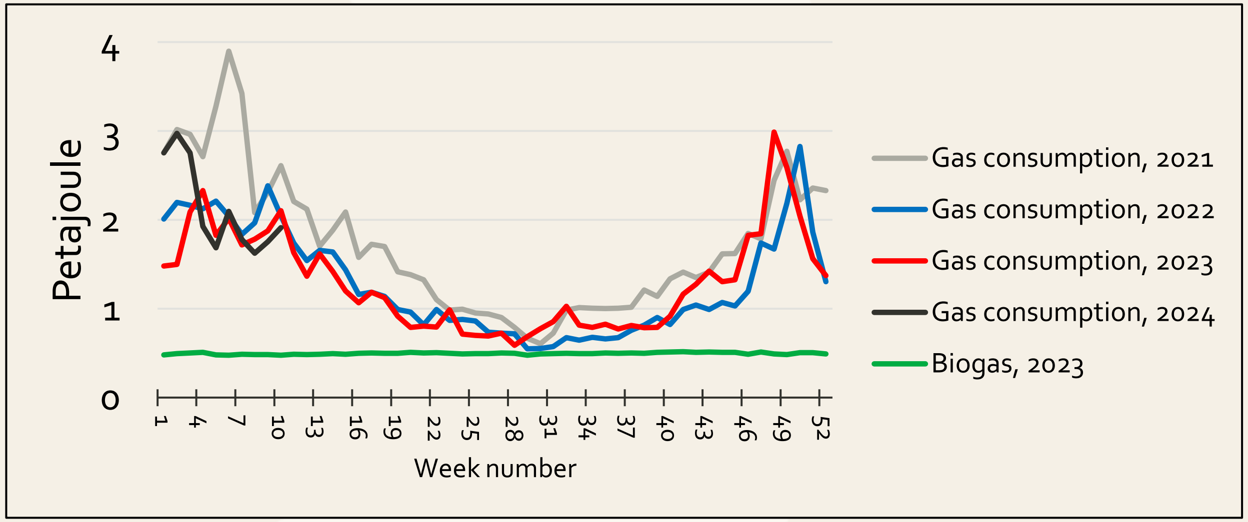
Correlation between degree days and gas consumption – jan 2022-jan 2023 (8)



Weekly gas consumption from 2021 to 2024 and biogas production in 2023



The top figure is sourced from Biogas Data Online, and the bottom figure is extracted from the Energinet data service. (5)

Gas consumption

Biogas for heavy transport

Biogas can facilitate a rapid green transition.

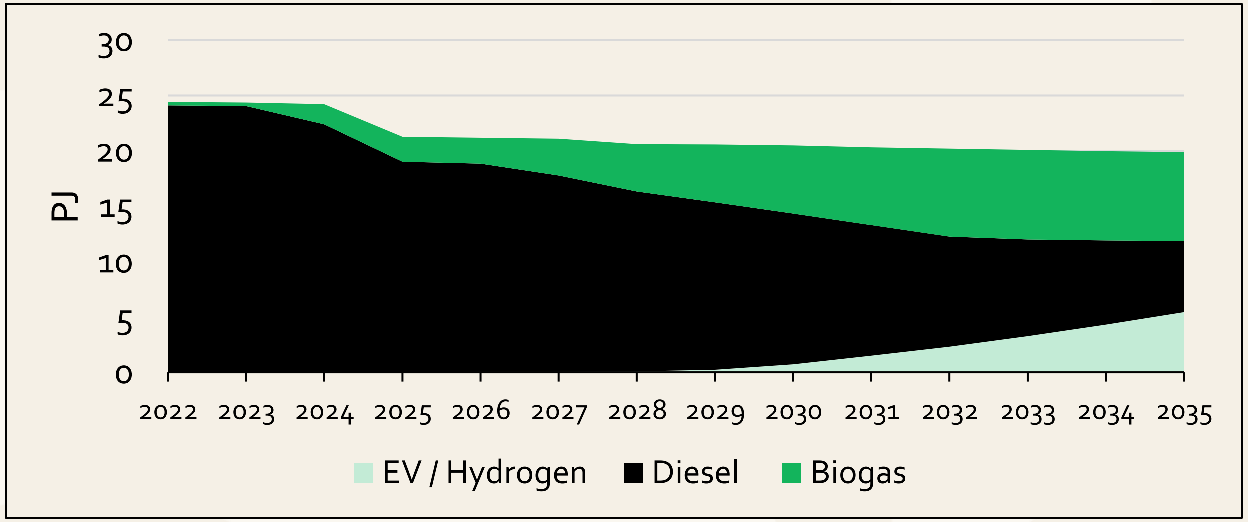
While current road freight transport exclusively relies on fossil diesel mixed with food-based biodiesel, various technologies and fuels, including electricity, hydrogen, biogas, and other green fuels, are generally expected to be used in the future.

In recent years, Denmark has gradually grown interested in transitioning trucks to biogas. From mid-2022, this biogas will be supplied without subsidies, as CO_2 displacement requirements, according to EU legislation, cannot be met with subsidized fuels.

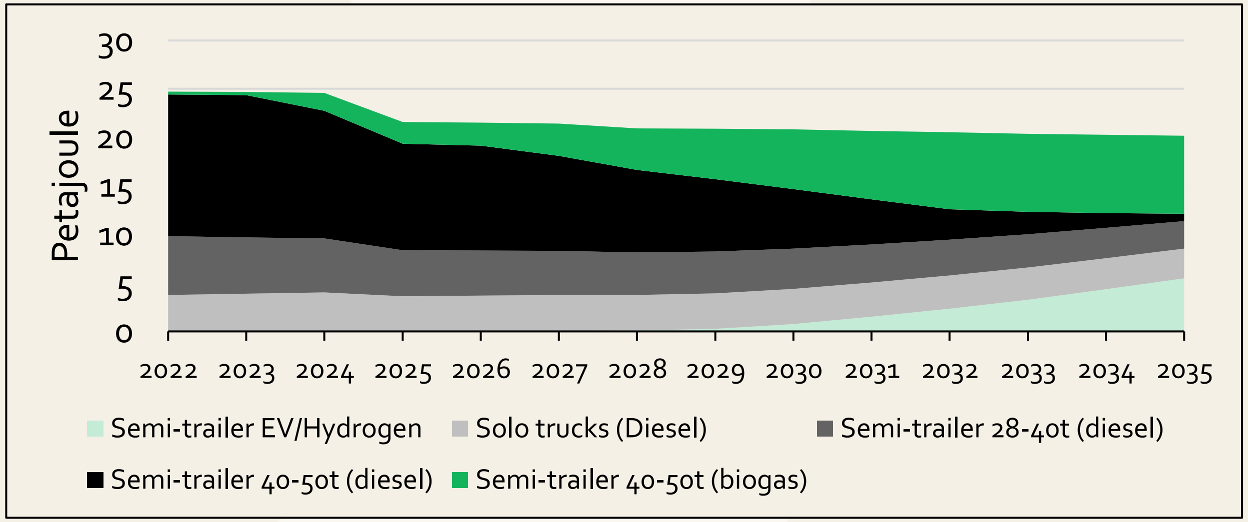
Biogas Danmark's Green Policy proposal indicates that Danish biogas plants could potentially supply about 10 PJ of unsubsidized biogas to the transport sector in 2030 and about 30 PJ in 2035. As the Energy Agency anticipates a diesel consumption for trucks of about 23 PJ in 2030, biogas could cover a significant part of this fuel consumption and be particularly suitable for the heaviest weight classes with a high distance requirement.

The top figure shows the Energy Agency's expectation of the proportion of diesel demand in heavy transport displaced by electricity and hydrogen, along with Biogas Danmark's estimate of what biogas can cover. The bottom figure shows Biogas Danmark's assessment of which green fuels best fit the individual weight classes.

Potential for biogas and EV/Hydrogen for road freight transport in Denmark [2]



KF23 heavy transport energy distribution[2] and biogas potential from Green Policy



Biogas Danmark

Energy production and use of bioresources

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Energy production and use of bioresources

Production potential and demand of biogas in Denmark

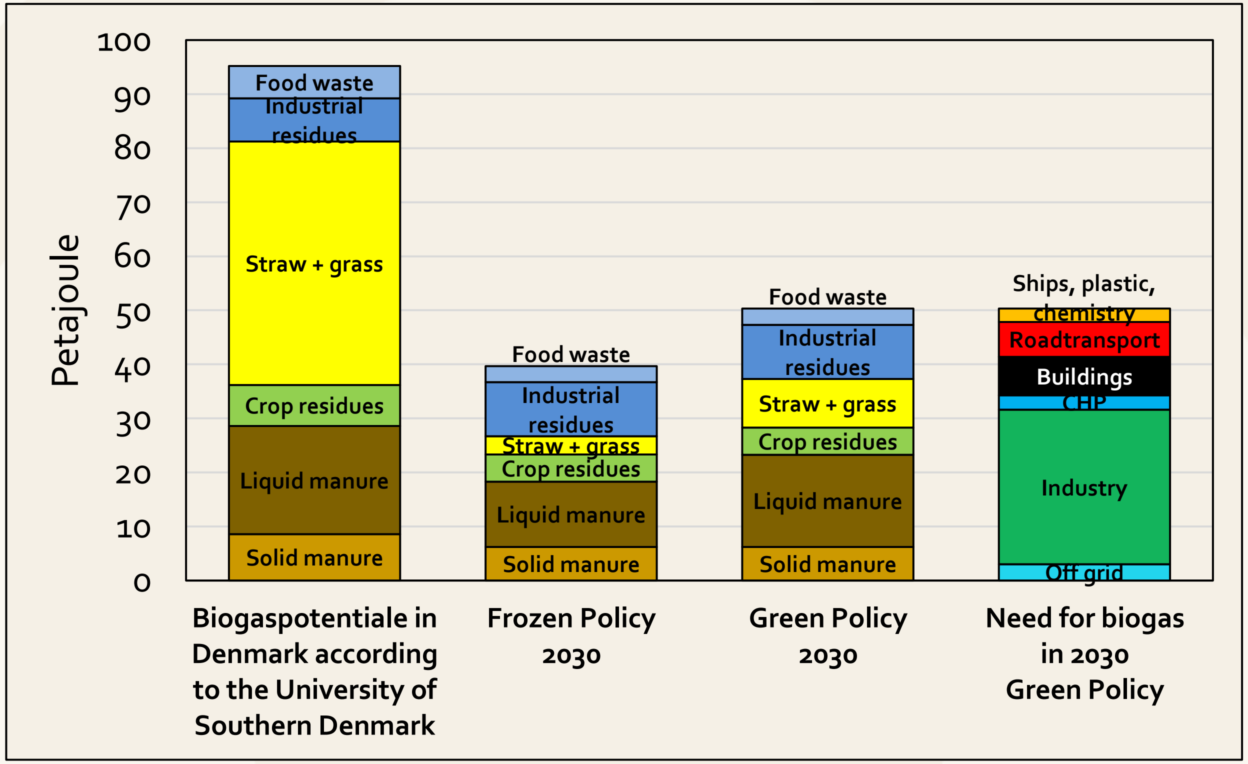
The potential for biogas production in Denmark exceeds the demand.

The bioresources suitable for biogas production comprise of livestock manure and residual products from households, industry, and agriculture. According to a report by the University of Southern Denmark for the Danish Energy Agency, the energy content in these resources amounts to 94 petajoules (PJ). [(10)]

This abundance of resources can accommodate the anticipated biogas production in both the Frozen Policy scenario, with a biogas production of 40 PJ in 2030 and the Green Policy proposal with 50 PJ in 2030 and 60 PJ in 2035.

The Green Policy from 2030 will not only cover the expected gas demand in AF22 but will also provide an additional 6.5 PJ for heavy transport in 2030 and cover fuel needs for ships, airplanes and plastic production of 2.5 PJ. By 2035, this can increase to 8.6 PJ for heavy transport and cover fuel needs for ships, airplanes, and plastic production at 20.4 PJ, assuming the establishment of appropriate market conditions for unsubsidized biogas.

Biogas potentials, bioresources, and the need for biogas in 2030



The left column shows the biomass potential for biogas production estimated by the University of Southern Denmark. [(10)] The two middle columns show the feedstock in 2030 in the Frozen Policy and Green Policy scenarios, respectively. The right column shows the use of the produced biogas in the Green Policy scenario.

Biogas Danmark

Energy production and use of bioresources

Development in biomethane production

Biogas production leveled off in 2022, following a significant growth period starting from 2014.

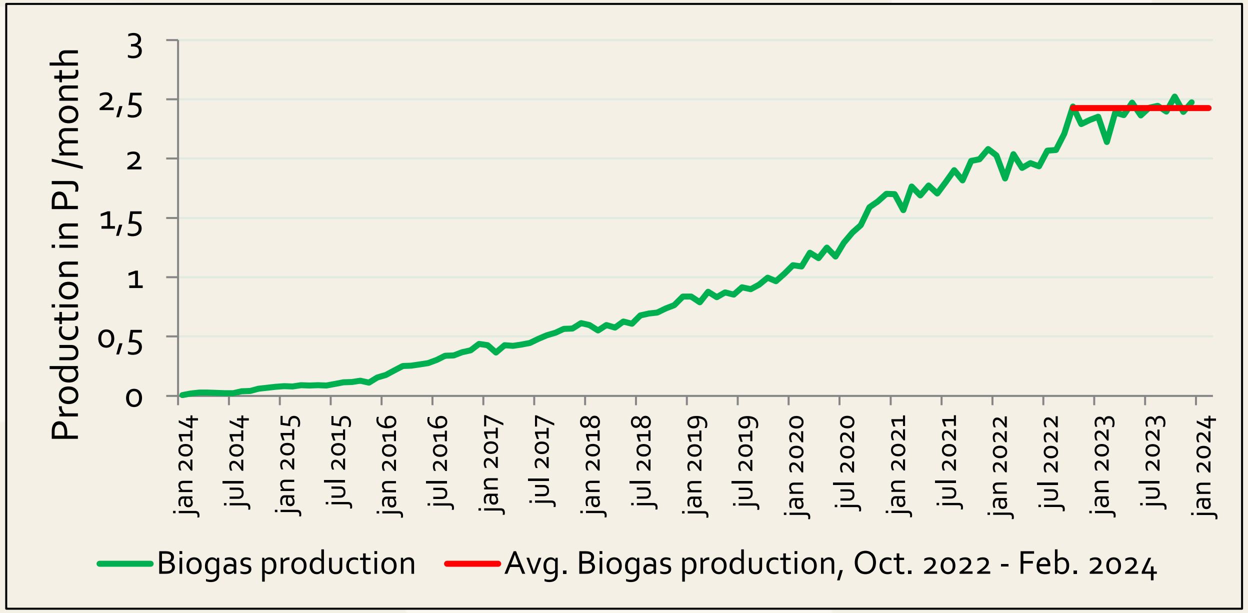
After approximately ten years of growth under the subsidy scheme, which was shut down in 2020, production development has stagnated since 2022 when the last facilities under the scheme were commissioned.

The new politically decided tender pools, which were supposed to increase biogas production from January 2024, have been postponed. Additionally, the conditions have deteriorated to such an extent that it is doubtful whether there will be any significant contribution from this. If there is, it won't be until at least 2026. This sets the stage for the "Frozen Policy" scenario.

Therefore, a continued increase in biogas production requires better market conditions for unsupported biogas, instead of the following deteriorations of the framework conditions, which can make the Frozen Policy scenario even more negative:

- New feed-in tariffs from Evida
- Overcompensation regulation
- Significant increase in the CO_2 tax on biogas delivered via the gas grid
- Lack of CO_2 displacement requirements in the heat, transport, and infrastructure sectors.

Progression of biogas production into the gas grid since 2013



The evolution of upgraded biogas production for the gas grid since 2014. Note the stagnation from October 2022 onwards. In addition, approximately 6.5 PJ per year has been produced and delivered directly from biogas plants to energy production and industries outside the gas grid for several years.

There are approximately 180 biogas plants in Denmark.

Plants without upgrading typically produce power and heat in CHP plants or in industry

- 100 agriculture-based biogas plants, of which 55 upgrade to biomethane
- 49 wastewater treatment plants, of which 2 upgrade to biomethane
- 7 industrial biogas plants, of which 1 upgrade to biomethane
- 27 landfills where biogas is collected

The overview of biogas plants in Denmark in 2022 by the Danish Energy Agency:
https://ens.dk/sites/ens.dk/files/Bioenergi/liste_over_biogasanlaeg_i_dk.pdf

Energy production and use of bioresources

Biogas production distributed by bioresources

More biogas from livestock manure and straw

While livestock manure accounts for about three-quarters of feedstock for the biogas plants in tonnes, it only delivers about one-third of the gas.

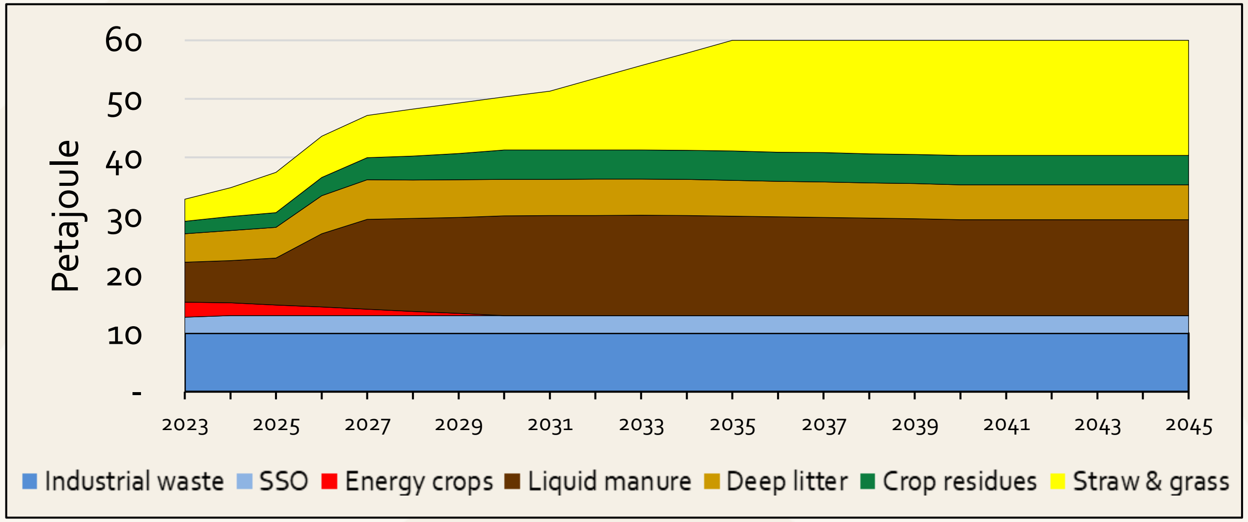
The biogas is produced by anaerobic digestion of the organic matter in the feedstock. Therefore, the biogas yield is lower per tonne of fresh weight feedstock than drier biomasses such as deep litter, straw, industrial residues and household food waste.

By 2035, manure from livestock is projected to constitute 79 percent of the input in the Green Policy scenario.

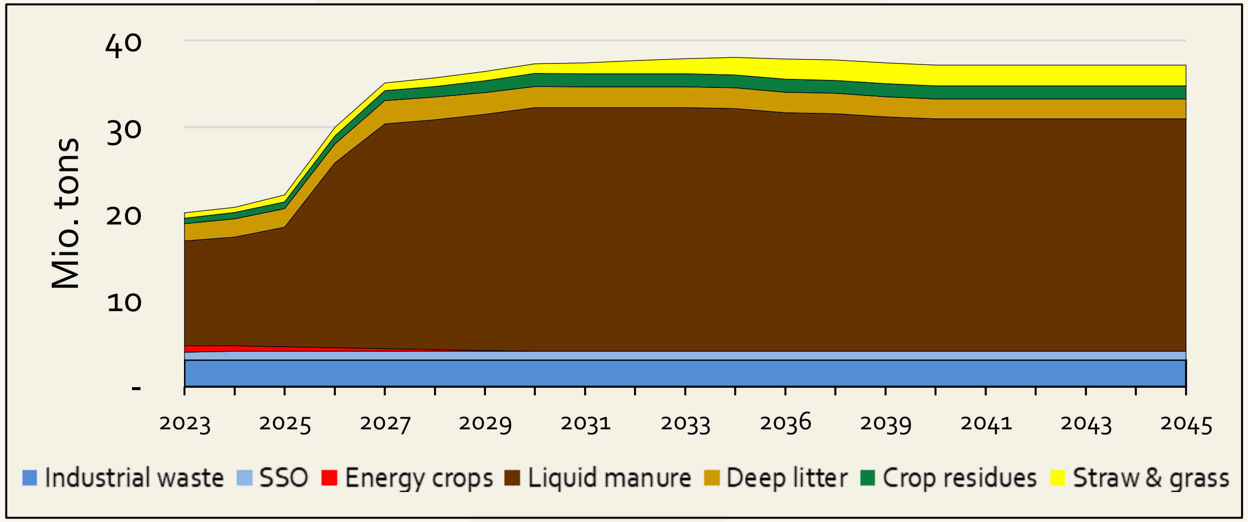
The significant increase in straw gasification requires further development of methods and technologies for efficient anaerobic digestion of straw. At the same time, it would result in a higher fiber content in the gasified biomass. This is expected to encourage a shift towards the separation of gasified biomass, thus leading to the production of customized fertilizers tailored to the needs of the recipients.

