Biomethane: bridging for cooperation

Between Denmark and the Netherlands

CE Delft

Committed to the Environment

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Content

1 General introduction

What are the possibilities for Denmark and the Netherlands to bridge and cooperate in the fields of green gasses like biogas and hydrogen? That was the fundamental question last year, during a Royal Business Digital Conference between Dutch and Danish governmental leadership and business leaders, guided by Royal attendance. It was a positive outcome with various synergies. In the field of biogas, The Danish Embassy in the Netherlands, Groen Gas Nederland and Food & Bio Cluster Denmark took further steps resulting in this document.

The document is written as concise high-level input for an executive round table event in November 2021, to discuss the proposed opportunities for cooperation. In this event business leaders and strategic stakeholders can discuss and agree where and how to move forward. Both countries have strong positions and can create various synergies that can pave the way for European Climate ambitions in the field of biomethane.

This document is meant as a summary, therefore it contains no summary itself.
The proposed opportunities for cooperation are listed and briefly described in Chapter 5. Chapter 2 gives a short factsheet of the general energy system of both countries with entries that are deemed relevant for the topic and with a focus on ‘gas’. Chapter 3 provides a comparison of relevant information about biogas/biomethane, also structured as factsheet. Based on two short case studies, Chapter 4 describes the lessons that the Netherlands can learn from Denmark, and vice versa, considering biomethane.

The views and content represented in this report lay with the authors and do not necessarily represent the views of the interviewees or their organizations.

2 Energy system

2.1 Introduction

In this chapter we explain the role of biomethane in the energy system, comparing the Netherlands and Denmark. The countries are comparable in size and shape (both countries are mostly flat). Both countries have a large agriculture sector, and they share a history in natural gas. There are however also many differences between the two countries, such as the total annual energy consumption and the consumption per energy carrier.
These differences influence the role that biomethane plays in each country. To get a bit of a background, this chapter shows two factsheets in which we compare the two countries in terms of final energy use; the history of energy; biomethane development and the future of biomethane.

2.2 Comparison of Danish and Dutch energy system

The factsheets on the following two pages show the similarities and differences between the countries. From the factsheets we recap the most important differences:

- Both countries have a history in fossil fuel production (the Netherlands mainly natural gas, Denmark both oil and natural gas) and still depend on fossil fuels. However, Denmark already has a much higher renewable energy share in their energy supply.
- The second difference is the size of the challenge that lies ahead: the energy consumption in the Netherlands is almost 4 times that of Denmark, with a natural gas use 12 times as large as Denmark's. The population in the Netherlands is about threefold that of Denmark. The difference in energy consumption lies in the presence of a large energy-intensive industry (chemical, electro-technical, food and metal) in the Netherlands, that found its base in part due to low natural gas prices.
- The development of biomethane differs in the sense that in Denmark biogas production initially started as one of the means to reduce environmental problems with leaching of nutrients from intensive livestock production. It was introduced as a form of waste treatment and nutrient recovery, although the energy production also played an important role. In the Netherlands the focus lies on the production of biogas and biomethane for energy, with less focus on the agri-environmental benefits from biogas production as compared to Denmark.
- Denmark aims to have 70% of the methane in the Danish gas grid to consist of biomethane in 2030. This is possible due to political support to biomethane production and a decrease in methane consumption, due to e.g. The Netherlands aims for a production of 70 PJ in 2030, a mere 10% of the current natural gas use. The natural gas use in the Netherlands is much larger and cannot be replaced by biomethane from regional waste[1]. Here, in the future biomethane could be used where natural gas use (or fossil fuel in general) is hardest to be replaced by alternatives. For those readers who seek further information: the sources are:[2][3][4][5][6][7]

1 The Dutch natural gas consumption will diminish due to e.g. efficiency measures (like isolation of buildings), growth of district heating, electrification, et cetera, but will remain much larger in volume in the coming decades as compared to Denmark.