Biogas Danmark

Biogas production distributed by bioresources in PJ – Frozen Policy



Biogas production distributed by bioresources in tons – Green Policy



Energy production and use of bioresources

Anaerobic digestion of livestock manure and straw

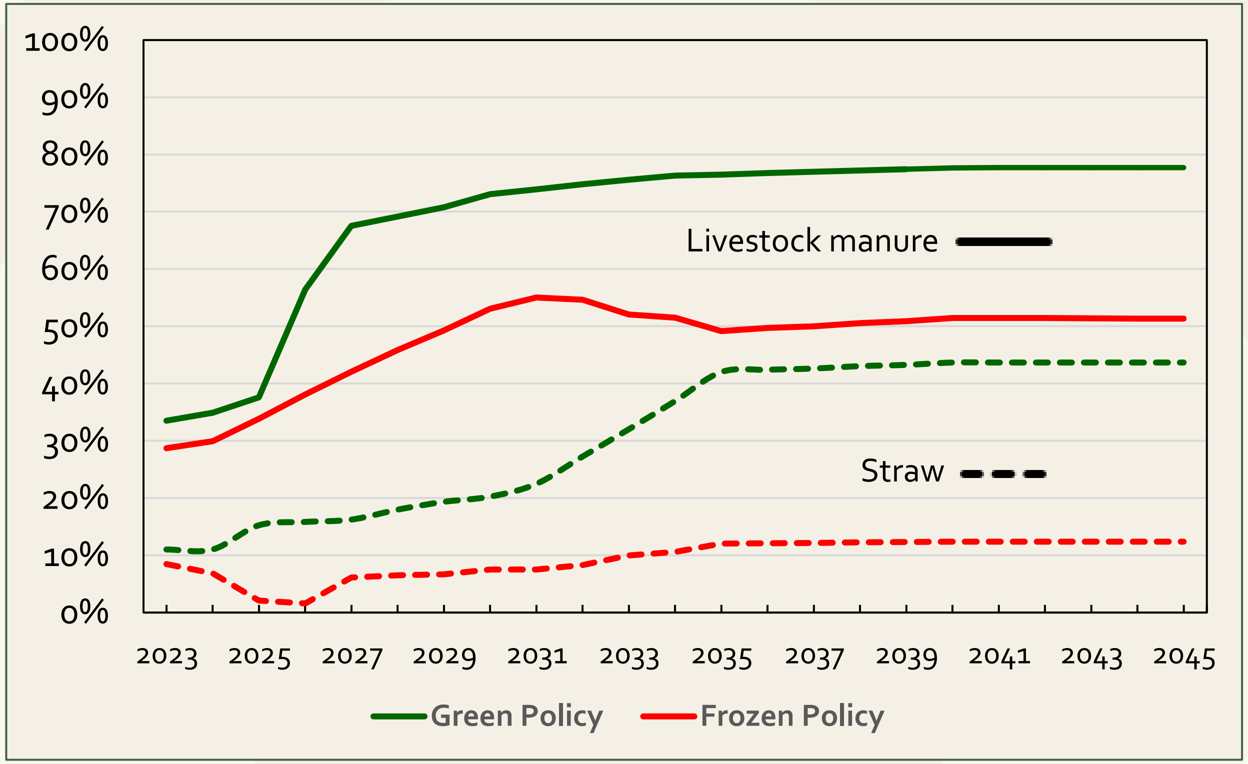
Huge potential, especially in straw

Although the Green Policy scenario involves higher shares of livestock manure and straw being digested in biogas plants compared to the Frozen Policy scenario, there will still be a significant unutilized resource of, especially straw

The Frozen Policy scenario assumes that 54 percent of livestock manure will be digested in biogas plants in 2030. The Green Policy scenario depicts the digestion of 73 percent of the livestock manure, as the total biogas production in this scenario is increased to 50 petajoules.

For straw, the Frozen Policy scenario requires that about 10 percent of the straw resource be used for biogas in 2030. In the Green Policy scenario, 20 percent of the straw will be anaerobically digested in biogas plants in 2030, increasing to 40 percent in 2035.

Utilization of the potential available livestock manure and straw for biogas



The proportion of the total resources of livestock manure and straw that is utilized for production of biogas in the two scenarios.

Research shows that when straw and deep litter are digested in biogas plants, most of the slowly degradable carbon is recycled to the agricultural soils. Therefore, the same quantity of carbon is stored in the long term as if the straw is incorporated directly into the soil. (11)

Energy production and use of bioresources

Simultaneous wind power production in Northern Europe

Huge demand for backup during calm wind periods

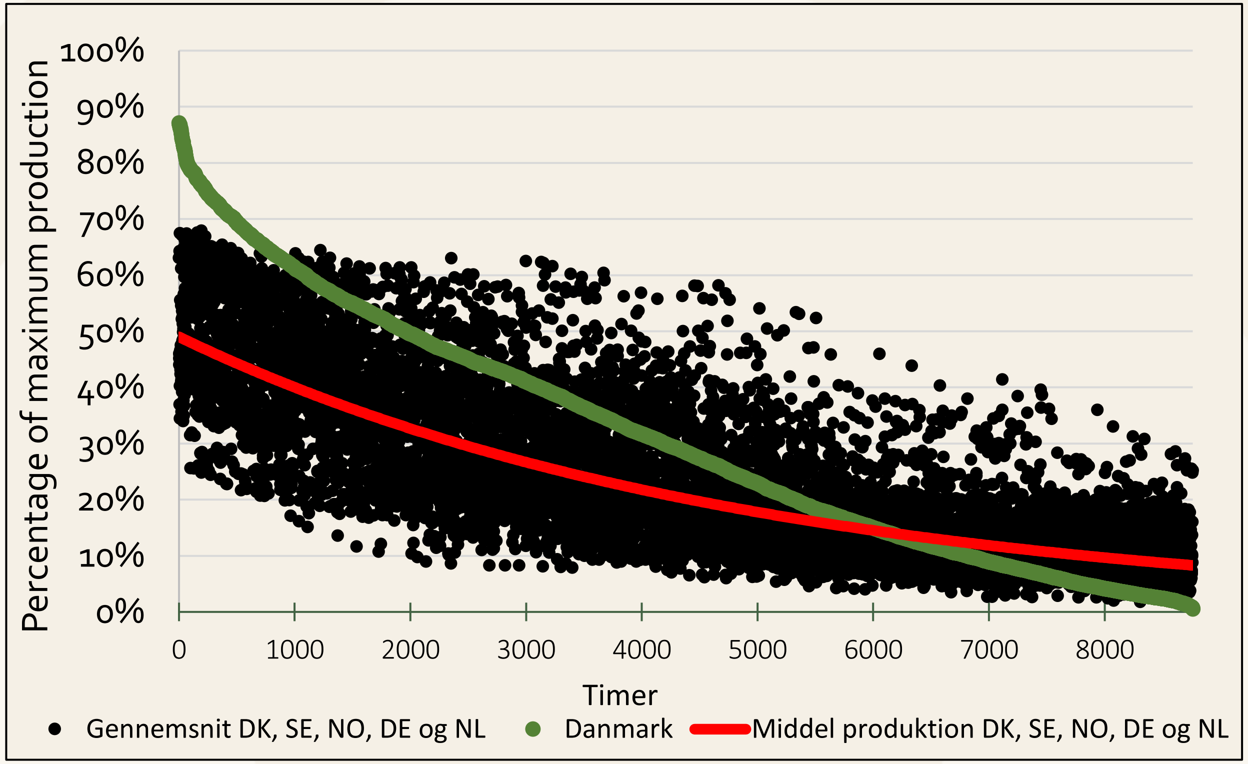
In the hours when wind energy production is low in Denmark, it is typically low in our neighboring countries as well, and conversely, it is high almost simultaneously.

This implies that even a significant expansion of international connections cannot compensate enough to make wind power a constant energy source that can serve as a base load.

A major expansion in wind power capacity is required to cover a large percentage of the electricity consumption during the 3000 hours per year with the lowest wind power production. However, this would result in electricity production exceeding consumption for the rest of the year by at least three times the amount needed during the 2000 hours with the highest wind power production.

Therefore, a combination of backup sources during calm periods and new utilizations for Power-to-X (PtX) when wind power is at its maximum must be introduced to balance electricity production.

Duration curves for electricity production in Denmark and neighboring countries simultaneously



Source: entsoe.eu - Actual Generation per Production Type [12]

The share of the installed capacity that delivers power is plotted for each hour. The green curve represents the Danish wind power, with the hours with the highest utilization of the installed capacity to the left and decreasing towards calm at the right. The dots show electricity production in wind areas in neighboring countries, and the red line shows the average trend in these areas.

Biogas Danmark

Energy production and use of bioresources

Potential for balancing the power grid with PtX production

The biogenic CO_2 that every day is captured in the upgrading facilities on biogas plants can be utilized in at least five different ways:

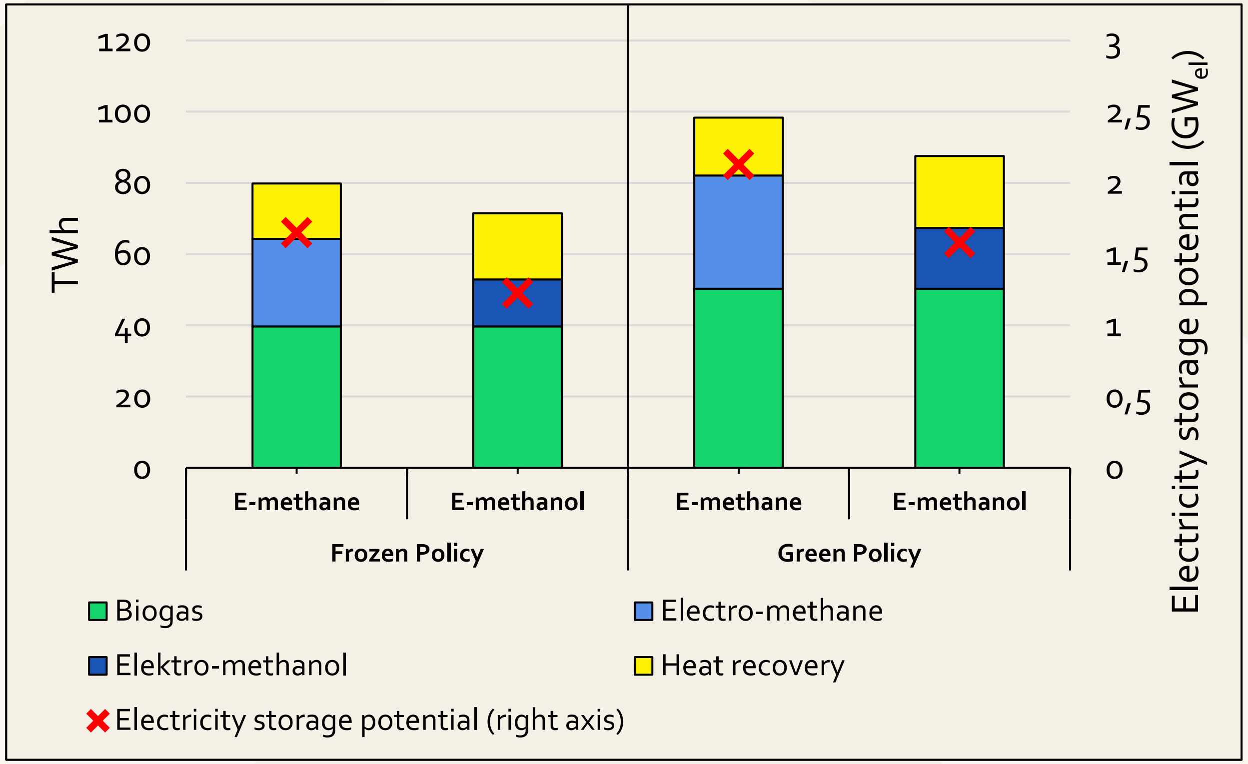
1. Replace industrial CO_2 currently produced from natural gas.
2. Deposition by Carbon Capture and Storage (CCS)
3. Produce electro-methane (e-methane) through methanation utilizing hydrogen from renewable electricity (e-metan) (13)
4. Produce electro-methanol (e-methanol) utilizing hydrogen from renewable electricity (e-metanol) (13)
5. Produce biogenic carbon-based plastic and textile production replacing hydrocarbons of fossil origin.

Solution 1 is implemented at several facilities without subsidies. Solution 5 is the long-term solution, as the world needs these products even in a fossil hydrocarbon independent future.

The figures compare the capacity to balance electricity from wind and solar panels via PtX and CCS in the two scenarios.

The most straightforward solution is to switch between PtX and CCS depending on the need for balancing electricity hour by hour.

CCUS potential in 2030 with CO_2-capture at the biogas plants – Green Policy and Frozen Policy scenarios



The red crosses indicate how much electric power can continuously be converted to PtX fuels per hour. The blue show the electro-fuel (e-methane or e-methanol) production potential by utilizing the CO_2 content of the biogas production (green). The yellow indicates the heat recovery from the electrolysis process that delivers the hydrogen. The scenarios require large storage facilities of either CO_2 or hydrogen.

Biogas Danmark

Energy production and use of bioresources

CO_2 from biogas enables large-scale production of PtX fuels

Storage of surplus electricity from solar and wind

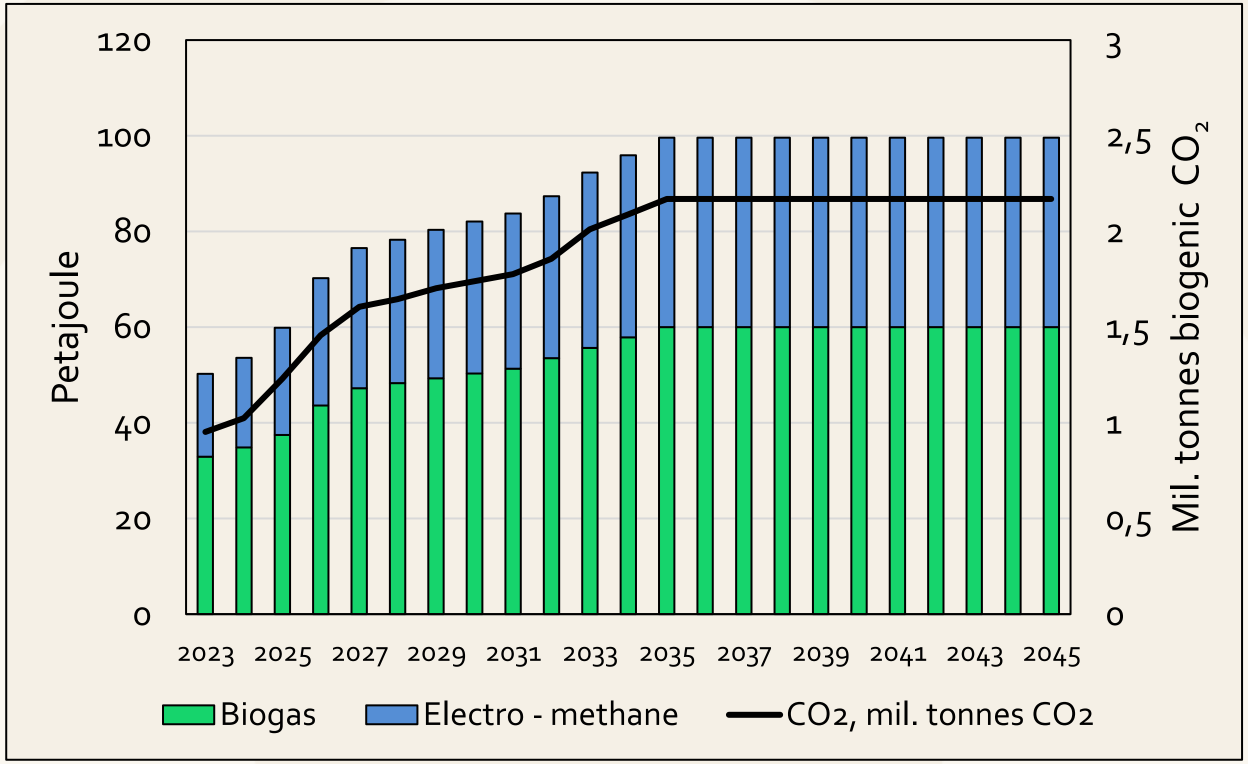
Biogenic CO_2 from biogas is easily available for Power-to-X fuel production as it is released during the biogas upgrading process. These fuels are produced using electricity derived from wind and solar energy to create hydrogen through electrolysis. The hydrogen is then combined with CO_2 to produce either methane or methanol.

Hence, biogenic CO_2 can be utilized to store surplus electricity as easily usable electrofuels, such as e-methane or e-methanol.

The e-methane production potential if all captured biogenic CO_2 from the biogas production in the Biogas Danmark scenario is shown in the graph. This would, however, require huge storage facilities. Either for CO_2 in the hours without a surplus of electricity production from solar and wind or for hydrogen during the hours with a considerable surplus of electricity from solar and wind.

Surplus electricity from solar and wind can occur when electricity production exceeds consumption or the capacity of the electric grid.

E-methane production potential – Green Policy scenario



The black line shows the annual CO_2 content that can be captured when the biogas is upgraded to biomethane that is injected into the gas grid (green). The blue columns show the e-methane production potential if all the captured biogenic CO_2 reacts with hydrogen.

Biogas Danmark

Climate effect

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Biogas Danmark

Climate effect

Overall climate effect of biogas

Biogas substantially contributes to climate effect

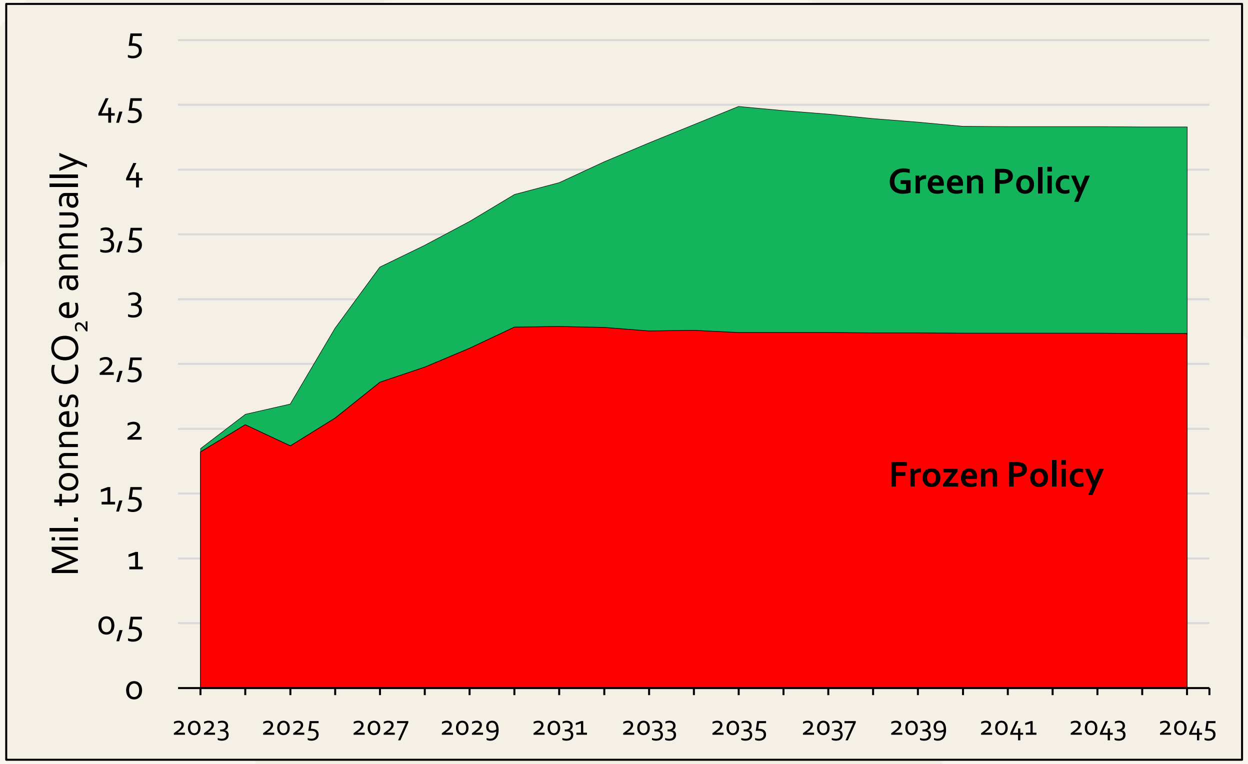
Biogas production has the potential to make a substantial contribution towards Denmark's 70% climate target for 2030.

The Frozen Policy scenario shows that biogas contributes to a net CO_2 reduction of 1.9 million tons by 2025, and 2.8 million tons by 2030.

Implementing Biogas Denmark's Green Policy proposal could further increase this reduction to 2.2 million tons of CO_2 by 2025 and 3.8 million tons by 2030.

The Green Policy decline after 2035 is due to the Energy Agency's expectation of a reduced availability of manure, leading to a decrease in the amount of manure used for methane production in biogas plants.

Annual net CO_2e reduction by biogas production in the two scenarios



The figure illustrates the difference in climate impact between the revised forecast in the Frozen Policy and the Green Policy. It is particularly important to note the difference between the Frozen Policy, which is based on the new and worsened framework conditions, and the Green Policy, which includes the climate effect of Biogas Denmark's policy proposals.

Climate effect

Climate impact of biogas

The net climate impact of biogas exceeds the CO_2 savings from substituting fossil fuels.

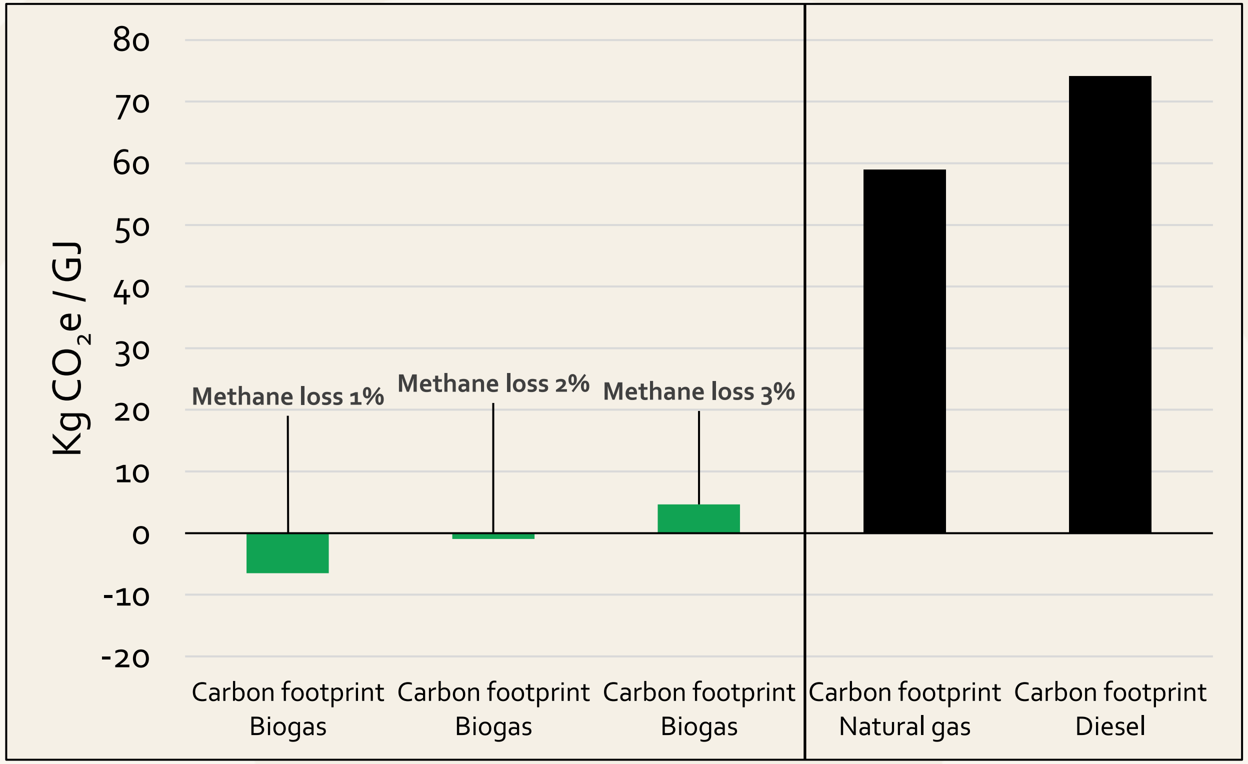
Not only does biogas substitute fossil fuels, but it also reduces the carbon footprint from methane emissions during agricultural manure storage. However, biogas production also has a climate impact in the form of methane loss, energy consumption, and transportation of biomass and manure.