2 PBL 2020, Availability and applications of sustainable biomass

3 Information on the Dutch certificate system can be found on the website of Vertogas, the Dutch biomethane certificate trader

4 CBS 2021, statistics on energy in the Netherlands

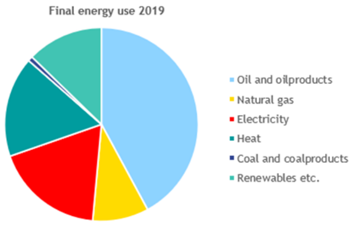
5 Verkenning BioLNG (report only in Dutch) and English summary

6 CE Delft 2020, Potentieel van lokale biomassa en invoedlocaties van groengas (only in Dutch)

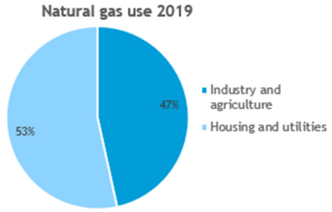
7 Danish Energy Agency ; Annual and monthly statistics

Denmark

Final energy demand per carrier (PJ)



Final energy use: 620 PJ.
Most of the final energy in Denmark comes from fossil fuels: 42% oil and oil products; followed by renewable energy (including electricity) 31%
Natural gas use: 58 PJ
Natural gas is used as a main energy source for heat in housing and utilities.



History

1972: First oil and gas production in the DAN field in the North Sea.

1979: As a result of the oil crisis and a need to become more self-sufficient, the Danish Parliament decided to establish the Danish natural gas supply system, which now supplies 400.000 houses with gas.

1984: First cooperative owned biogas plant was commissioned in 1984. An ownership model which is the predominant in Denmark now due to economy of scale advantages.

1985: The Danish Government launched the so-called NPO plan due to increasing problems with nutrient leaching and water quality. The NPO Plan set requirements to create harmony between the farmed area and the number of livestock, as well as to the minimum capacity for storage of livestock manure on farms. This plan gave environmental and production optimization incentives to promote biogas production.

1993: Denmark becomes net exporter of oil and gas. A status Denmark lost again in 2018.

2000: The export of food products is important to the Denmark, but there is a growing focus on sustainability, nutrient management and the environment impacts from intensive farming. This puts pressure on the agricultural sector to implements different environmental technologies incl. biogas production.

2009: The Green Growth Agreement from 2010 required that each municipalities to include the location of biogas plants in the municipal planning.

Biomethane development

2007: Aarhus University establishes full-scale experimental facilities for biogas production in Foulum which later included Power-2-X facilities.

2011: DONG, now Ørsted commissioned the first biogas upgrading plant at Fredericia Waste Water Treatment Plant.

2012: The Energy Agreement 2012-2020 was signed, and important introduction of biomethane subsidies. Restrictions on the use of crops for biogas production at 12%. Introduction of biomethane grid-injection, and a certificate scheme for biogas trading. Foundation of the public-private Biogas Taskforce, for sustainable biogas development.

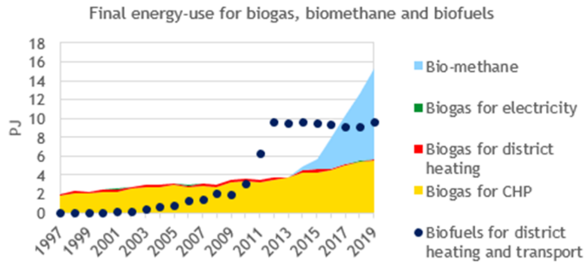
2013: New grid connection regulation. Owners of the natural gas grid is obliged to connect biomethane plants to the grid. The biomethane plant owner pays for the first part of the connection; gas grid for moving biomethane further upstream.

2019: Majority in the Danish Parliament agreed on a legally binding national Climate Act: reduce greenhouse gas emissions by 70 per cent by 2030 compared to 1990.

2020: More than 100 Power-2-Gas R&D projects have been finalized from 2004 to 2020. 8 large scale plants are on the way.

2020: New Climate Agreement signed. Public support to biogas production and green gas via a tender based system. Also investments in Power-2-Gas integration and infrastructure.

2021: 54 biomethane plants are connected to the grid. Denmark has a green gas share of around 22%, which is the highest in the world. A very high share of the fertilizer used in farming in Denmark is livestock manure or digestate from biogas plants.



The future of biomethane

2021: National Power-2-X and Gas strategies developed: Focus on reduction of gas consumption and increase in biomethane production to 100% green gas consumption in DK by 2034 latest. Relevance of hydrogen and possibly CO_2 infrastructure for P2X production, converting hydrogen and biogene CO2 into biomethane, methanol or other relevant renewable fuels.