The net climate effect is calculated by subtracting the CO_2e emissions from the biogas plants' energy consumption and methane loss from the gross climate effect.

The figure shows the net climate effect per GJ of biogas produced and delivered to the gas grid at methane losses of 1, 2, and 3 percent, respectively, where the biogas plants' energy consumption is also subtracted.

Biogas's carbon footprint is significantly lower than that of natural gas and diesel. Therefore, even with a 2 percent methane loss, it can be considered CO_2-neutral and green.

Comparing the carbon footprint of biogas with different methane losses to natural gas and diesel



The net greenhouse gas reduction for the Frozen Policy scenario indicates that biogas, which substitutes fossil gas, is climate neutral if methane loss is 2 percent.

In 2020-21, methane loss was measured at around 2 percent in several agriculture-based biogas plants.[14] *In 2022, a new regulation was adopted to reduce methane loss. This includes leak control performed by external experts and self-monitoring programs at the biogas plants. This regulation came into effect on January 1, 2023.*[15]

Biogas Danmark

Climate effect

Klimarådet*: Denmark can not meet its EU obligations

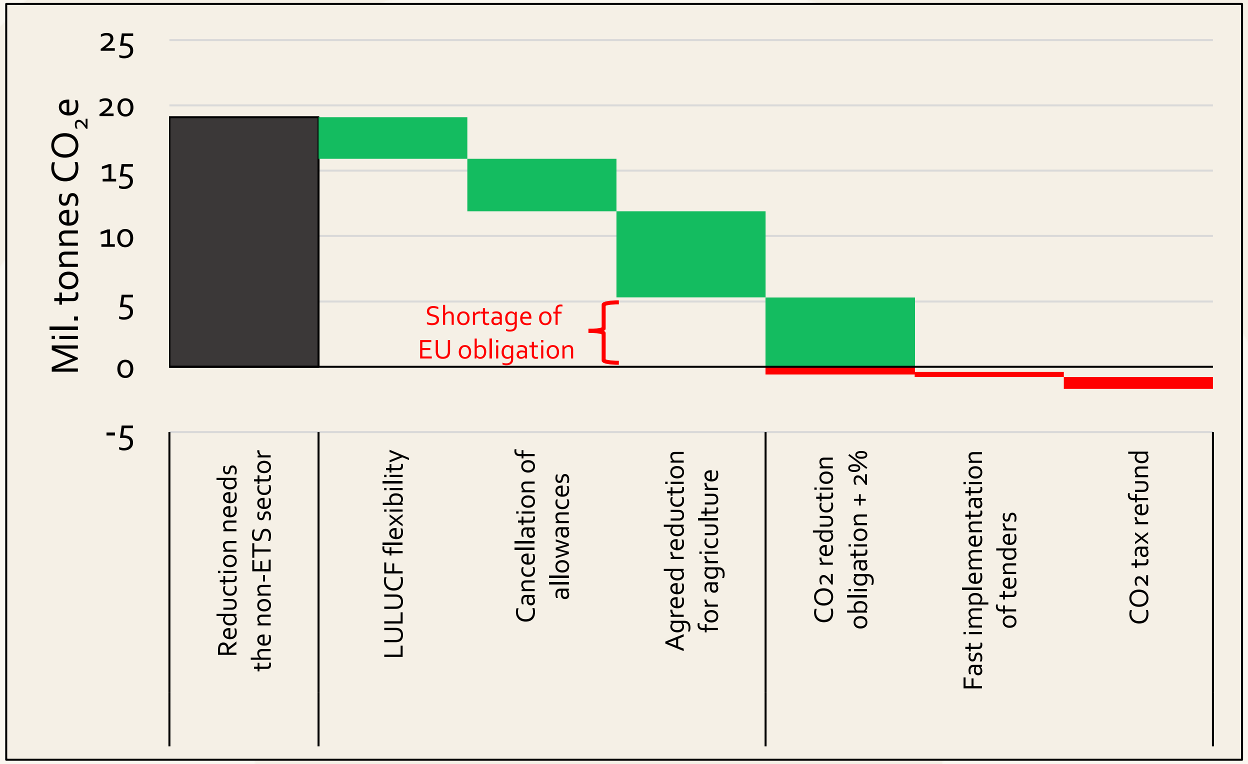
Klimarådet points out in their 2023 evaluation that Denmark cannot meet the EU's climate obligations

The Climate Council's 2024 status report states that even if Denmark meets its own climate goals of 54% and 70% reduction in greenhouse gas emissions by 2025 and 2030, respectively, it will still not be able to meet the EU's requirements for reducing greenhouse gases outside of the quota sector and in LULUCF during the period 2021 to 2030.(16)

The Climate Council estimates the reduction needed to be 19 million tonnes of CO_2 equivalent. However, the flexibility in LULUCF, cancellation of CO_2 quotas, the agreed reduction in agriculture, and adherence to Denmark's 2025 climate goal are insufficient to meet EU requirements. There is still a shortfall of approximately 5.6 million tonnes of CO_2 equivalent.

The policy proposal by Biogas Denmark's Green Policy can significantly contribute to eliminating this shortfall, as illustrated in the figure. The fact that the Climate Council casts doubt on other initiatives only makes Biogas Denmark's proposal even more important.

Reduction gap and biogas' contribution to EU goal fulfillment



The figure on the left illustrates the Climate Council's calculation of Denmark's shortfall in meeting the EU requirement to reduce greenhouse gas emissions outside the quota sector and in LULUCF (land and forest).
On the right, Biogas Denmark's policy proposal illustrates how it can substantially contribute to climate change. The climate effect of CO_2 substitution requirements, the advancement of biogas supply and CO_2 tax refund for biogas delivered via the gas grid are estimated to affect both non-quota and quota sectors.

*Klimarådet is The Danish Council on Climate Change

Biogas Danmark

Climate effect

Climate effect of production and use of biogas

Biogas significantly reduce greenhouse gas emissions

The Frozen Policy scenario projects an annual net reduction in greenhouse gases from 2030 to 2035 of about 2.8 million tons of CO_2 equivalent.

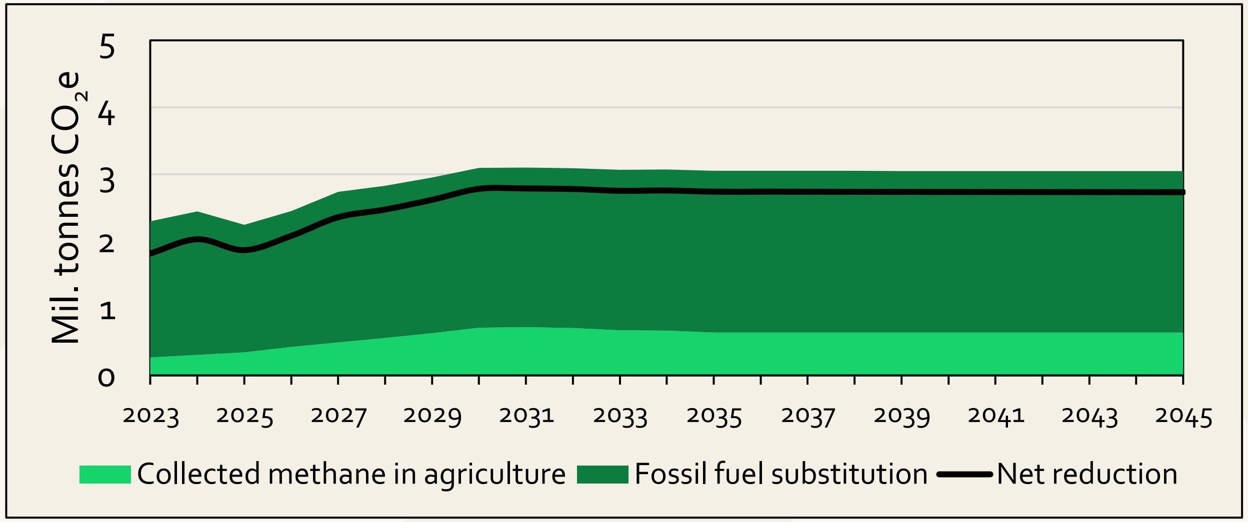
The Green Policy scenario increases this reduction to 3.8 million tons of CO_2 equivalent in 2030, rising to 4.5 million tons in 2035.

The net climate effect calculation is based on reducing methane emissions from agricultural livestock manure and substituting fossil fuels. Furthermore, it takes into account the CO_2 emissions from the transportation of biomass and manure, the energy consumption of biogas plants and methane losses from these plants.

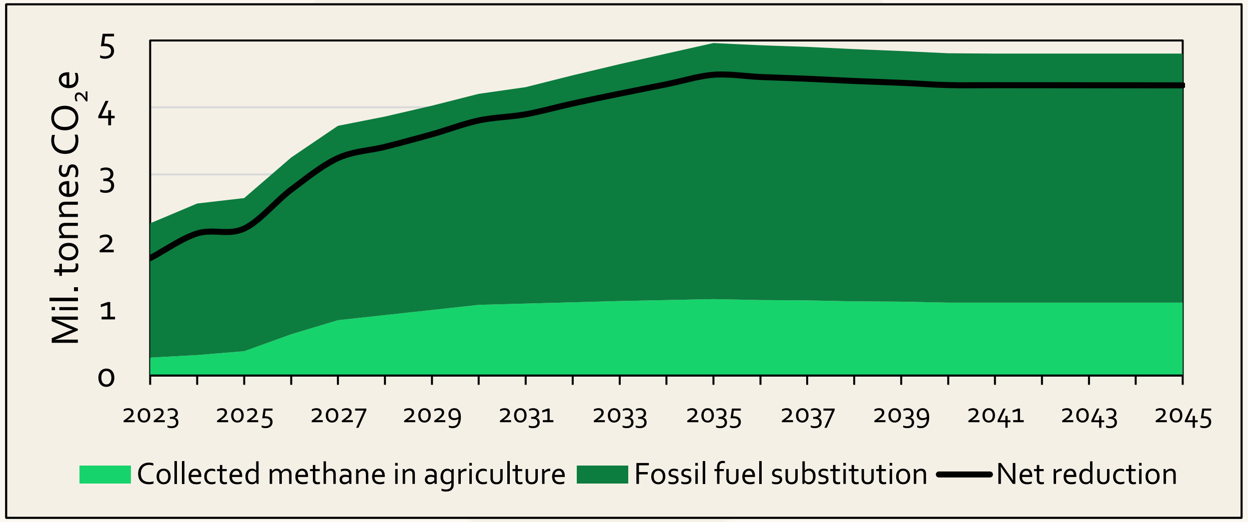
It is assumed that the CO_2 emissions from the energy consumption of biogas plants will gradually be reduced by introducing heat pumps.

Regulation of methane loss will be implemented starting January 1, 2023. Based on this, it is assumed that methane loss will gradually be reduced to 1 percent from 2024, assuming a 1.4 percent loss in 2023.(15)

Climate effect of biogas production and use – Frozen Policy



Climate effect of biogas production and use – Green Policy



The net reduction in greenhouse gas emissions takes into account the deductions for methane losses and the energy consumption of biogas plants for process and transportation.

Climate effect

Climate impact of gas and electricity consumption

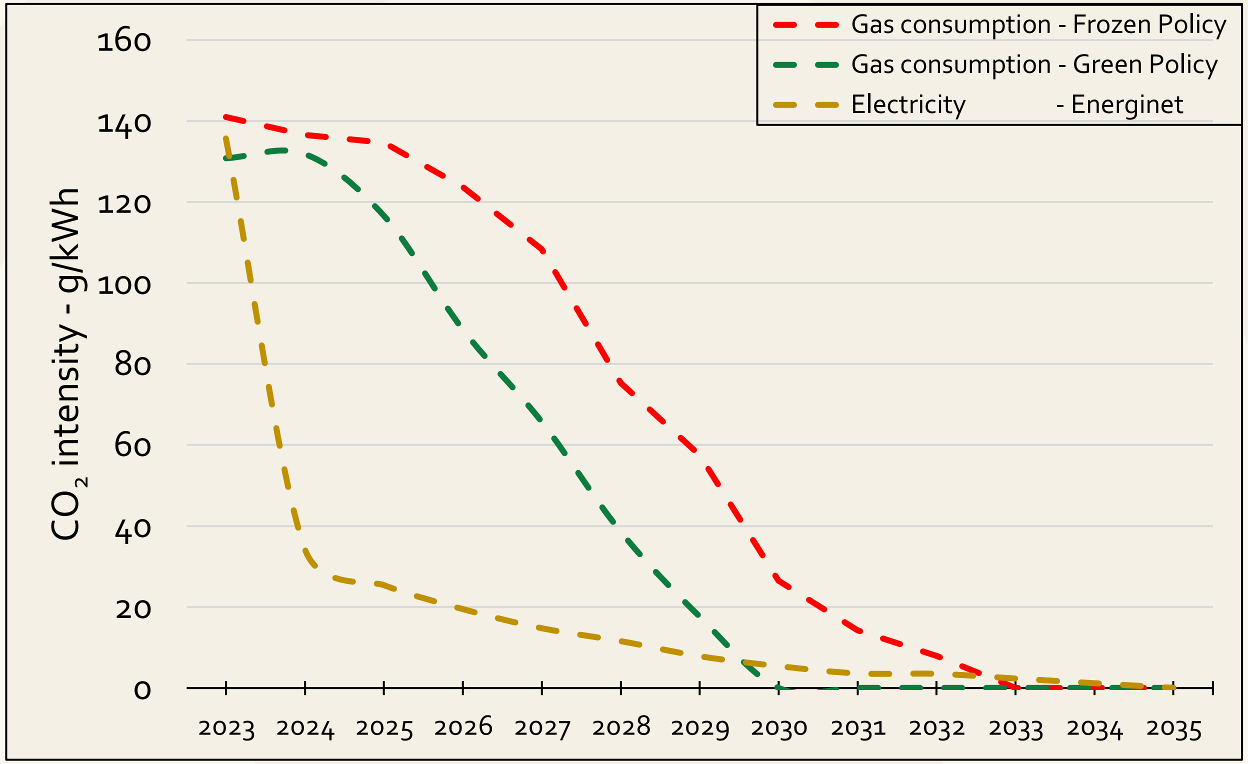
The carbon footprint of gas and electricity consumption can be drastically reduced by 2030

The Danish gas and electricity consumption currently have the same climate footprint expressed as the CO_2 intensity.

If Biogas Denmark's policy proposals are implemented and the politically approved offshore wind farms are realized, the carbon footprint from gas and electricity consumption could be close to climate-neutral by around 2029/30.

Without changes to the current framework conditions for biogas production, the Frozen Policy scenario will not be able to meet the government's desire for a climate-neutral gas system by 2030. It would only be possible around 2033.

Future carbon footprint of gas and electricity consumption in Denmark



Biogas Denmark has projected the carbon footprint in electricity consumption for 2023 based on data from Energinet [8]. Energinet has also carried out projections for 2024 and beyond.[17] Biogas Danmark has calculated the carbon footprint in gas consumption based on the expected developments in biogas production and gas consumption in the Frozen Policy and Green Policy scenarios.

Biogas Danmark

Climate effect

Life cycle analysis of biogas for heavy transport

The most CO_2e-efficient choice for heavy transport.

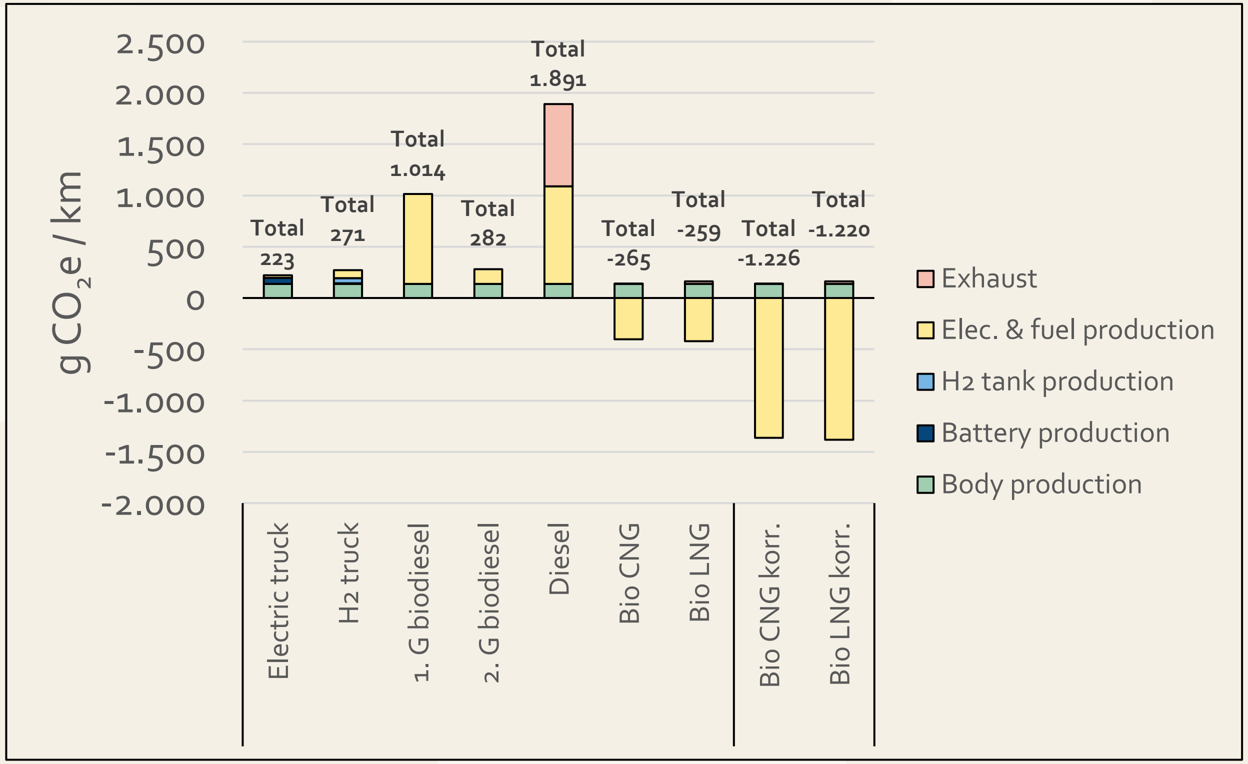
According to a new lifecycle analysis conducted in 2023 by Copenhagen Electric in collaboration with consulting firm COWI, biogas is the fuel that can contribute most to the green transition of the transport sector.

The analysis examined which fuels have the lowest carbon footprint per kilometer driven for 12 and 40-ton trucks, as well as route buses.

The fuels compared were electricity, hydrogen, biogas, 1st and 2nd generation biodiesel, and diesel mixed with 7 percent biodiesel.

The conclusion was that for trucks, biogas solutions—in the form of compressed (Bio CNG) or liquefied (Bio LNG) biogas —are clearly the most climate-friendly fuel, even when compared to electricity in heavy transport.

LCA analysis of CO_2e emissions for a 40-ton truck [18]



The seven pillars on the left show Copenhagen Electric's lifecycle analysis results. The climate effect of biogas is calculated based on the mix of biomasses used in Danish biogas production. Additionally, a methane loss of 2.5 percent was factored into the calculations. Biogas Denmark calculates the two pillars on the right and shows the climate effect of using biogas produced solely from livestock manure. Here, a methane loss of 1 percent was used in the calculation of the climate effect.

Climate effect

Climate effect of LBG and transport costs

Possibility for a green transition of heavy transport

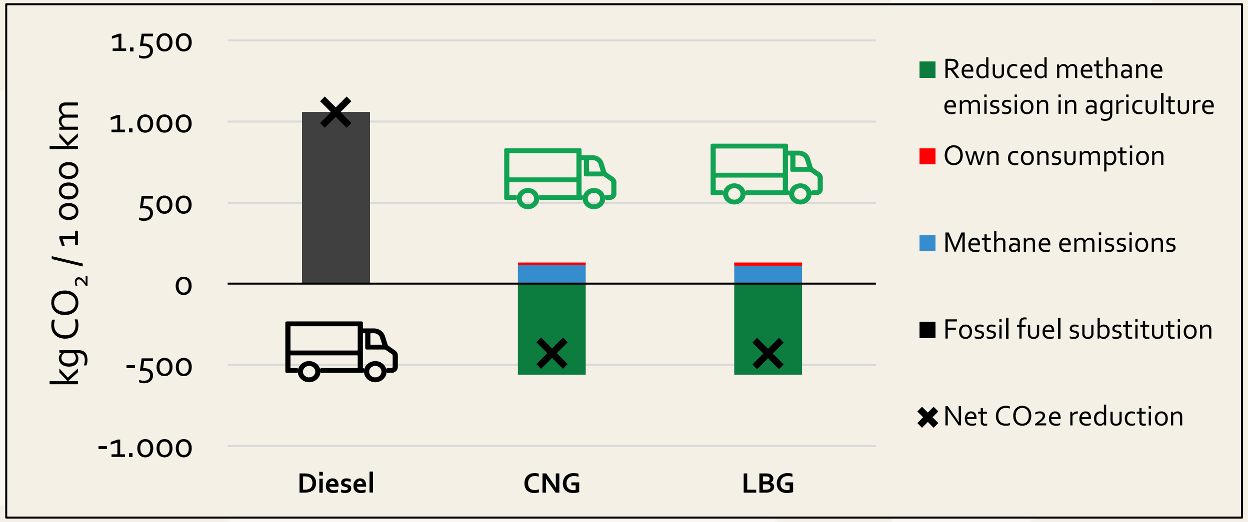
Liquefied Biogas (LBG) is cooled to approximately -160°C to achieve a higher energy density and thus a smaller volume. This feature is advantageous when the gas is used as fuel for ships or trucks that require long-range travel.

The demand for LBG trucks is increasing in our neighboring countries, especially Germany. In Denmark, LBG could significantly contribute to the green transition of the heaviest weight classes in road freight transport and shipping.

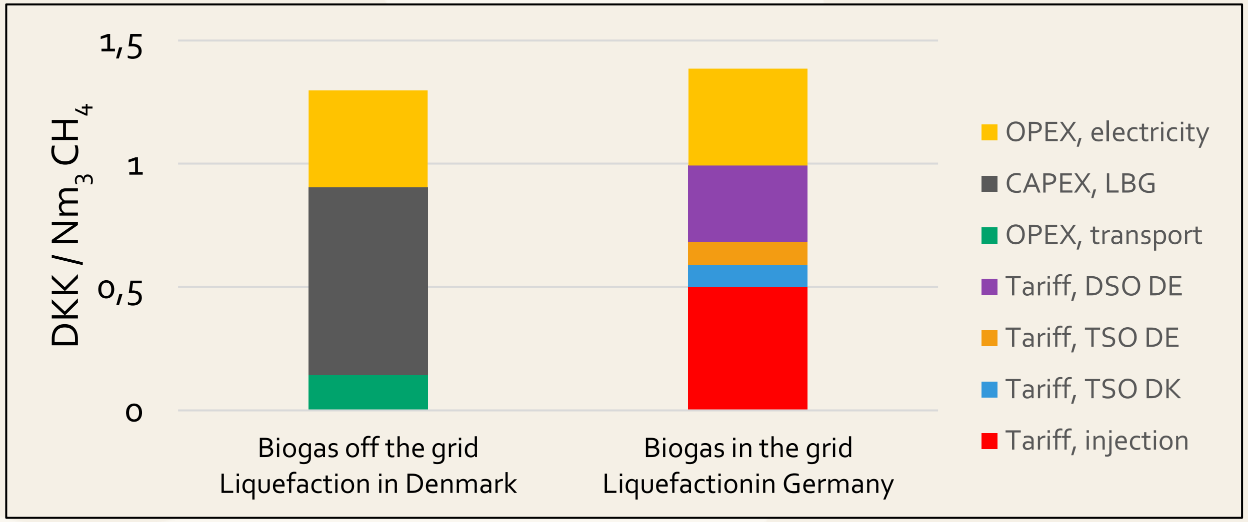
As shown in the top figure, using biogas from livestock manure results in a net climate reduction across sectors, which far exceeds the substitution of fossil diesel, making biogas a climate-neutral fuel.

The Danish gas distribution company Evida has announced new tariffs for biogas supply to the gas grid. These tariffs would result in the costs of transporting biogas via the gas grid exceeding the costs of liquefying it and transporting it by truck to Germany. This situation presents a risk that significant amounts of biogas would bypass the Danish gas grid and instead be transported to Germany by trucks.

Climate effect of substituting diesel with LBG



Costs of liquefying the biogas in Denmark or sending it through the gas grid for liquefaction in Germany[19] [20]



Biogas Danmark

Climate effect

Optimal climate effect through utilization of the captured CO_2

Biogenic CO_2 captured at biogas plant upgrading facilities can be utilized in at least five different ways:

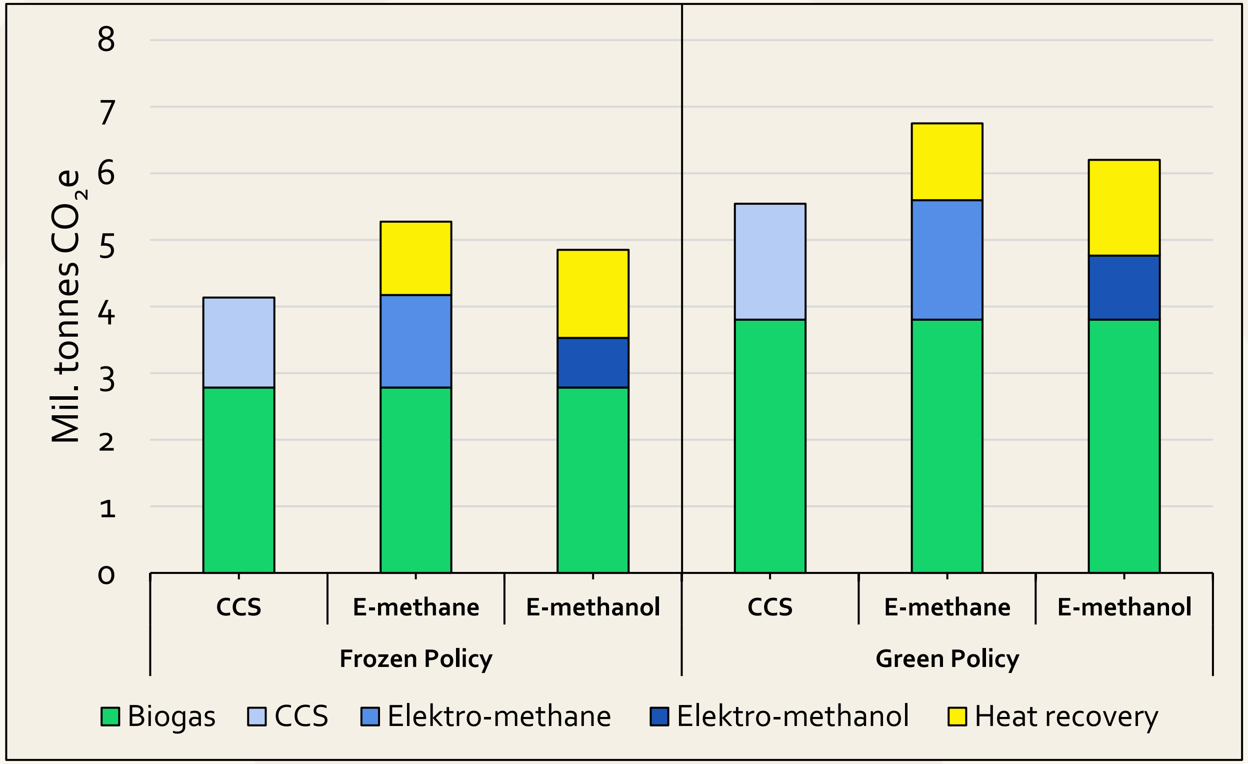
1. Replace industrial CO_2 currently produced from natural gas.
2. Deposition by Carbon Capture and Storage (CCS)
3. Produce electro-methane (e-methane) through methanation utilising hydrogen from renewable electricity (e-metan) (13)
4. Produce electro-methanol (e-methanol) utilising hydrogen from renewable electricity (e-metanol) (13)
5. Produce biogen carbon-based plastic and textile production replacing hydrocarbons of fossil origin.

Option 4 would be the quickest, most obvious, and likely the one with the highest climate impact. Data for this is not yet available.
In 2023, there was significant industrial demand and high prices due to a shortage of natural gas.

E-methane significantly reduces greenhouse gases due to its ability to bind more renewable energy. However, since CO_2 is re-released upon use, CCS could have a more significant climate impact if renewable energy is used differently.
Solution 5 would be the most beneficial in the long term, as it limits the use of fossil hydrocarbons.

Biogas Danmark

Greenhouse gas reduction potential in 2030 by CO_2 capture at biogas plants – Frozen Policy and Green Policy scenario



The figure compares CCS and two PtX solutions, including their immediate climate value and the ability to balance electricity from RE plants.

Climate effect

Biogenic CO_2 fra biogas

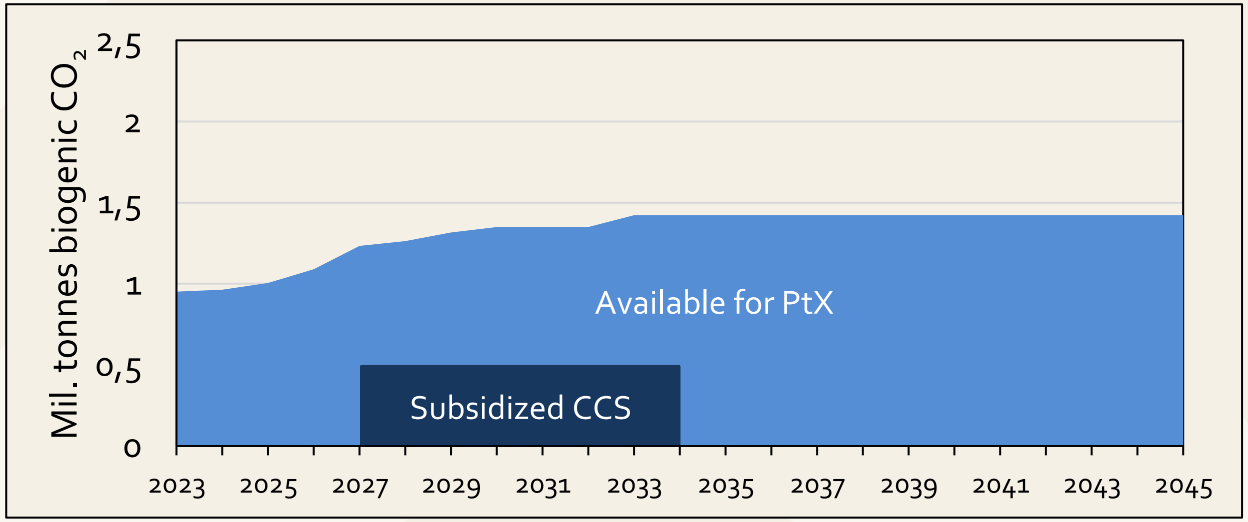
There is significant potential in using CO_2 from biogas for PtX or CCS.

CO_2 from biogas is called biogenic as it originates from plants that CO_2 assimilated CO_2 from the air through photosynthesis. This CO_2 would be recirculated into the atmosphere through the natural degradation of the dead plants.

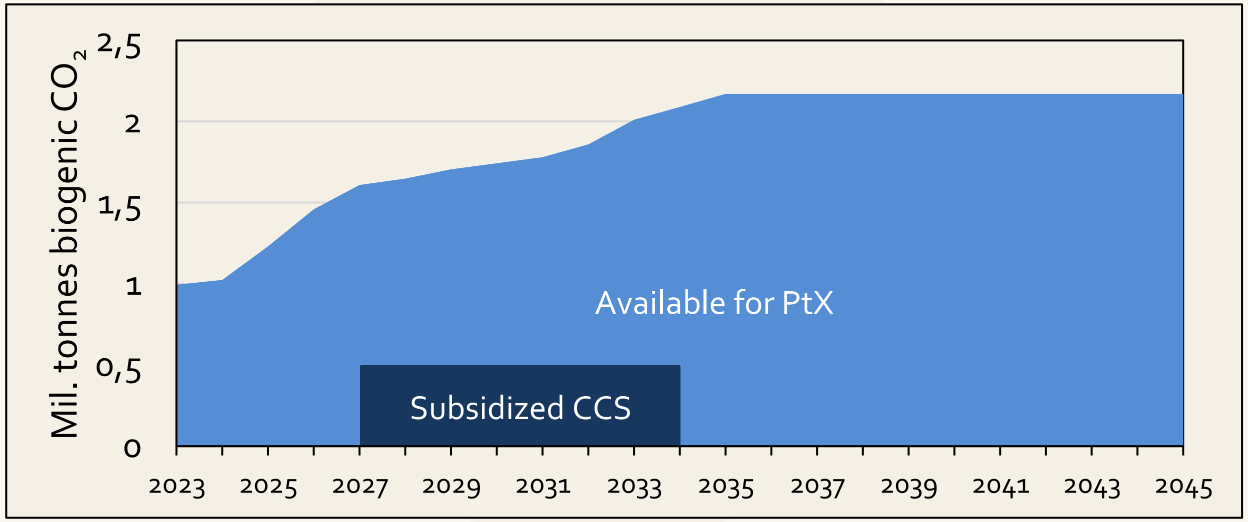
Biogas typically contains 60-65 percent biomethane and 35-40 percent biogenic CO_2. To meet the quality requirements for injecting biomethane into the gas grid, CO_2 is segregated from the biogas at the upgrading facilities on the biogas plants. This CO_2 has excellent potential for applications like Carbon Capture and Storage (CCS), power-to-X (PtX) processes, or industrial uses of CO_2, which currently rely on fossil-based sources.

While the Frozen Policy scenario is estimated to provide a CO_2 potential of just under 1.7 million tons annually, the Green Policy scenario could offer more than 2.2 million tons annually by 2030. A support scheme has been adopted, allowing for the storage of biogenic CO_2 between 2024 and 2032. This scheme is expected to result in 4 million tons of biogenic CO_2 storage over eight years. (21)

Available CO_2 for PtX and CCS – Frozen Policy scenario



Available CO_2 for PtX and CCS – Green Policy scenario



Climate effect

Climate impact in agriculture

Huge synergies between biogas and frequent discharge and cooling of livestock manure.

Like the rest of the society, agriculture faces a significant climate challenge. Agriculture is the only sector with a mandatory greenhouse gas reduction obligation. The climate agreement for agriculture from 2021 requires frequent flushing of manure from existing stables for slaughter pigs and all new pig stables from January 1, 2023.[22]

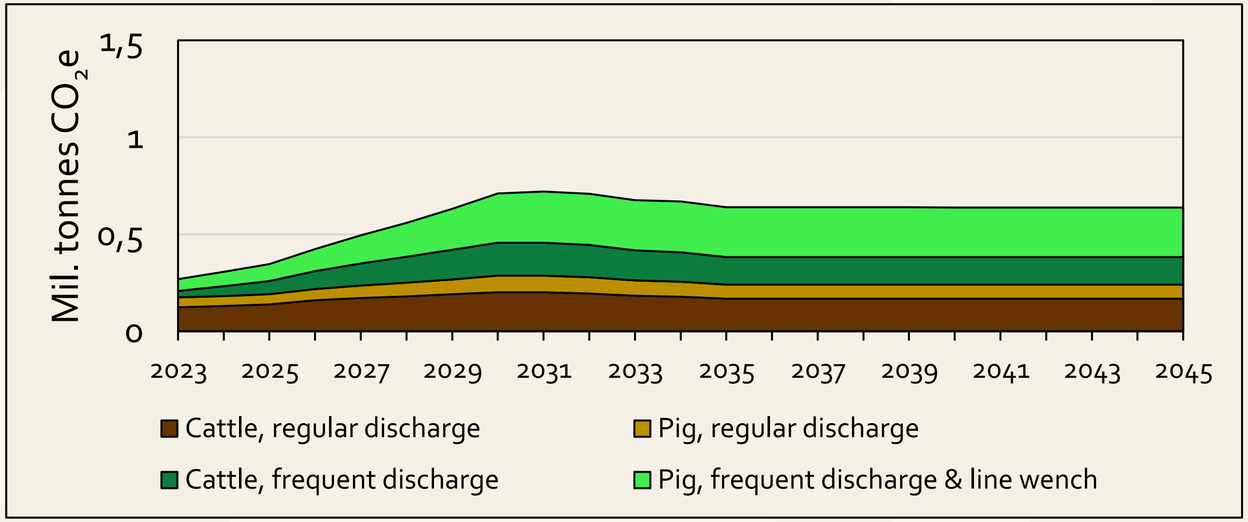
The Danish Agricultural Agency has previously financed a project to assess the climate impact of frequent discharge of liquid manure from pig stables delivered to biogas plants. 400 farms participated.

There was an effect in most existing stables, but it will be even higher in new stables, where frequent discharge with weekly pumping of manure or daily in stables with line winch is established.

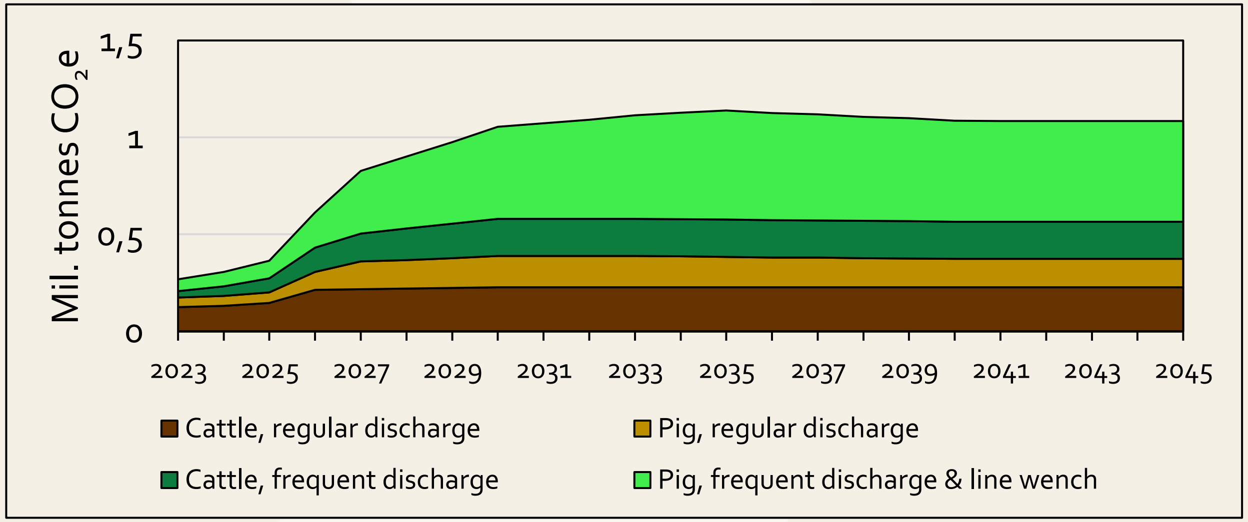
Thus, the anaerobic digestion of livestock manure has an additional climate effect, as methane emission from stables and manure storage is reduced. In addition, the produced biogas substitutes fossil natural gas and thereby reduces the emission of CO_2e.

In the Frozen Policy scenario, the total greenhouse gas reduction is approximately 2.8 million tons of CO_2e by 2030, with agriculture contributing to a roughly 0.7 million tons reduction. In the Green Policy scenario, this reduction increases to 3.8 million tons of CO_2e, with agriculture contributing to a 1.1 million tons of CO_2e reduction.

Climate impact of frequent discharge / cooling of manure – Frozen Policy



Climate impact of frequent discharge / cooling of manure – Green Policy



Biogas Danmark

Climate effect

Climate impact of manure management

Frequent discharge and anaerobic digestion of livestock manure reduces climate impact.

When livestock manure is stored beneath the slattered floors in the stables or in the outside liquid livestock manure storage tanks, there is a natural production and emission of the greenhouse gas methane. When the manure is anaerobic digested in a biogas plant, this methane is collected, thereby reducing the greenhouse emissions in agriculture. In addition, the produced biogas can substitute fossil energy and reduce overall CO_2 emissions.

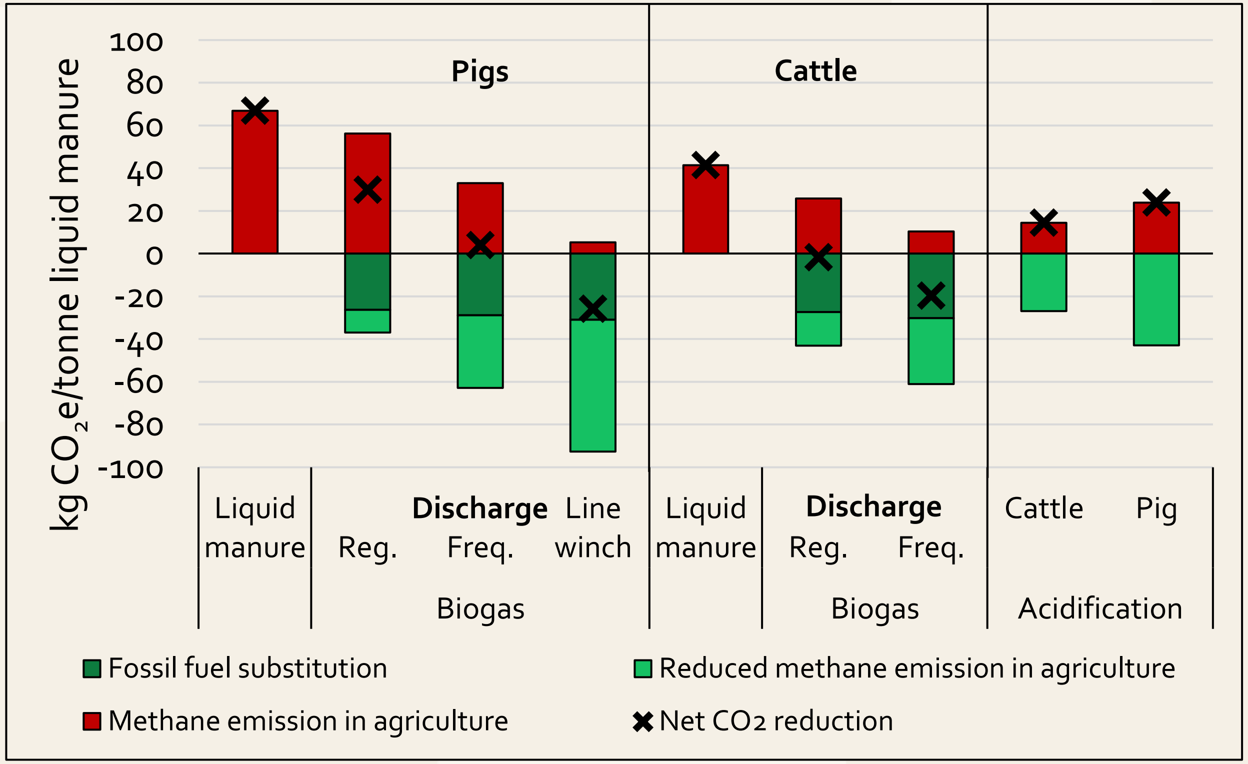
The climate benefit can be optimized by faster delivery of the livestock manure from the stables to the biogas plant, either by pumping once a week or daily via a line winch system.