2022: Launch of the new tender-based green gas support scheme by The Danish Energy Agency. Around 90 mio. € will be invested in the new program from 2024 to 2030 to further increase the production of green gas with around 10PJ. Total Danish consumption of energy 750-800 PJ.

2022: The new energy crop agreement is put into action. Gradual decrease in allowed amount of energy crops: maximum of 8% in 2022 to 4% in 2025 when it is fully implemented. Before 2022, 12% of energy crops was allowed.

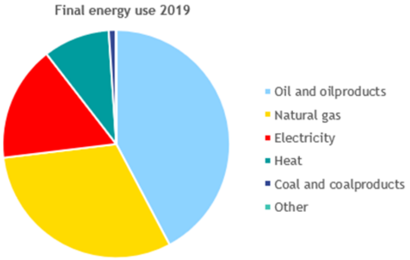
2023: By the start of the year all municipalities will have to separate waste resources into ten fractions. This includes food waste which will be available for biomethane and fertilizer production.

2030: The Danish Energy Agency projects a 51PJ biogas production, equal to around 70% of all gas in the grid. Of that around 40PJ will be for biogas upgrading and 12 PJ use directly for process, heat and electricity production. This will reduce about 2,9 million tons of CO_2 equivalents. Furthermore, a potential use of power-2-gas processes can boost the production of biomethane and replace even more natural gas.

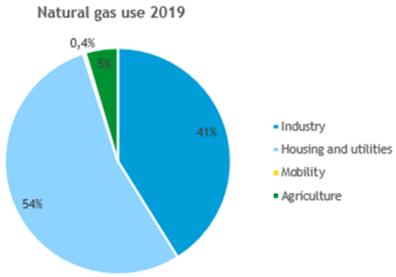
2050: Oil and gas production in the North Sea will terminate. Denmark is expected to become fossil free, which also means a 100% green gas grid. 70% of energy comes from renewable power, the rest comes from other renewable sources incl. biomethane.

The Netherlands

Final energy demand per carrier (PJ)



Final energy use: 2354 PJ.
Most of the final energy in the Netherlands comes from fossil fuels: natural gas 31% and oil 42%.
Natural gas use: 726 PJ
Natural gas is used as a main energy source for heat in housing and utilities. The Netherlands has a large industrial sector. A large part of the natural gas provides energy for the industry.

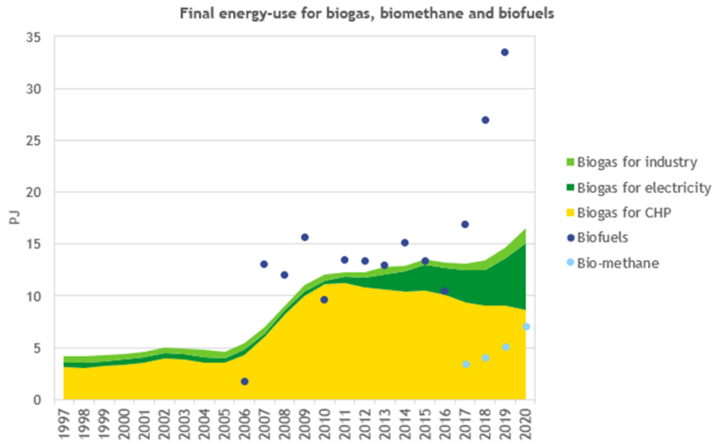


History

1959: The **natural gas field of Slochteren** is discovered with an initial supply of ~100 exajoules. Part of the gas is exported, part will be used for the national energy supply.
1964: Start of the build of the **national gasgrid.** In about 5 million households coal stoves are replaced by gas stoves.
1962: A fast rising economy, the Netherlands expands its infrastructure: Eemshaven north of Groningen is built. Rotterdam becomes the biggest harbour of the world, with 97 million tons of transshipment per year.
1974: Following the oil crisis the government changes policy towards offshore fields and small onshore gas fields, assuring energy supply from Dutch natural gas.
1978: The Netherlands suffer from the "Dutch disease", the export of gas, consequently a strong coin, causes unemployment to rise. **Energy-intensive industry,** specifically greenhouse agriculture, and industry using natural gas as their feedstock (e.g. chemical industry) grows due to low energy prices. Netherlands becomes the largest gasproducer in the EU, and 9th largest in the world.
2018: Groninger gasfield drastically reduces production and will stop producing in 2022 as a response to the increasing occurence of earthquakes. Gasuse in the Dutch energy system decreases slightly, but remains high. 91% of the households are connected to the natural gas grid.