Proper management of the stables, combined with biogas, can significantly reduce the climate impact of livestock manure.

Alternatively, the farmers can reduce the methane emissions by acidification of the livestock manure with sulfuric acid, but then it cannot be utilized to the same extent in biogas plants.

Acidification does not have the double climate effect of biogas, and therefore both the climate effect in agriculture and the overall net CO_2 reduction are smaller with acidification than with biogas.

Climate benefits from different manure management practices [23, 24]



The figure shows the climate effect of different manure management strategies and technologies. The red is GHG emissions in agriculture. The light green is avoided methane emission in agriculture, while the dark green shows the climate effect of substituting fossil natural gas and diesel with biogas. The black crosses show the net climate effect. In pig production, the most effective technology is line winches with a net climate effect of -25 kg CO_2 per ton of manure, while frequent discharging is most effective in cattle with a net climate effect of about -20 kg CO_2 per ton of manure.

Climate effect

Climate impact in husbandry

Biogas eliminates greenhouse gas emissions from livestock manure

Anaerobic digestion in biogas plants is an efficient tool for reducing methane emissions from livestock manure.

It has the potential to almost eliminate emissions. The benefits are illustrated for two typical farms: one with 400 cows with offspring and another with 1,100 sows fattening all the piglets.

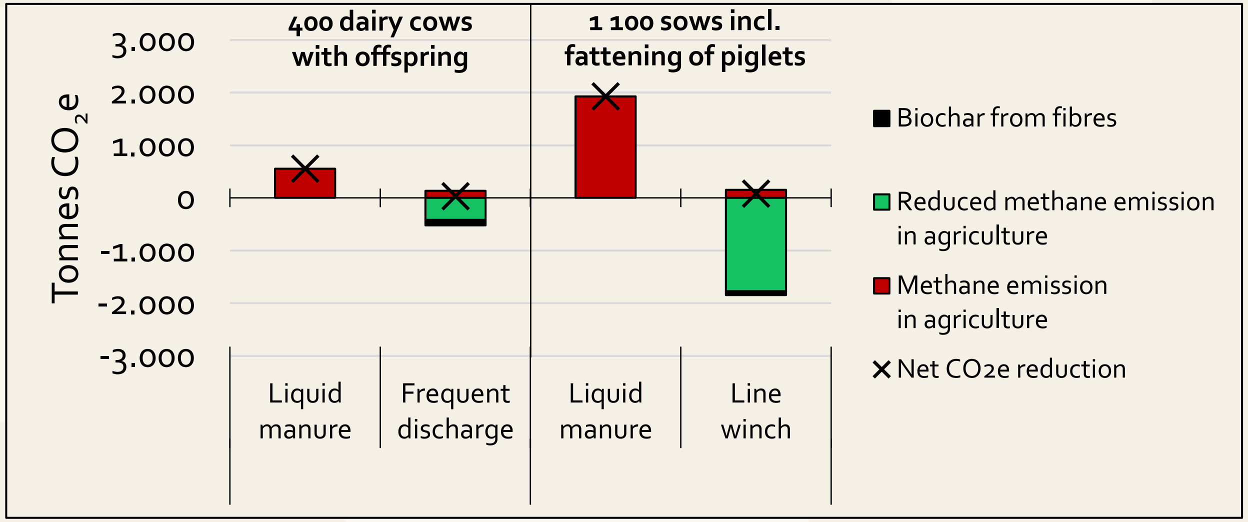
Anaerobic digestion in biogas plants can significantly reduce the methane emissions from livestock manure from cattle and pigs. In both cases, the reduction is up to 95 percent when the manure is delivered fast from the stables to the biogas plant.

An additional climate effect can be achieved if the digestate is separated and the fiber fraction is supplied to a pyrolysis plant. The produced pyrolysis oil and gas can substitute further fossil fuel, and the CO2 absorbed from the atmosphere can be retained for a longer period in the form of biochar.

Reduced methane emissions from the anaerobic digestion of animal manure in biogas plants are an essential tool for reducing agriculture's climate impact.

Biogas Danmark

Climate impact of frequent discharge combined with biogas and pyrolysis of fiber fraction in two typical animal farms



Climate effects measured per animal farm and per ton of manure

Climate effect of biogas, frequent manure discharge, pyrolysis, and biochar		
Tonnes of CO_2e per typical farm	**Dairy cows with offspring**	**Sows with piglets**
Emissions from stable and storage for liquid manure	553	1.926
Emissions after frequent discharge, biogas, and biochar	33	80
Overall on-farm reduction	**520**	**1.846**

Climate effect in agriculture of frequent manure discharge for biogas and pyrolysis of fibre		
kg CO_2e per tonne liquid manure	**Cattle**	**Pigs**
Emissions, liquid manure	41	67
Emissions, digestate	10	5
Effect of biogas	**-31**	**-62**
Biochar from fibres	-8	-3
Reduced emission of greenhouses gases	**-39**	**-64**
Reduced emission of greenhouses gases, percent	**-94**	**-96**

Climate effect

Overall climate impact of optimal management

Significant GHG emission reduction with frequent discharge to biogas plants and pyrolysis.

If 73 percent of livestock manure is frequently discharged from the stables and delivered to biogas plants by 2030, the digestate is separated. The fibre fraction delivered to a pyrolysis plant, the methane emissions in agriculture can be reduced by approximately 1.3 million tons of CO_2e.

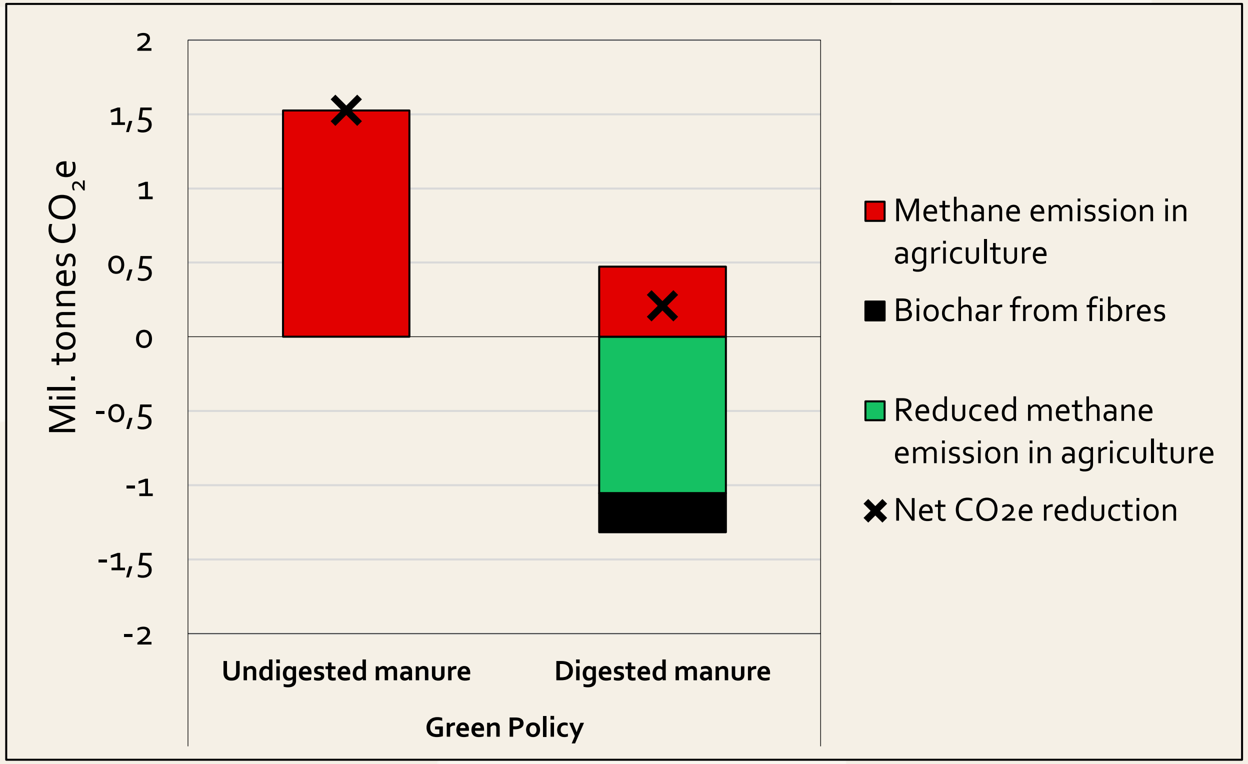
The 73 percent corresponds to the proportion of livestock manure that is anaerobically digested in the Green Policy scenario.

If all livestock manure undergoes this treatment, the reduction is correspondingly increased.

The effects of the individual measures are shown in the figure.

The pyrolysis effect is achieved by depositing biochar from the fibrous part left after the degassing of livestock manure.

Overall climate impact in agriculture when 73 percent of the livestock manure is handled in an optimal way – Green Policy



The figure illustrates the nationwide climate footprint of approximately 73 percent of livestock manure anaerobic digested in the Green Policy scenario. The red column indicates the total emissions if the livestock manure is not frequently discharged out of the stable and delivered for anaerobic digestion in biogas plants. The column on the right shows how much various measures can reduce the climate footprint.

The net emissions for untreated and treated livestock manure are marked with crosses.

Climate effect

Potential climate effect of pyrolysis and biochar

Significant synergies between biogas and pyrolysis

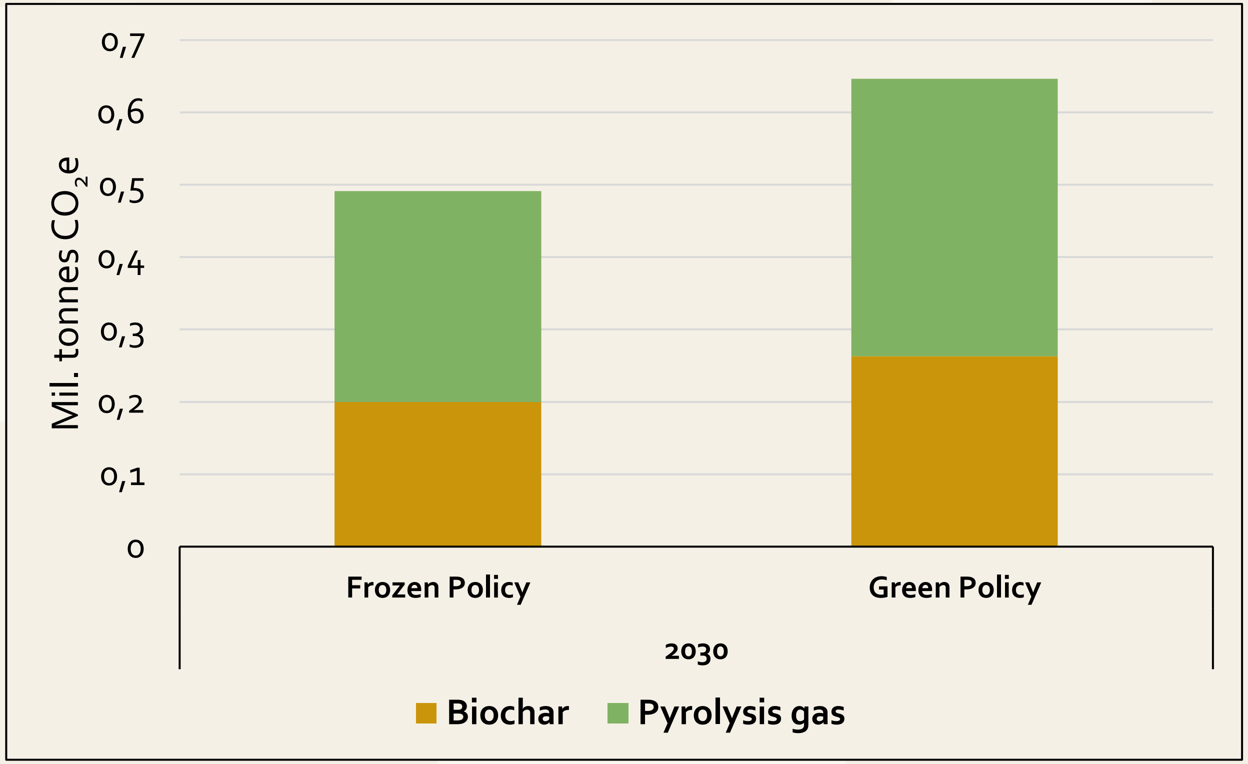
Exploiting the synergies between biogas production and pyrolysis has great potential to improve agriculture's climate performance. The digestate can be separated into a liquid fraction and a fibre fraction.

The liquid fraction contains most of the plant-available nitrogen and is, therefore, an attractive fertilizer. The fibre fraction can either be used as a fertilizer and soil improver or in a pyrolysis plant.

In a pyrolysis plant, the fibres are heated to several hundred degrees. In this process, pyrolysis gas is emitted, and the solid fraction is turned into biochar. The pyrolysis gas is used as process energy to dry the fibre fraction before pyrolyzation. The heat from the drying process can be reused as process energy in the biogas plant's upgrading units.

The carbon-rich biochar can be incorporated into the soil on farms where the carbon is stored for a long time.

Potential climate impact of pyrolysis gas and biochar produced from the fiber fraction of digestate based on livestock manure [25]



The Frozen Policy scenario has a greenhouse gas reduction potential of 0.5 million tons if the digestate is separated and the fibre fraction goes to a pyrolysis plant. In the Green Policy scenario, the potential is around 0.7 million tons. The climate effect of pyrolysis gas is calculated based on its ability to reduce gas consumption, thereby substituting more natural gas. For biochar, a 100 percent long-term effect is assumed.

Biogas Danmark

Climate effect

Life cycle analyses of climate impact from pyrolysis & biogas

Significant CO_2 reduction from pyrolysis and biogas

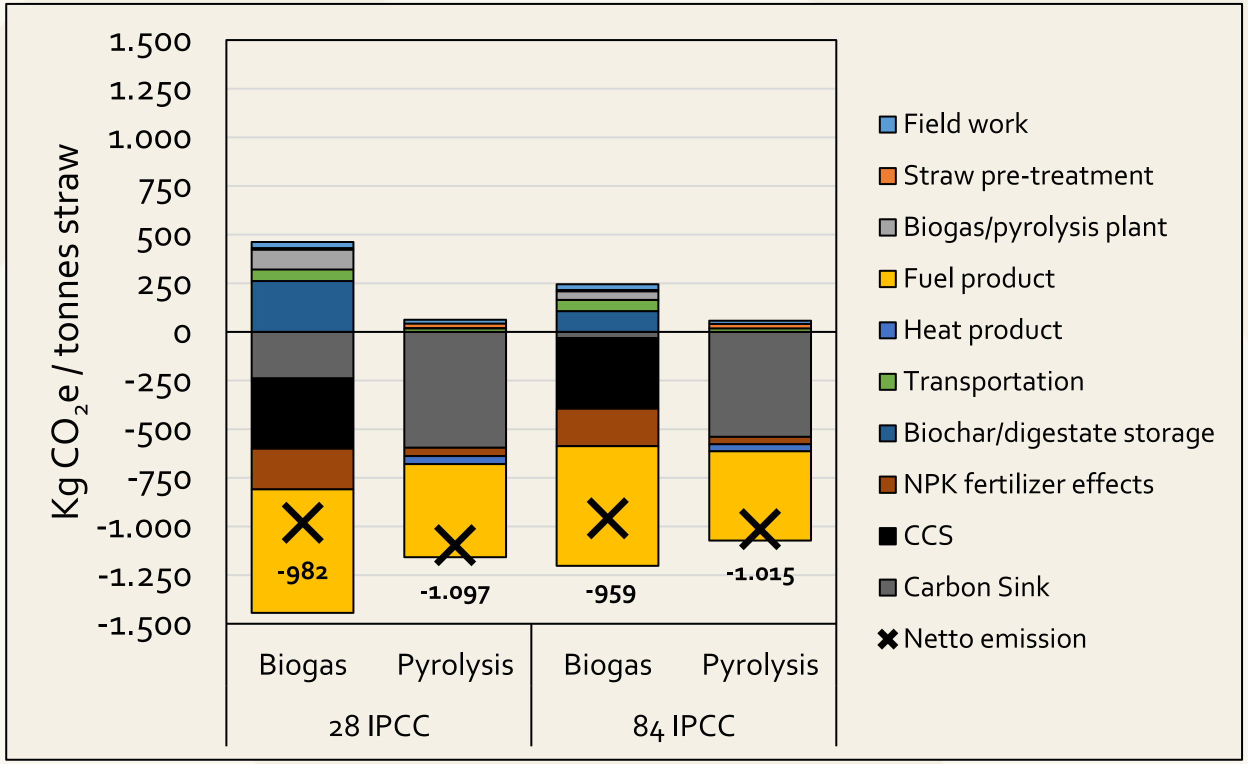
A certified life cycle analysis of the potential of using straw for both pyrolysis and biogas, conducted by RUC in 2021, demonstrates that using straw in combination with manure for biogas production is environmentally beneficial. [26]

Pyrolysis plants convert straw into fuel and biochar, a type of charcoal that is deposited in agricultural soil. Biogas plants transform straw and manure into upgraded biogas and CO2, which are also deposited. The analysis takes into account the impact of their own consumption and biomass transportation, among other factors.

Based on the analysis, both technologies significantly impact the climate and are comparable.

The most optimal solution is to digest the straw in a biogas plant, after which the fibre fraction obtained by separating the digestate is sent to the pyrolysis plant.
The first full-scale facility is currently being constructed at a biogas plant in Jutland.

Comparison of carbon footprint from pyrolysis of straw and biogas with CCS.



In a life cycle analysis, the use of straw for biogas in combination with manure (including CO_2 storage) was compared with the direct pyrolysis of straw. The black markings indicate the total reduction of greenhouse gases in kg CO_2 equivalents per ton of straw at a methane emission factor of 28 (100-year period) and 84 (20-year period). [26]

Biogas Danmark

Climate effect

Overall climate potential of biogas, CCS, and pyrolysis

Full utilization of the potential for CCS and pyrolysis significantly increases the climate impact of biogas

Biogas plants efficiently reduce methane emissions from animal manure in agriculture. In addition, the produced biogas can substitute fossil fuels in the energy sector, industry and heavy-duty transport.

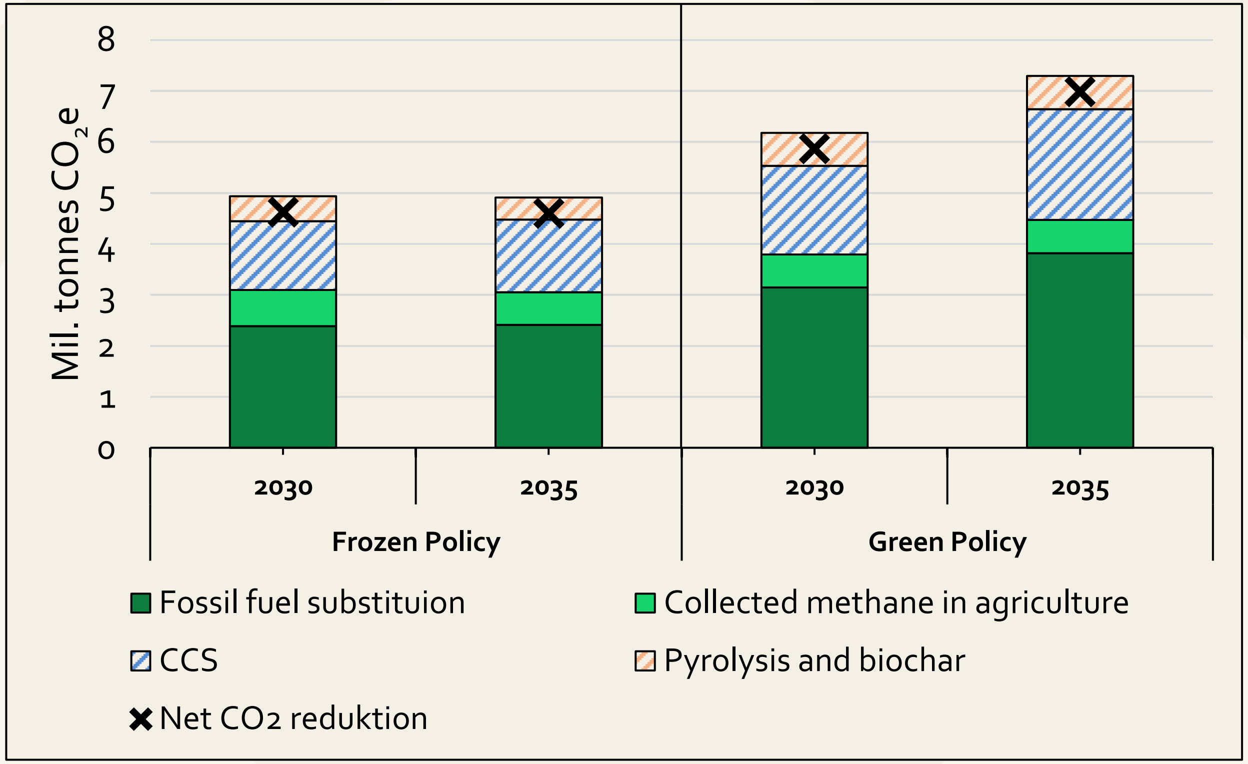
The climate impact can be significantly enhanced by storing the biogenic CO_2 from biogas and treating the residual fibres in a pyrolysis plant. The pyrolysis plant produces pyrolysis gas and biochar. The pyrolysis gas can be used to produce process heat for the biogas plant, and the biochar can be stored in agricultural soil.

In the Frozen Policy, the climate effect will increase from 3.7 million tons to 5.5 million tons of CO_2e by 2030 if the potentials in CCS and pyrolysis are fully utilized.

In the Green Policy scenario, fully utilizing the potentials of Carbon Capture and Storage (CCS) and pyrolysis will amplify the climate effect to 5.9 million tons of CO_2 equivalent by 2030.