Biomethane development

2003: 2014: Biogas is produced by digestors and used in CHP in greenhous agriculture. Subsidies are volatile (MEP) and biogas suffers from a bad reputation.
2009: Vertogas is founded to issue certificates. For these certificates the biogas needs to be upgraded to biomethane (quality of natural gas).
2013-2020: Bio-methane is produced from biogas, and is either injected in the gasgrid - for which Stimulering Duurzame Energie (SDE) provides subsidies-; or sold to the transport sector, for which Hernieuwbare Brandstofeenheden (HBE) can be aquired. Largest digestor produces 80 million Nm³.
2020: About 200 million Nm³ (7 PJ) of green gas is injected in the national gas grid.



The future of biomethane

2023: Biogas/syngas 3.0 a shift towards syngas enables routes to renewable gasses (hydrogen or bio-methane); schaling up to industrial schale, focus on innovation such as (super critical water) gasification.
2030: Klimaatakkoord sets target for 70 PJ/year.
2050: 30-50% of the total energydemand is still expected to be in the form of molecules. The demand for greengas is on average estimated at around 240 PJ/year.

3 Biogas value chains

3.1 Introduction

In this chapter, we zoom in on biogas and biomethane. The chapter contains a comparison between the Danish and Dutch biogas value chains in the form of two factsheets, one for each country. Biomethane plays an important role in the future of renewable energy in Denmark and in the Netherlands. Biomass, the source for the biomethane, is an essential part in understanding the context of biomethane. Production routes of biomethane vary, as do the input and output products. The production of biomethane is more costly than natural gas. Subsidies are therefore necessary to stimulate the production and to acknowledge the environmental benefits for society. For the future, different innovations are likely to make a large impact. The factsheets on the next two pages provide a comparison between both countries on renewable energy, biomass, rules and regulations, production, the use of biogas and biomethane, subsidies, legislation and innovation.

3.2 Comparison Danish and Dutch biogas value chains

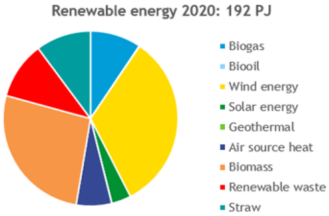
The factsheets on the following two pages show the similarities and differences between the countries. From the factsheets we recap the most important differences:

- In both Denmark and the Netherlands manure has the largest share in biomass for biogas production. Denmark uses food and industrial waste, straw and (a decreasing amount of) energy crops in the co-digestors, and as a direct feedstock for renewable energy production. The Netherlands has ambitions to unlock potential of residual products of seaweed as a source for biogas production.
- Denmark has a higher production with a lower number of biogas plants (186 in DK, versus 300 in NL). Biomethane production in Denmark was 14,4 PJ (and increasing) compared to 7,1 PJ in the Netherlands. Denmark projects 51 PJ biogas production in 2030, of which approximately 40 PJ will be upgraded to biomethane. The Netherlands has an ambition of 70 PJ in 2030.
- Subsidies in the Netherlands are in competition with other renewable energy technologies such as wind and solar. In Denmark subsidies in the form of feed-in tariffs are a separate category from wind and solar. The current subsidy scheme provides subsidies for 20 years forward, and has recently ended for new entries. This will be replaced by a tender system expected to produce the first gas in 2024.
- Both countries have a limit on nitrogen application on fields. In Denmark biogas plants are positioned as a solution to this problem as digestate increases the plant's speed of nitrogen uptake and replace a significant part of chemical fertilizers produced from natural gas. Biomethane plays an important role in the context of a circular economy: it handles waste streams from households and industry and provides nutrients to the agricultural sector. In the Netherlands the surplus on digestate due to co-digestion is more perceived as a problem. Biomethane is valued as an important energy carrier, and innovation (e.g. with new conversion techniques) is stimulated to increase production.
- Innovation in Denmark focusses on process optimization, feedstock treatment, CO_2 use, biomass pre-treatment, process optimization, and product valorisation. The Netherlands focusses on innovative production paths such as (super critical water) gasification and on unlocking new residual biomass streams.

Denmark

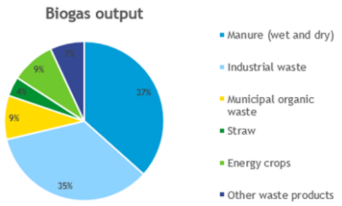
Renewable energy

2021: ~34% of the Primary energy use is renewable. Biogas represents 9% of the renewable energy produced in Denmark. Most of the renewable energy is generated by wind.



Biogas from biomass

2021: Large co-digestors produce all biogas. The main input is manure (77%). The use of energy crops are limited but still serves a fair share in the output. Industrial and municipal organic waste are important feedstocks for the production of biogas.



Rules and regulations - biomass

2021: Danish plants have to register the input to the plant, following a fixed set of categories. All input needs to comply to the BIB database containing 8 main biomasscatagories such as e.g. "Industrial waste, potato juice". The amount of energycrops allowed today is 12%.

Allowed amount of energycrops in the input to the production plant:
2022/2023: 8%
2023/2024: 6%
2024/2025: 4%
2025/2026: 4%
2025: Maise no longer receives subsidies.

Biogas / biomethane production

2019: Biogasproduction was 16,6 PJ, with 9,1 PJ biomethane production.

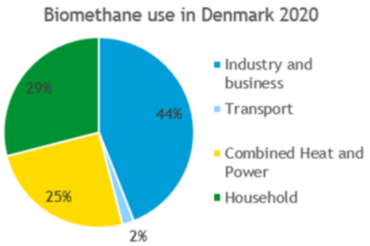
2021: 54 of 186 biogas plants are connected to the grid. This include 25 cooperative plants representing the majority of the biomethane production, 26 farm based plants, one industrial biogas plant and two plants at wastewater treatment plants.

2030: The Danish Energy Agency projects 51 PJ biogas production, equal to around 70% of all gas in the Danish national grid. Of this 51 PJ around 40PJ will be from biogas upgrading plants and 27PJ is expected to come from power-2-gas processes.

Biomethane use

2021: The biomethane that is produced in Denmark is traded through certificates. According to the Danish TSO Energinet, the 4,2 million green gas certificate issued in Denmark were sold in Sweden, Germany, Denmark and rest of Europe. These numbers are based on the total gas consumption, there is no direct information on who buys the certificates.

Biomethane is distributed along with and mixed with the natural gas in the gas system and consumed as system gas.



Aproximately 24% of the system gas is consumed in heat and power production in Denmark. Most of the biogas that is not converted to biomethane, is used in CHP.

Biogas is expected to play a bigger role in greening of the heavy transport and industry sectors. This also includes fuel for ships and aviation in 10-15 years.

Subsidies

The Danish support system for biomethane is currently in a transition phase between two programs.

2012-2020: The feed-in subsidy scheme was implemented in 2012 ended for new entries in the beginning of 2020. The 2012-2020 subsidy program supports biogas based electricity (€10,6/GJ to €15,4/GJ); biomethane (€15,4/GJ) and use of biogas for industrial heat, transport fuel and heating purposes (€10,0 /GJ). Most of the support was given to biomethane projects. From the connection agreement and 20 years forward.

2021-onwards: New tender-based subsidy for green gas production. The new subsidy was part of the climate and energy agreement from summer 2020 and wanted to prevent unexpected increases in cost for subsidies, and to decrease the cost of biomethane in general.

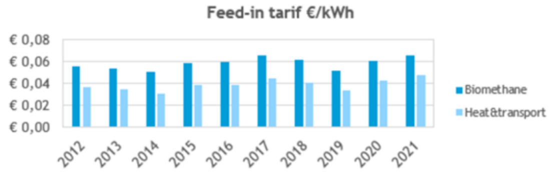


Figure source: Energy Agency Denmark

Legislation - digestate and bio-methane

A number of legislative regulations have been implemented throughout the years.

- Restricted application of nitrogen and phosphorous on fields;
- Manure management and storage;
- Ban on organic waste on landfill since 1998;
- Fees for (industrial) waste treatment;
- A focus on circular economy. Waste hierarchy 2020: prevention, re-use, recycling. Target: 50% recycling of Danish municipal solid waste by 2022.