Biogas Danmark

Potential climate impact of biogas, CCS, and pyrolysis in 2030 and 2035



The diagram illustrates the potential climate impact of biogas, CCS and pyrolysis combinations. The dark green represents the climate impact of replacing natural gas and diesel with biogas. The light green indicates the reduced methane emissions from livestock manure due to anaerobic digestion in biogas plants. The shaded areas represent the potential climate impact of CCS, pyrolysis gas, and biochar. The climate impact of net CO_2 reduction, marked with the black crosses, considers 1 percent methane leakage and energy consumption involved in biogas production and transportation.

Circular economy and effects in agriculture.

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Circular economy

Phosphorus recycling

Biogas plants recycle scarce resources.

In biogas plants, significant volumes of residues from agriculture, households and industry are digested, ensuring the recycling and reuse of the content of nutrients as fertilizer.

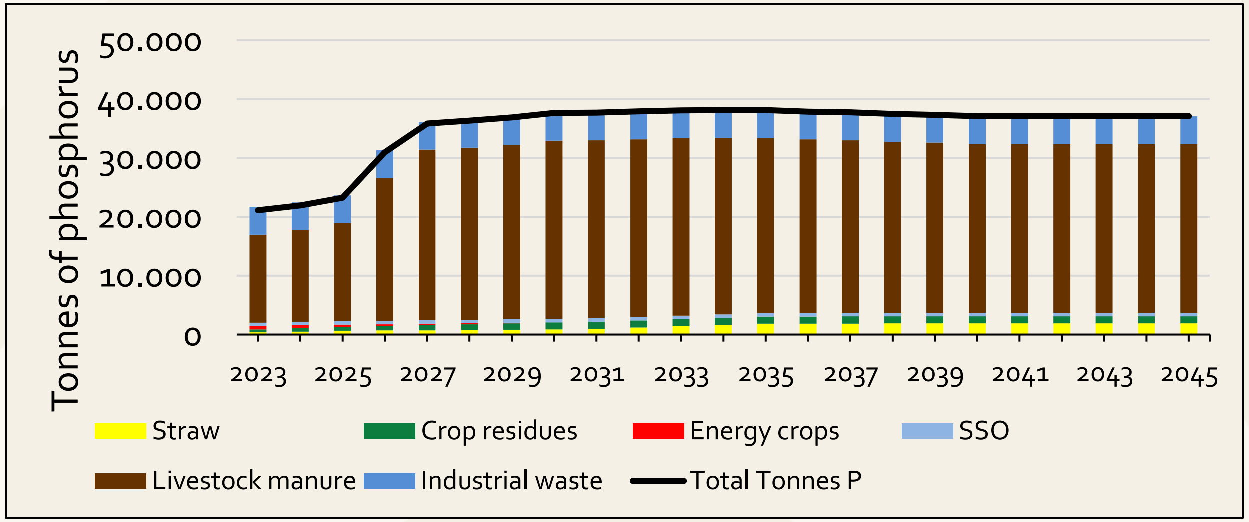
The most considerable quantities of phosphorus in the feedstock are in livestock manure, but significant amounts of phosphorus are also recycled from residues from industry and food waste from households.(27)

In the Green Policy scenario, biogas plants will recycle approximately 37,500 tons of phosphorus by 2030, of which almost 5,800 tons will come from industrial and food waste. About 2,100 tons of phosphorus will be recycled from agricultural straw and crop residues.

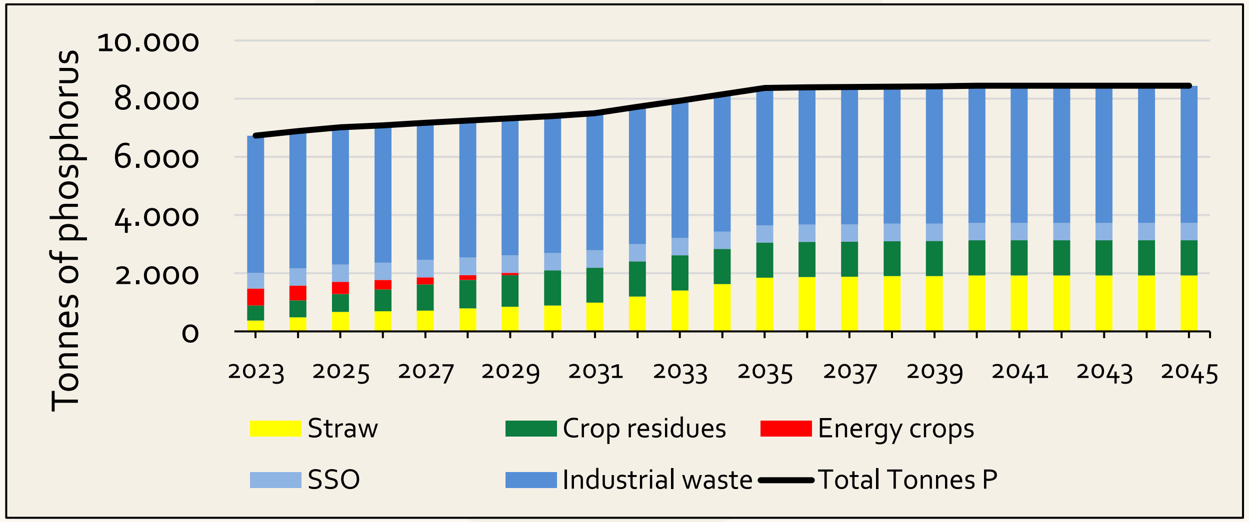
In comparison, 13,500 tons of phosphorus is applied to Danish crops in commercial fertilizers. (28)

Both figures relate to the Green Policy scenario

Phosphorous handled in livestock manure and industrial waste via biogas plants



Recycled phosphorus via biogas plants



Biogas Danmark

Effects in agriculture

Reduced nitrogen leaching to the aquatic environment

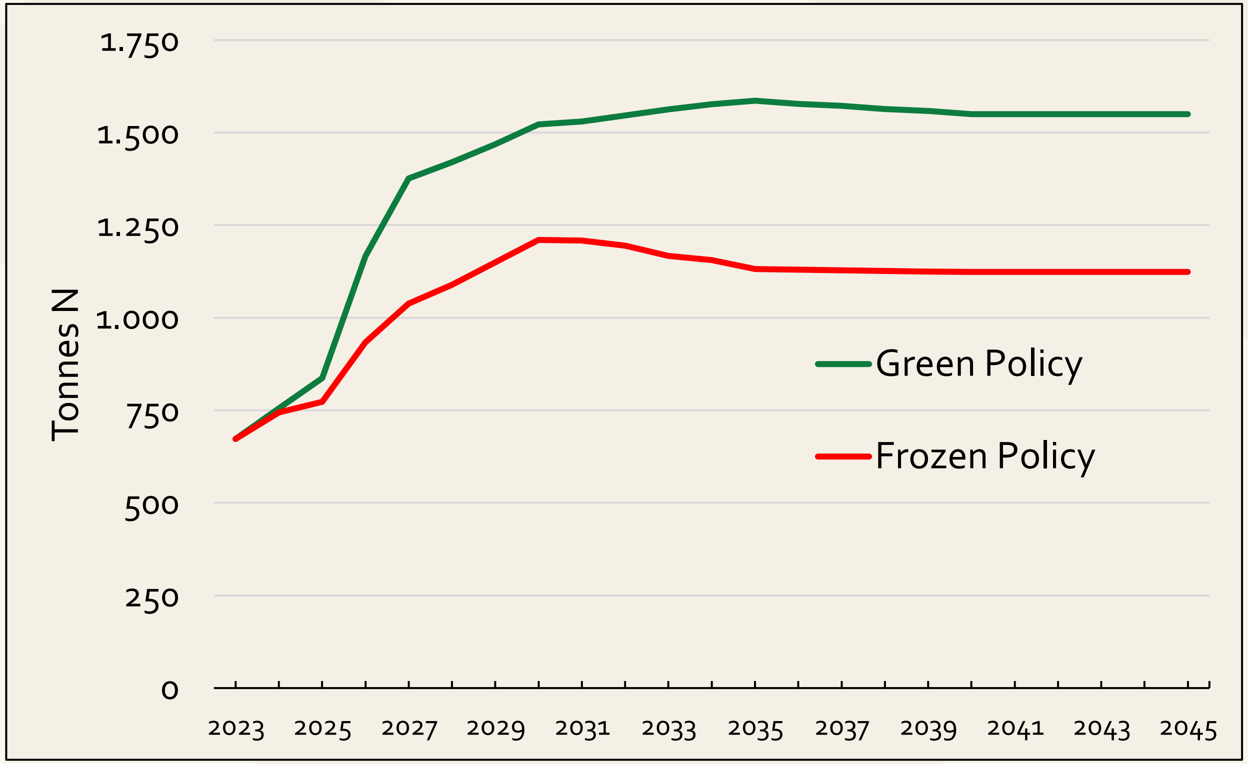
Biogas plants can contribute to the agricultural agreement's goal of lower nitrogen emissions

When livestock manure is digested in biogas plants, the nitrogen is converted into a form that crops can readily utilize as a natural and efficient source of fertilizer. This results in improved plant growth, increased yields, and a reduced risk of nitrogen leaching into the aquatic environment.

In the 2021 agricultural agreement, the Danish Parliament has set a target to reduce nitrate leaching by 10,400 tons by 2027,[22] to meet the European Union water quality goals. The production of 40 petajoules of biogas in the Frozen Policy scenario, where 54 percent of the livestock manure is digested in biogas plants, will reduce the leaching with approximately 1,050 tons of nitrogen per year by 2027.

With Biogas Danmark's Green Policy proposal, the increased and earlier digestion of animal manure will reduce nitrogen emissions by 1,400 tons per year by 2027.

Annual reduction in nitrogen leaching through digestion of livestock manure.



According to the Frozen Policy scenario, anaerobic digestion of 54 percent of the livestock manure by 2030 could reduce the nitrogen leaching by nearly 1,200 tons. If the biogas production is increased according to the Green Policy scenario, nitrogen leaching could be further reduced to almost 1,500 tons annually by 2030. [29]

Biogas Danmark

Effects in agriculture

Synergies between biogas and organic farming

Biogas plants can support organic agriculture.

Recycling nutrients from food waste and agricultural and industrial residues via biogas plants can enhance the political objective of doubling the organic acreage.

According to SEGES Innovation, the conversion of 300,000 hectares to organic farming depends on 60,000 hectares of clover grass, which can collect nitrogen from the atmosphere.[30] If there is no market for clover grass as feed, it can be utilized in biogas plants to produce energy and fertilizer. Compared to ploughing it down, the anaerobic digestion of the biomass in the biogas plants reduces the risk of nitrogen leaching and greenhouse gas emissions.

1.4 million tons of clover grass silage from 60,000 hectares can produce nearly five petajoules of biogas. Biorefineries extracting protein for feed and food from grass are expected to be developed in the future. This will generate significant quantities of byproducts that can be used for feed or biogas production. If the fibres are used as cattle feed, the liquid residue has a biogas potential of around 0.9 petajoules. If both the fibre and liquid residues are utilized in biogas plants, they produce 3.8 petajoules of biogas.

Biogas potential from approximately 60 000 hectares of organic clover grass.

In organic farming, the cultivation of clover grass is essential to supply crops with nitrogen. The clover grass can be utilized in biogas plants if it cannot be used as feed for ruminants. In the future, it can probably be utilized in bio-refineries that extract protein from which the residues, fibre and brown juice can also be used for biogas and feed production. Source: SEGES Innovation. [30]

Biogas Danmark

Effects in agriculture

Biogas and biorefineries

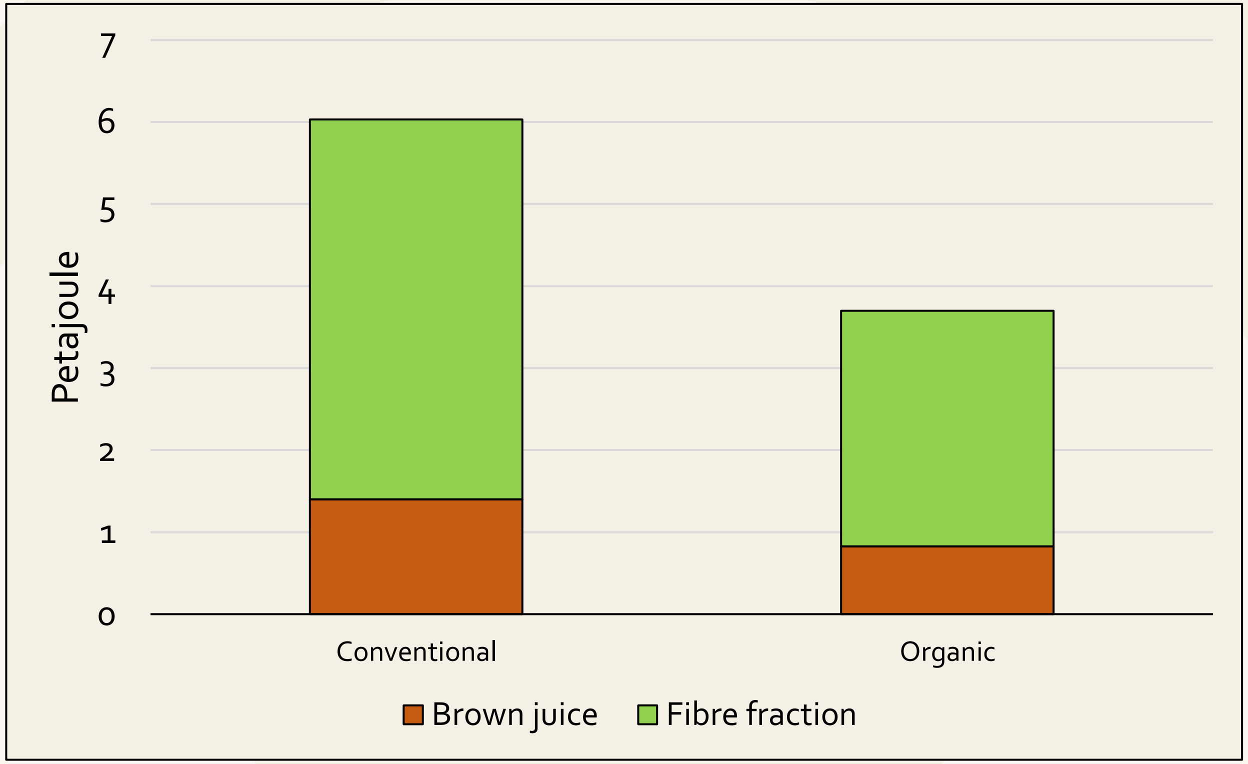
Biogas plants supports green biorefineries.

There is a growing interest in replacing imported protein with domestically produced protein from biorefineries that extract protein from green crops. In the coming years, the Ministry of Food, Agriculture and Fisheries will implement a subsidy scheme for feasibility studies and the establishment of biorefineries. The focus is on synergies between biorefining and biogas, which can ensure sustainable utilization of byproducts for energy and fertilizer.

SEGES Innovation has assessed the biogas potential in the byproducts from biorefineries, which yielded 50 000 tons of conventional and 30 000 tons of organic protein, respectively. The production of such quantities requires 56 500 hectares of organic clover grass and 74 000 hectares of conventional grass, respectively.

If the brown juice and fibre fraction are utilized for biogas production, the total biogas potential is estimated to be 9.7 PJ. If only the brown juice is anaerobically digested in biogas plants, the biogas potential would be 2.2 PJ.

Biogas potential from biorefineries handling grass from 74 000 hectares of conventional clover grass and 56 500 hectares of organic clover grass.



Source: Seges Innovation. [30]

Denmark imports approximately 700 000 tons of crude protein annually. In addition, 30 000 tons of protein are imported annually for organic feed, which can be substituted with Danish grass protein.[31]

Economy and market

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Biogas Danmark

Economy and market

Guarantees of origin

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

Biogas producers sell upgraded biogas via the gas networks to customers in Denmark and internationally.

The independent organization, Energinet, owned by the Ministry of Climate and Energy, is responsible for issuing **G**uarantees of **O**rigin (GO) for every biogas injected into the gas grid.

To make a green choice, gas customers must buy the GO in addition to the gas. The specific GO is then cancelled in Energinet's register, verifying that the gas has been utilized and cannot be resold.

In Germany and other countries, the authorities recognize GOs as a basis for CO_2 tax refunds in case of unsubsidized biogas.

In Denmark, GOs are recognized in CO_2 quota purchases but are not yet recognized for tax refunds.

Flow of biogas and related guarantees of origin and national differences in CO_2 tax refund.

Biogas Danmark

Economy and market

Guarantees of origin and sustainability certification

Guarantees of origin documents the origin - sustainability certificates declare sustainability

Origin guarantees are used in the market to document the source of biogas, whether it has received support, and to ensure it is used only once. The supply chain will be documented in the new EU database UDB from 2024 onwards.

The sustainability aspects, such as the carbon footprint and the bio-resources used, are certified by an EU-accredited organization like ISCC, RedCert, or similar.

The market price of the guarantees of origin depends on the sustainability certification.

Customers of biogas receive:

1. A receipt from Energinet, which confirms the transfer and cancellation of guarantees of origin from a specific producer, along with information on its subsidy status

2. A sustainability declaration for the delivered gas containing information regarding its climate footprint. The climate footprint is typically determined based on standard values outlined in the RED II directive, based on the "Cradle to Grave" principle.

Sustainability Statement - Biomethane

Company Name	
Contact Name and telephone number	
Customer	
Production site	
Item Short Name and name	
Batch number	

The product that was delivered to the costumer complies with requirements in EU Renewable Energy Directive 2009/28/EC "RED"

GHG Emission CO2eq/MJ – values and savings have been calculated according to the methodology in Directive 2009/28/EC.

The reference GHG value in RED/Directive 2009/28/EC for fossil transport fuel is equal to 83,8 g CO2eq/MJ.

An example of a sustainability certificate section is where the carbon footprint is certified according to EU-approved certification systems and by approved auditors.

Economy and market

Distribution of costs and revenues for biogas

The economy of the biogas supply is challenged due to the lack of opportunities to sell origin guarantees.

Unlike wind and solar power plants, biogas plants' production costs are not dominated by investment costs but by operational expenses, with the costs for acquiring and managing biomass being the most significant.

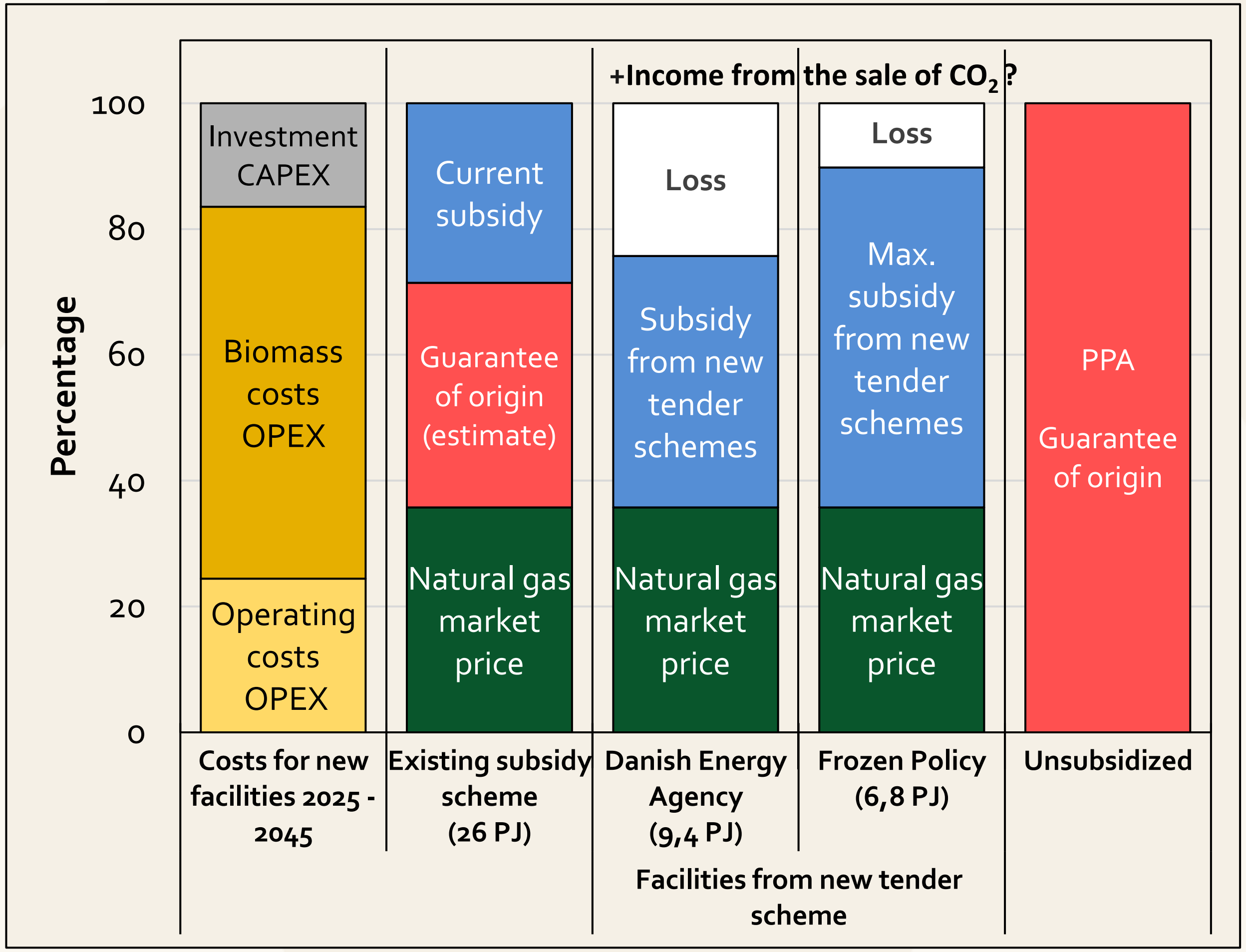
Economies of scale have already reduced investment and operating costs for larger biogas plants.

The figure shows that the decided lack of opportunity to supplement the subsidy with sales of origin guarantees in the upcoming tenders challenges the realism in increasing biogas production. Therefore, increased biogas production depends on CO_2 substitution requirements and CO_2 tax refunds in several European countries. Denmark has not secured similar market conditions for unsubsidized biogas with origin guarantees as documentation.

As a result, Denmark is losing renewable energy shares to purchasing countries, resulting in a corresponding revenue loss.

Biogas Danmark

Costs, revenues, and potential subsidy needs for biogas plants



The figure illustrates the fundamental correlation between production costs [32], market revenues, and need of subsidy for biogas delivered via the gas grid. The two pillars regarding the upcoming bids indicate a significant loss in the industry if biogas production is to reach the Energy Agency's expectation of 9.4 PJ. Even if the maximum subsidy cap is exploited as in the Frozen Policy, resulting in the production of only 6.8 PJ, the economics of the bids will still be unfavorable.

Economy and market

Climate effect of biofuels according to the RED II

Are used in the market to comply with CO_2 reduction obligations

To ensure a consistent basis for assessing the sustainability of fuels used in the transport sector, the EU has established a comprehensive list of standard values in the Renewable Energy Directive II. These can be used without further documentation and represent a "cradle to grave" approach.

This is evident, for example, in the emissions value for diesel being 94 rather than 74 kg of CO_2 per GJ, which is the CO_2 content of diesel. Upstream emissions are, therefore, included. For the same reason, biogas produced from manure has a negative value, as biogas plants reduce methane loss in agriculture. (33) These values are particularly significant in countries that have implemented CO_2 displacement requirements. As shown, biogas from manure can displace nearly five times more CO_2 per GJ than biodiesel.

When an actor's over-fulfilment of a displacement requirement triggers a CO_2 ticket, which can be sold to actors who under-fulfil the requirement, these values provide a strong economic incentive to choose sustainable fuels.

Climate effects according to the RED II directive and the Sustainability Ordinance

RES II Directive [kg CO2eq/GJ]	GHG emissions [Diesel]	GHG emissions [Default value]	GHG emissions [CCS]	Emission savings compared to diesel	Emission savings in per cent
Biogas:					
Manure	94	-100	-31	**225**	**239%**
Organic waste	94	14	-31	**111**	**118%**
Maize	94	30	-31	**95**	**101%**
Biogas, 2025	94	-25	-31	**150**	**160%**
Biodiesel:					
Waste oil (HVO)	94	15		**79**	**84%**
Rendered animal fat	94	20		**74**	**79%**
Rapeseed (1.gen.)	94	50		**44**	**47%**
Emmelev (1.gen.)	94	20		**74**	**79%**

The table displays selected standard values for carbon footprint and reductions. These are approved in the Renewable Energy Directive for calculating CO_2 substitution in the transport sector. (33) Individual values can be used to the extent that they are certified according to the Renewable Energy Directive. Biogas Danmark estimates the carbon footprint for Carbon Capture and Storage (CCS). This calculation includes the self-consumption for transport and storage, estimated at approximately 7 kg of CO_2 equivalent per GJ.

Biogas Danmark

Economy and market

CO_2 reduction obligations in the transport sector

Differences in climate ambitions between Denmark and Germany hamper Denmark's carbon footprint.

From January 1, 2022, Denmark has implemented a CO_2 displacement requirement, mandating a reduction in CO_2 emissions from fuels supplied to the transport sector. Only unsubsidized biofuels, including biogas, can be used to meet the CO_2 displacement requirement.

Climate requirements for the transport sector are significantly higher in Germany than in Denmark. The high German CO_2 displacement requirement has a knock-on effect of making German diesel more expensive than Danish diesel. Consequently, German hauliers are filling up on diesel in Denmark, adversely impacting Denmark's climate balance and reducing the effect of the German CO_2 substitution requirement.

Simultaneously, Danish biogas producers find it attractive to sell biogas via the gas grid with origin guarantees and liquefied biogas (LBG) delivered by truck to the German transport market.

With the upcoming Renewable Energy Directive III (VEIII), the renewable energy shares follow the origin guarantees abroad. At the same time, the export of LBG by truck means that the climate effect of the biogas shifts abroad.

Biogas Danmark

CO_2-displacement requirement for the Danish and German transport sector

CO_2e displacement requirement	2025	2030
Denmark's displacement requirement	5,2%	7,0%
ILUC requirement	Pending	Pending
Germany's displacement requirement	**10,5%**	**25,0%**
ILUC non-food factor value	2	2
ILUC max. 1st generation displacement	4,4%	4,4%
New legislative proposal	2,1%	0,0%

The table shows the Danish[34] and German [35] transport sector's CO_2 displacement requirements. The German ILUC requirements mean that the climate effect is multiplied by a factor of 2 for non-food-based biofuels. Additionally, there is a limit to how much CO_2 substitution requirement can be met with first-generation biofuels.

Biogas Danmark suggests tightening the Danish CO_2 substitution requirement by increasing the CO_2 substitution requirement towards 2030 and introducing so-called ILUC requirements, which account for indirect CO_2 emissions from food-based biofuels. Germany already manages this requirement with a factor system and an absolute cap.

Economy and market

Taxes on biogas for transportation

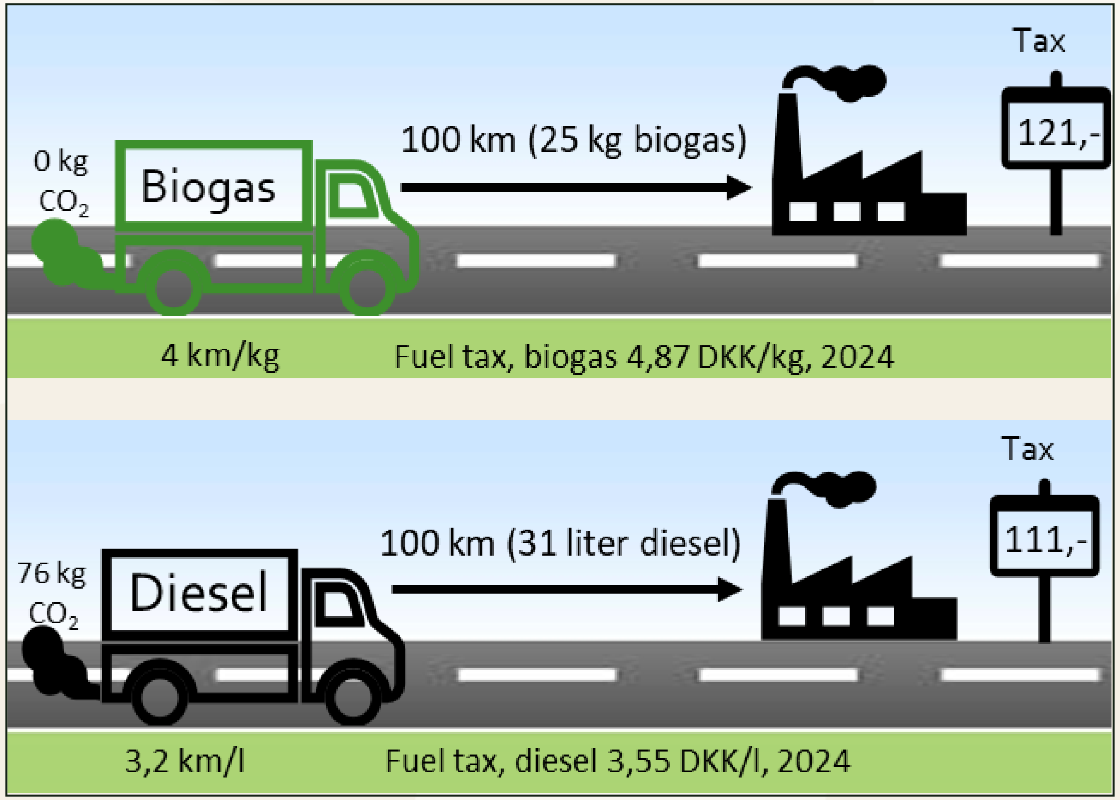
Biogas reduces CO_2 emissions in the transportation sector, yet it is taxed as a fossil fuel.

Using unsubsidized biogas in trucks is part of Denmark's CO_2 displacement requirement. Despite this, biogas is taxed with a CO_2 levy as if the biogas trucks were using fossil natural gas. Furthermore, the fuel tax per kilometer is higher for a biogas truck than for a comparable diesel truck.(36) From January 1, 2025, biogas-powered trucks will also be taxed with a new kilometer-based road charge.

As part of the Green Tax Reform, the energy tax is converted to a CO_2 tax. Under the current framework, this change will result in an increased CO_2 tax for biogas while providing tax relief for food-based biofuel, which is exempt from CO_2 tax. Thus, the tax reform further distorts competition in favor of food-based biofuel, while extra taxation is imposed on biogas based on livestock manure, organic waste, and residual products.

Biogas Danmark's Green Policy scenario is, therefore, based on a proposal to introduce a CO_2 tax refund for unsupported biogas supplied via the gas grid.

Fuel tax on biogas and diesel used in the transport sector



Even today, the use of biogas for transport is taxed with a higher CO_2 and energy tax per kilometer than a comparable diesel truck. For a diesel truck that travels 100 km, a fuel tax of 111 DKK is paid, while 121 DKK is paid for a comparable biogas truck travelling the same distance. Even though the diesel truck emits 76 kg of CO_2 on the trip, the biogas truck does not impact the climate.

Biogas Danmark

Economy and market

CO_2 tax refunds on biogas delivered via the gas grid

Tax refunds give foreign companies an advantage

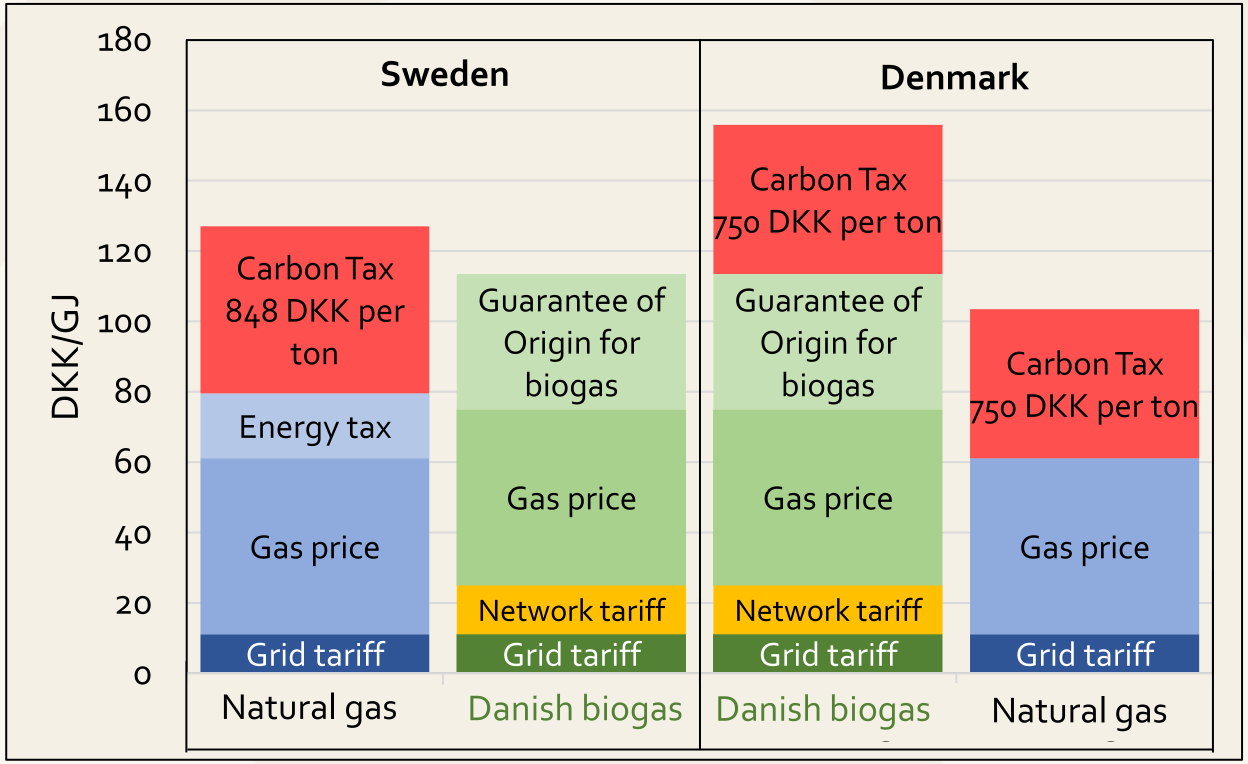
The Danish tax system differs significantly from that of Germany and Sweden, which is why a large part of the biomethane produced on Danish biogas plants is exported.

In Denmark, gas consumers are charged the same taxes for climate neutral biogas as they are charged for fossil natural gas. In Sweden, industries have to pay significantly higher CO_2 taxes on natural gas than their Danish counterparts. Still, they have achieved full tax refunds when purchasing biogas, which are documented with guarantees of origin from Denmark. The European Court of Justice has rejected the Commission's state aid approval of the Swedish tax exemption for subsidized Danish biogas. However, this does not change the considerations for unsubsidized biogas.

In an agreement on green tax reform from June 2022, the Danish Parliament has agreed to analyze the possibilities of introducing a CO_2 tax refund for unsubsidized biogas delivered via the gas network documented via guarantees of origin. This would provide a level playing field with biogas delivered directly from biogas plants to industry.

Biogas Danmark

Gas costs for non-ETS-based industry in 2030.



Swedish process industries have a strong tax incentives to choose climate-neutral Danish biogas compared to natural gas. In Denmark, however, the process industry has no tax incentives to choose biogas unless there is an opportunity for CO_2 tax refunds for biogas delivered via the gas grid documented with guarantees of origin. The figure shows the difference in expected energy costs and taxes for Danish and Swedish companies in the non-ETS sector in 2030, depending on whether they purchase Danish biogas or fossil natural gas..

Economy and market

Export of biogas and renewable energy shares

Over 85 percent of biogas exported in 2023

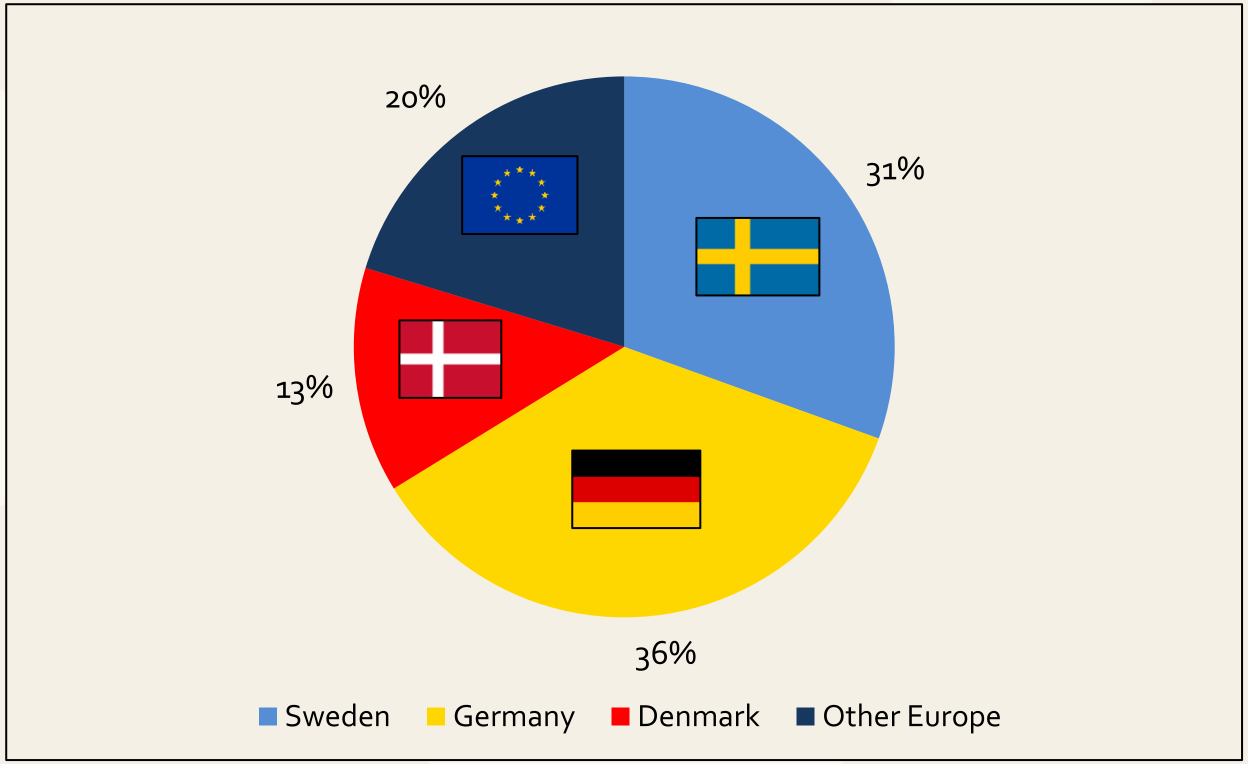
Over the years, foreign companies have purchased most Danish-origin guarantees for biogas delivered to the gas grid. Sweden and Germany dominate these markets. A 2023 estimate shows that foreign companies bought 87 percent of the biogas.[38]

The high export of Danish biogas is mainly because the tax authorities in Sweden and Germany accept the EU-based origin guarantees. These guarantees can be used to refund high CO_2 taxes in these countries.

Since Denmark hasn't had high CO_2 taxes or the opportunity for tax refunds for biogas delivered via the gas network, Danish companies haven't had the same incentives to choose climate-neutral biogas over fossil natural gas.

Biogas Danmark's Green Policy proposal introduces several incentives to buy unsupported biogas, documented with origin guarantees, in the Danish market. This would lay the foundation for an increased production of unsupported biogas in Denmark. Consequently, a larger share of the EU-obliged renewable energy shares would end up in Denmark, with Danish gas customers wanting a green profile.

Export of Danish biogas in 2023



The figure displays the distribution of origin guarantees for Danish-produced biogas among the countries that purchased these guarantees in 2023. [37]

Climate impact remains in Denmark – Renewable energy shares are exported
Origin guarantees allow foreign companies to get tax refunds and promote their green energy consumption. Even though these guarantees, and thus the biogas, are exported, the climate impact of biogas production is still included in Denmark's national climate calculations. However, implementing the upcoming Renewable Energy Directive III means the renewable energy shares will follow the export of origin guarantees. For biogas, this will reduce Denmark's current renewable energy share obligation by 60 percent by 9 percentage points.

Biogas in EU

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Biogas in EU

Biogas production in EU countries

High biogas production in Denmark arouses interest in many European countries

In 2022, the combined production of biogas and upgraded biogas reached a volume of 223 TWh, equivalent to 21 billion cubic meters. This amount exceeds Poland's total domestic gas consumption, representing 5.9 percent of the EU's total gas consumption for that year.(38)

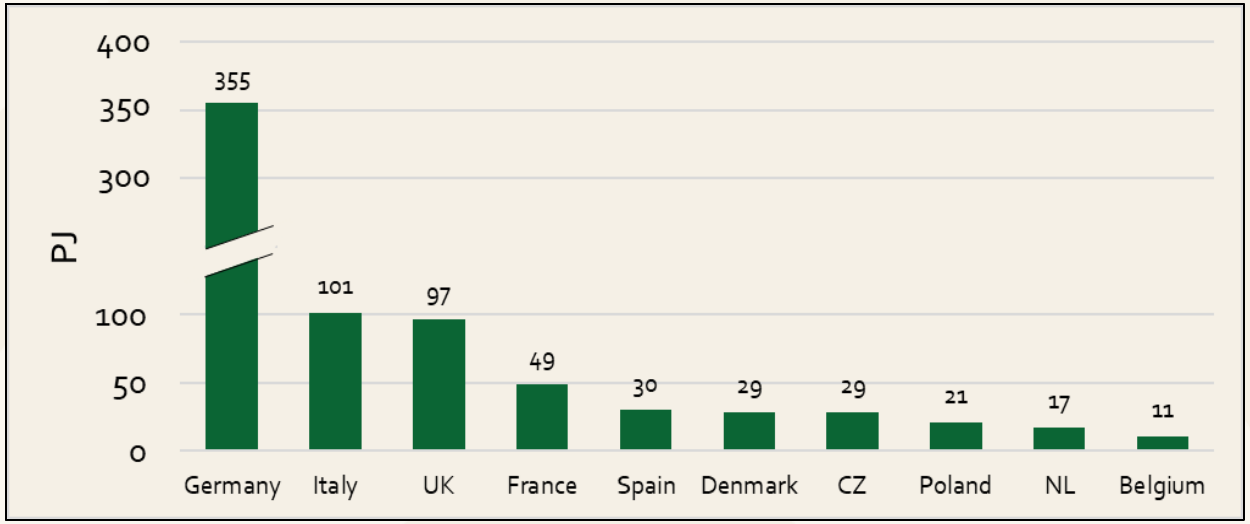
Despite Denmark's geographical constraints and relatively small size, we have achieved a comparatively high biogas production. When comparing the total biogas production per capita in different countries, only Germany comes close to our level. However, Denmark still surpasses Germany with a margin of around 15 percent measured per inhabitant.

On the other hand, Danish production per capita is three to five times higher than in many countries. This has sparked international interest in learning from Denmark's experiences and technologies. This is reflected in the frequent visits from abroad to the Danish biogas industry.