Other drivers have been dialogue and joint efforts with key stakeholders through follow-up programs and a Biogas Taskforce, support of research, development and demonstration of new technologies and a limit on the use of energy crops in biogas production.

Innovation

The Danish biogas sector focus on at least four overall innovation topics:

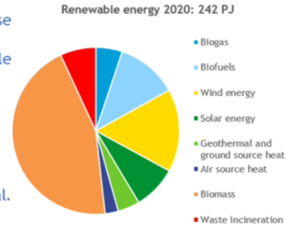
- Process optimization: According to Biogas Danmark, the cost of producing biogas have decreased from around 0,67 € to around 0,50 € within the last five years. This development is expected to continue in the future and possible through increased investments in biology, management, new technology and digitalization.
- Logistics, pretreatment and use of straw, food waste and other more difficult bioresources replacing parts of the energy crops currently being used.
- Utilization of CO_2 for food ingredients and for Power-2-Gas related solutions: Utilization of CO_2 from biogas upgrading plants and hydrogen from renewable surplus power to produce biomethane.
- Increased valorization of digestate: Customized fertilizer for specific crops applications.

The Netherlands

Renewable energy

2021: ~10% of the Primairy energy use in the Netherlands is renewable. Biogas consists of 4% of the renewable energy content. Most of renewable energy is generated by biomass.

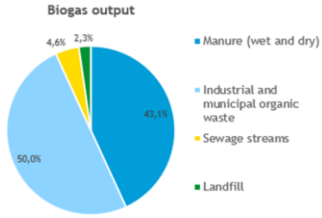
2030: Goals for renewable energy: wind and solar: 11 GW wind at sea and 35 TWh wind and solar on land; **70 PJ biomethane**; 15 PJ geothermal.



Biogas from biomass

2021: Biogas is produced in co-digestors on farms. Manure makes up for the largest part of the input material. Though smaller in input volume, industrial and municipal organic waste produce a larger part of the biogas.

2030: Ambition to unlock potential of residual biomass: **Seaweed** / macroalgae / microalgae / sugarbeet leaf



Rules and regulations - biomass

2021: The law provides a list (bijlage Aa) of specific waste- and manure*products* allowed for use as manure / digestate. This list is reviewed twice a year. Digestate may be used on land if >50% of the feedstock of the digestor consists of manure.

2030: In October 2020 the sustainability framework for biomass is presented with a focus on the circular economy[1]. Biomass should be used for high value purposes first, cascading down the chain to energy and heat. Policy is directed towards reducing the use of biomass for low temperature heat; electricity and light transportation; and the increase of use of biomass for materials and feedstocks.

Biogas / biomethane production

2021: Only 7,1 PJ biomethane is currently produced. Total gas demand is 1340 PJ. 0,47% of this is biomethane.
About 100 companies/organisations are active; 300 digestors are in production:

- 200 are located near sewage treatment plants;
- 100 at industrial or agricultural sites.

15 large installations are being built.

2030: ambition total about **70 PJ/year**
In 2030 about 60 PJ/year can be produced from wet biomass.

Biogas use

2020: total biogas use is 17 PJ, total natural gas use is 726 PJ.
2021: Agriculture makes up for the largest use of biogas, for use in (usally small) combined heat and power plants. Waste water treatment plants, utilities and industry make up for the other part.

2021-2025: A ban on palm-oil, subsidies on biofuels (REDII) and maturing markets create a pull towards mobility. Biogas use in the form of bio-LNG in heavy transport is growing fast. A bio-LNG production of around ~260 kton (0,013 PJ) in the Netherlands is foreseen in 2025[3].

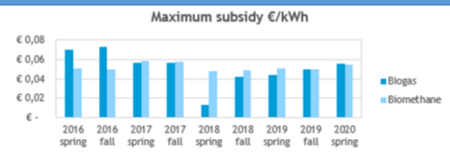
2030: From nationally available feedstock around 410 kton/yr bio-LNG can be produced[4]. Mobility sector has an ambition of 10.000 trucks driving on bio-LNG in 2030. Following different scenario's, markets are expected to mature with a demand of 6 to 212 kton for trucks; 0 to 260 kton for inland shipping and 0 to 2.250 kton for seagoing vessels.