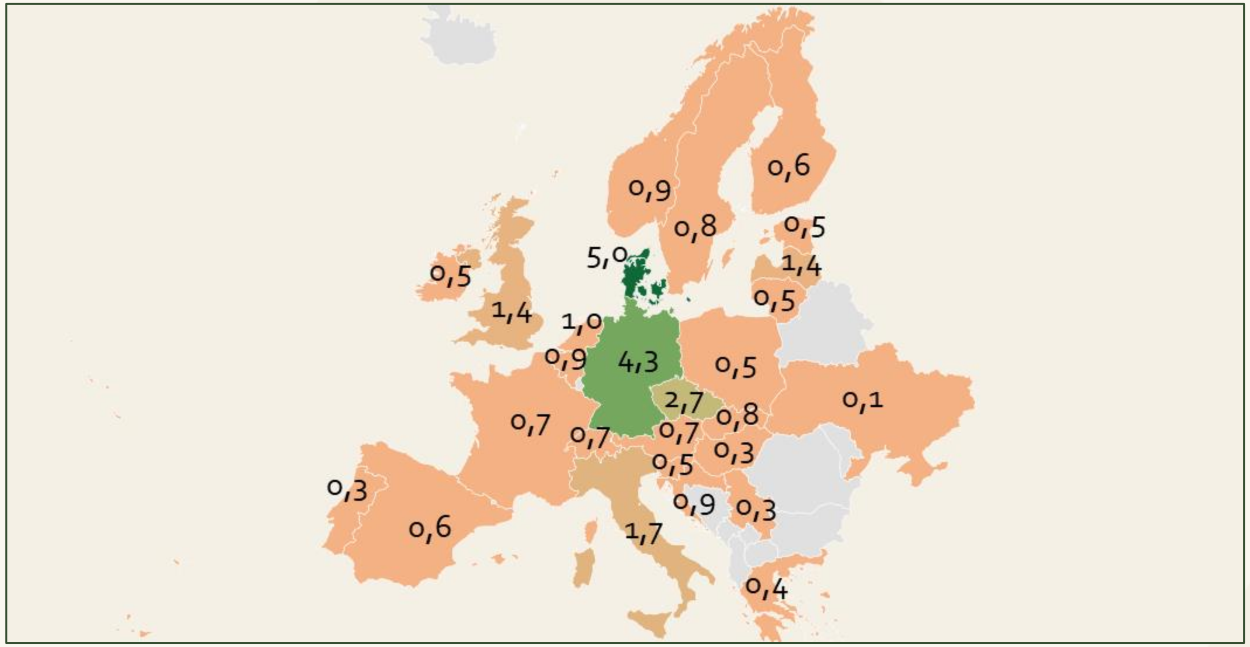
The data in the figures comes from the European Biogas Association, EBA Statistical Report 2023

Biogas Danmark

Total biogas production for the 10 countries with the most significant production in the EU (38)



Biogas production per inhabitant in EU countries. (GJ/person)



Biogas in EU

Production of upgraded biogas in the EU

European countries are catching up to Denmark

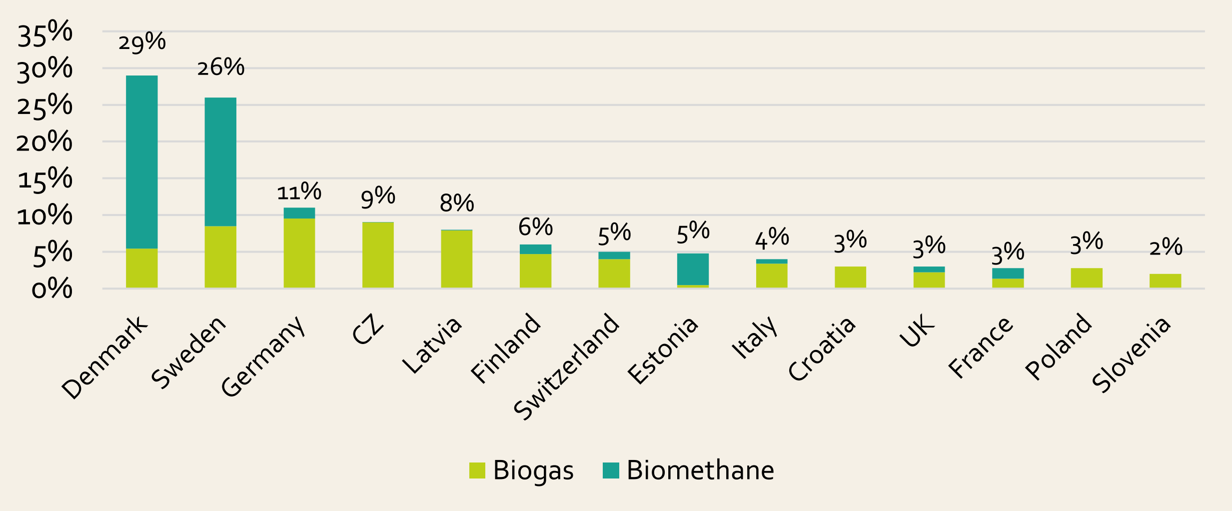
On a European level, Denmark is the fourth-largest producer of upgraded biogas, only surpassed by Germany, France, and England.

In 2022, several countries experienced significant growth in upgraded biogas production. These include France (+ 2 634 GWh), Italy (+ 2 125 GWh), Denmark (+ 819 GWh), and the United Kingdom (+ 713 GWh).

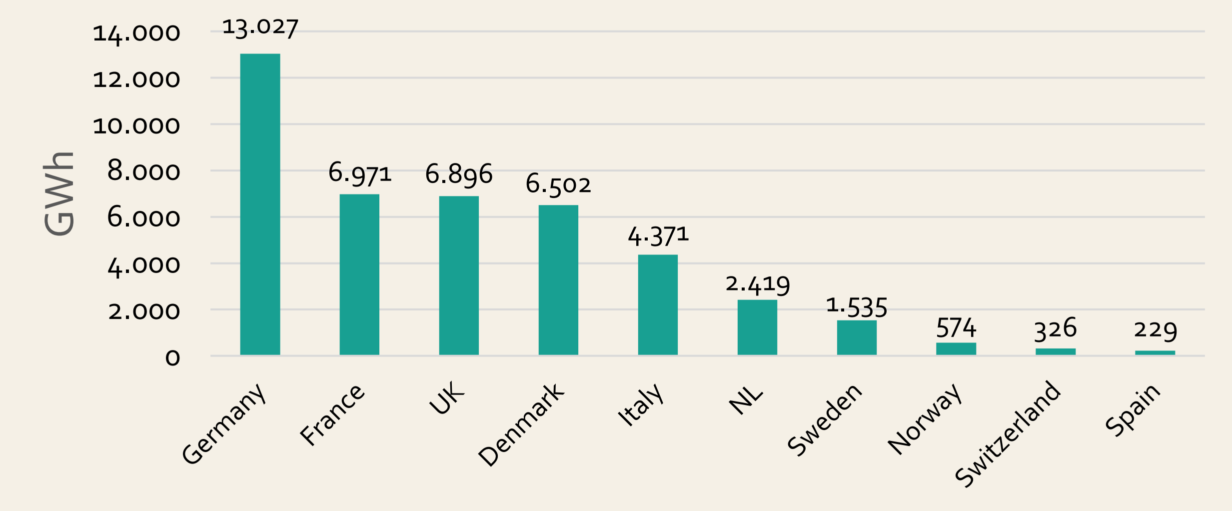
By 2023, the proportion of biogas supplied to the gas grid in Denmark reached approximately 40% of the country's gas consumption. When considering the biogas that substituted gas outside the network, this figure rises to 45%.

However, as highlighted in this edition of the Biogas Outlook, Denmark has experienced a stagnation in the development of biogas production since October 2022.

Biogas and upgraded biogas vs. natural gas consumption in 2022 for the top 15 countries *(38)*



Upgraded biogas production for the ten countries with the most significant production in the EU, 2022 *(38)*



The data in the figures comes from the European Biogas Association, EBA Statistical Report 2023

Biogas Danmark

Biogas in EU

Biogas potential in the EU

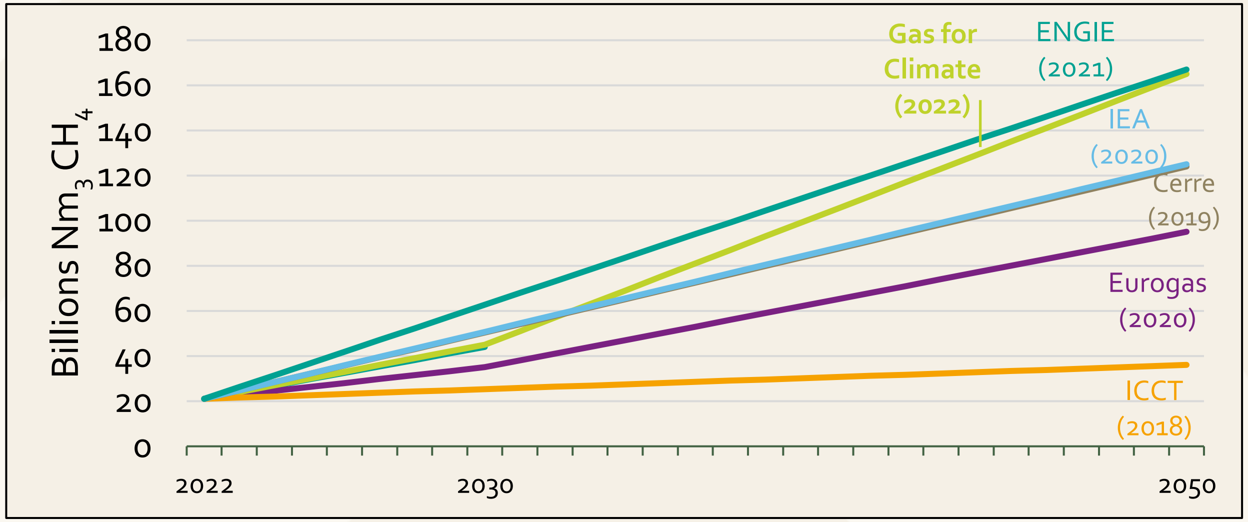
Denmark as a pioneer country in the EU

There is a production potential for upgraded biogas[38] in EU countries, Norway, Switzerland, and the UK, which is expected to be within the range of 95-167 billion cubic meters by 2050. Therefore, upgraded biogas in European gas grids is expected to meet between 30 and 60 percent of the anticipated gas demand in 2050.

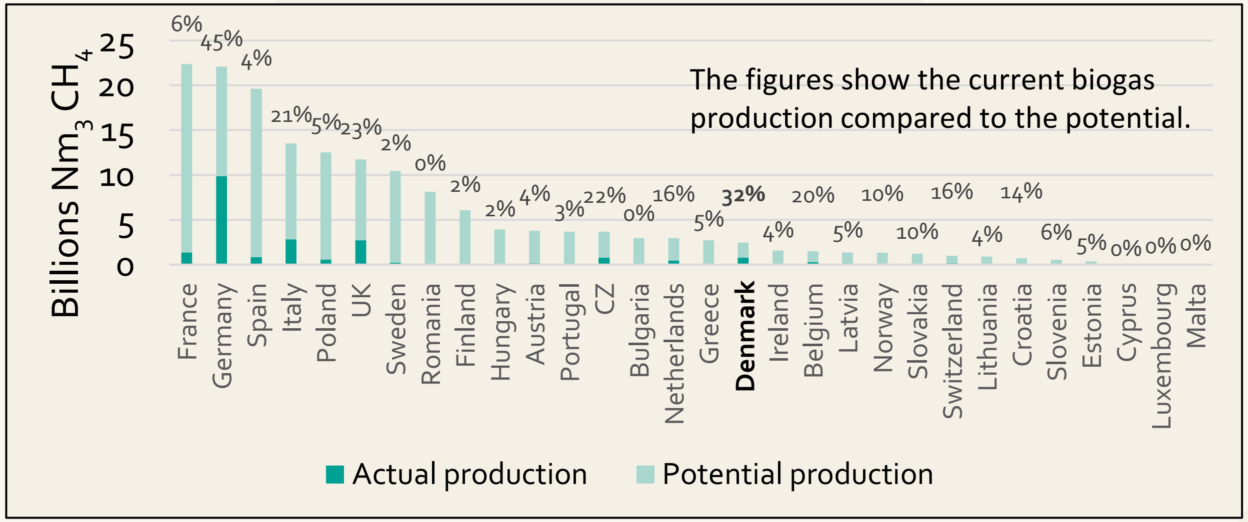
On a national level, France, Germany, Spain, and Italy have the most significant production potential for upgraded biogas in 2050. Several countries, including Germany, Denmark, and the UK, have already utilized a considerable portion of their biogas potential.

In the Danish debate, arguments are frequently put forward that the gas demand in Europe is so significant that Denmark should export its biogas to the European market. However, Biogas Danmark assesses that Danish production plays a minor role in a European context. The most important contribution will be for Denmark to demonstrate how much biogas and biogenic CO_2 production can contribute to energy security, reduction of the country's climate footprint, and a circular economy with nutrient recycling.

Potential for European biogas production in 2030 and 2050, according to studies [38]



Share of realized biogas potential in EU countries. [38]



The data in the figures comes from the European Biogas Association, EBA Statistical Report 2023

Biogas Danmark

Biogas in EU

Status of the EU's goal for biogas production

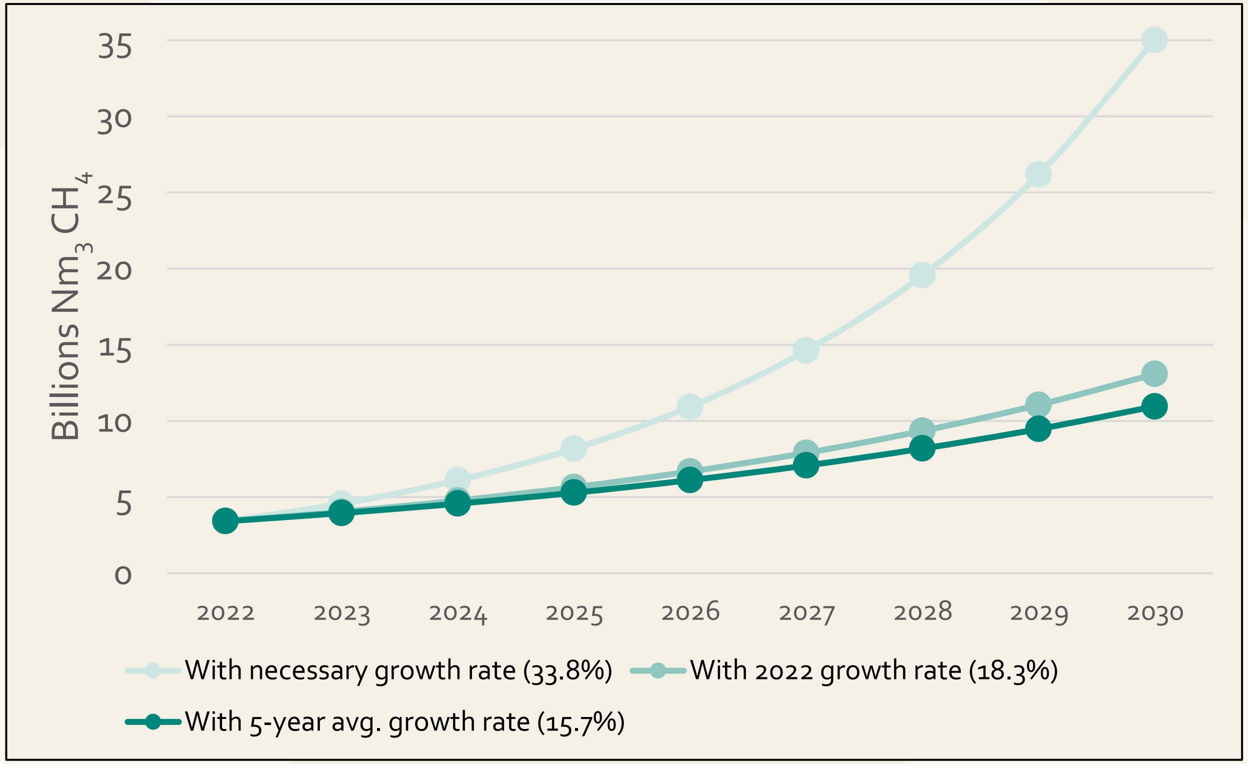
There needs to be more speed in the growth of European biogas production if the EU's goals are to be reached

To ensure green and independent energy production in Europe, the EU has set an ambitious goal to increase the production of upgraded biogas (biomethane) to 35 billion cubic meters per year by 2030.

Achieving this goal requires a steady annual growth rate of about 30 percent in the capacity for upgraded biogas production. In contrast, the growth rate in 2022 was 18 percent, indicating a need for accelerated growth to meet the target.

This suggests that Europe may increasingly become an attractive market for biogas solutions developed in Denmark, which currently has a lead over several other European countries.

The necessary growth rate to achieve the EU goal of 35 billion Nm³ CH_4 [38]



The graph illustrates the growth rate needed to reach the EU's production goal for upgraded biogas. For comparison, projections have been made using the growth rate for 2022 and the average of the last five years' growth. The data in the figure are sourced from the European Biogas Association, EBA Statistical Report 2023.

Biogas Danmark

This is how we did it

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Biogas Danmark

This is how we did it

Data foundation and assumptions

Biogas Outlook 2024 is based on Energinet's 2023 Analysis Assumptions (AF23) for biogas production and gas consumption in the 2022 Analysis Assumptions (AF22) [(1)]. The Energy Agency provides data on the development of biogas production and the amount of manure[(2)], that is digested but does not provide further information on which biomasses are expected to be used in biogas production. Therefore, Biogas Denmark has made assumptions on the biomass distribution based partly on the annual biomass reports to the Energy Agency [(3)], and partly on the University of Southern Denmark's assessment of biomass potential[(10)]. KF23 includes an expected distribution of cow and pig manure[(2)].

AF22, AF23 and KF23 also do not provide a detailed forecast for implementing of frequent manure removal from barns to biogas plants. At the same time, it is assumed that the Energy Agency has not incorporated the Agricultural Agreement's [(23)] decision to introduce frequent manure removal in pig barns from 2023. Therefore, for the period up to 2030, Biogas Denmark has made assumptions based on data on frequent manure removal from Aarhus University.

Moreover, it is assumed that the methane loss will decrease from approximately 2% to 1% in 2024, based on the Climate Agreement for Green Power and Heat from June 2022[(15)]. The agreement decided to introduce regulation of fugitive methane emissions from 1 January 2023

While the Energy Agency's scenario follows the biogas forecast in AF23, the Frozen Policy scenario is based on Biogas Denmark's evaluation of the implications of the framework conditions for biogas production during this period. The Green Policy scenario shows how biogas production develops with an acceleration of the planned tenders and by creating conditions for increased sales of unsubsidized biogas to the transport sector. Based on this, Biogas Denmark has developed assumptions for biomass distribution with higher biogas production. This leads to higher biogas production and more significant methane reduction in agriculture.

Reductions in nitrogen leaching are calculated based on research from Aarhus University[(29)]. Phosphorus recycling is calculated based on typical values from Seges [(27)]

The market value of biogas is calculated using data from the Energy Agency[(5)], EEX Gas Market Data [(6)] og Energinet [(7)].

CO_2 storage and Power-to-X calculations are primarily based on the Energy Agency's technology catalogues. [(13)] The CO_2 content is calculated based on the distribution of CO_2 and methane in biogas.

This is how we did it

Parametres and standard values

The tables on this page display key gas yield values for various types of biomass [2, 39], as well as the applied values for energy content in density, climate impacts, methane loss, and projection of frequent discharges.

Biomass	Dry matter [%]	Volatile soil VS [%]	Gas yield Nm^3 CH_4/ kg VS	Gas yield Nm^3 CH_4/ 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 waste	22	20	0,45	90
SSO	23	20	0,43	84

Overview of Parameters		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	MJ/Nm^3
Density, carbon dioxide	1,98	MJ/Nm^3
CO_2e emissions		
CO2 emission, natural gas	56,4	kg CO_2/GJ
CO2 emission, diesel	74,10	kg CO_2/GJ
CO2 emission, diesel RED II	94	kg CO_2/GJ
CO2 emission, electricity production	Energinet projection	
Own consumption		
Pretreatment and biogas production	26 - 36	kWh/tonne biomasse
Upgrading of biogas	0,1 - 0,6	kWh/Nm^3 CH_4
CO2, transport of biomass	1.080	tonnes CO_2 / PJ biogas
Upstream emission, natural gas	3.000 - 6.700	tonnes CO_2 / PJ biogas
Fugitive methane emission	2,1 → 1	%
Projection of frequent discharge	7	%, new stables
	9	%, old stables
PtX		
CH4/CO2 ration in biogas	60 / 40	%
PtX, elektromethane	35	%, Efficiency
PtX, methanol	48	%, Efficiency

References

Note no.	Subject	Link
1	Analysis assumptions for Energinet	Analyseforudsætninger for Energinet
2	Climate status and projections, 2023	Klimastatus- og fremskrivning, 2023
3	BiB analysis, 2021	BiB-analyse, 2021
4	Biogas Danmark	Biogas Danmark
5	Energinet, amount of biogas in the gas grid	Energinet, mængde biogas til gasnettet
6	Energistyrelsen, Subsidy rates 2024	Energistyrelsen, Støttesatser 2024
7	Spot market data	Spot market data
8	Biogas Data Online	Biogas Data Online
9	Green tax reform	Grøn skattereform
10	Energy crop analysis	Energiafgrødeanalysen
11	Digested biomass maintains soil carbon	Afgasset biomasse opretholder jordens kulstof
12	Electricity production by type	Elektricitetproduktion fordelt på type
13	Technology catalogue for renewable fuels	Teknologikatalog, fornybare brændstoffer
14	Methane emissions at Danish biogas plants 2021	Metantab på danske biogasanlæg 2021
15	Climate agreement on green electricity and heating 2022	Klimaaftale om grøn strøm og varme 2022
16	Climate Council status report 2024	Klimarådet statusrapport 2024
17	Energinet, Environmental report 2022	Energinet, Miljøredegørelse 2022
18	Transition to heavy transport	Omstilling til tung transport
19	Energinet, Tariffs for gas	Energinet, tariffer for gas
20	Evida, Gas Distribution tariffs	Evida, Distributionstariffer

Biogas Danmark

References

Note no.	Subject	Link
21	Agreement for CO_2 capture	Aftale for CO2-fangst
22	Agreement on green conversion of Danish agriculture	Aftale om grøn omstilling af dansk landbrug
23	Effects of normal and frequent discharge	Effekter af normal og hyppig udslusning
24	Seges Gris, note	
25	Knowledge synthesis of biochar in Danish agriculture	Knowledge synthesis of biochar in Danish agriculture
26	LCA Biogas and pyrolysis	LCA Biogas og pyrolyse
27	Phosphorus regulation	Fosforregulering
28	Phosphorus in Danish agriculture	Fosfor i dansk landbrug
29	Climate and environmental effects + nitrogen leaching	Klima og miljøeffekter + kvælstofudvaskning
30	Seges Innovation, notes	
31	Aarhus University on protein	Aarhus Universitet om protein
32	Production costs and own consumption	Produktionspriser og eget forbrug
33	RES directive, 2018	VE-direktivet, 2018
34	RES requirement Denmark	Fortræningskrav Danmark
35	RES requirement Germany	Fortræningskrav Tyskland
36	Skat, Tax rates 2024	Skat, Afgiftssatser 2024
37	Energinet on origin guarantees	Energinet vedr. oprindelsesgarantier
38	EBA Statistical Report 2023	EBA Statistical Report 2023
39	Article on gas yield from biomass	Artikel om gasudbytte af biomasser

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Fremtiden er cirkulær

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