2030: Considering the natural gas demand in 2020 -60% (390 PJ) of total energy demand in built environment- it is expected that biomethane will be used in the built environment.

Subsidies

2003-2006: MEP-subsidy (Milieukwaliteit Elektriciteitsproductie) is granted for a period of 10 years for renewable electricity production, and for a period of 3 years for combined heat and power (on biogas). The amount of subsidy is set between 0,0032 and 0,008 euro/kWh in 2003, with a set annual tarif based on the difference between the income and investment costs.[5].

2008-2020: SDE subsidies are set to fill the gap between production costs and the market price. The height depends on the production method. The subsidies are in competion (measured in €/ reduction in tonnes CO_2) with other alternatives including solar panels. Bio-methane is more expensive than for example solar power and therefore less eligible for subsidies. Biogas is converted into bio-methane with the use of certificates (worth € 0,09 / Nm[3] in 2015). Subsidies are stable.



2021: The value of HBE depends on the type of biomass. HBE trading sets a price for 1 GJ of renewable energy in mobility. Can cover costs up to € 0,50 / Nm[3].

2030: REDII 14% of the fuels at the gasstation need to consist of renewable energy. Similar blending obligation for the national gasgrid is explored.

Legislation - digestate and bio-methane

2021: The Netherlands has a total of 76 milion tonnes of manure and a surface of ~40.000 km^2.
A maximum of 170 kg of nitrogen may be spread over 10 000 m^2 of land from animal manure.
Digestate may be used as an alternative to direct use of animal manure.
Digestate becomes a waste material if it can not be used on own ground (art. 22.1 l 9 Wm). As a consequence, the Netherlands has a large surpluss in digestate.

Grid connection: There is no obligation for the TSO to connect the grid. The quality specifications for the high pressure grid are much higher than that of the regional grid.

Innovation

Innovation is directed towards unlocking unused residucal biomass flows, following from a cascaded use of biomass in the future. For a biobased economy unlocking biomass is essential. Innovation is stimulated through government fundings, and a close collaboration between industry, government and research institutes.
A strong focus lies on chemical processes:

- Bioraffinage: using biocrops and organic waste to produce biofuels and biobased products. Nutrients can be extracted from the output and used to grow crops again.
- Super Critical Watergasification cracks organic waste into syngas using water, high temperature and high pressure in a continuous fast proces. Virtually all organic compound is converted into syngas and minerals are a byproduct.
- Gasification of torrefied wood: produces bio-methane, carbon and steam;
- Gasification of wood: converts wood into syngas. Demonstration plants of >50 MW;
- Feedstock: unlocking the potential of seaweed as a feedstock for biorefinery. Ambition to have seaweed production between offshore wind 500 km^2 in 2030.

4 Lessons to be learned DK and NL

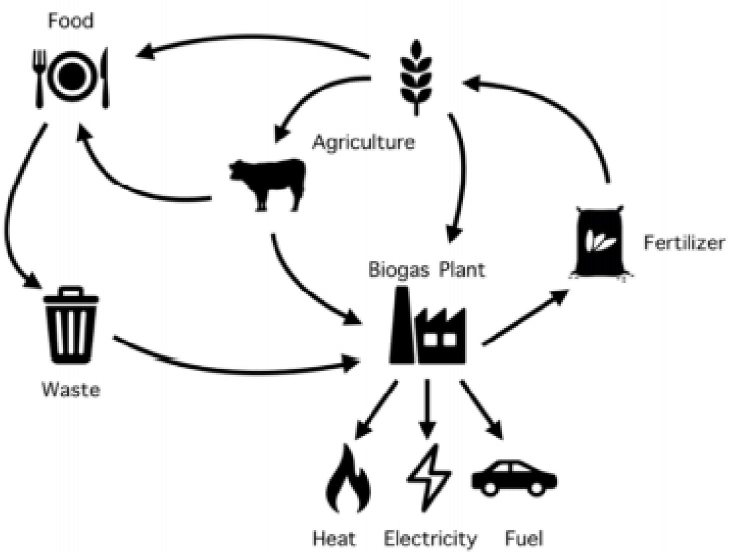
4.1 Introduction

In this chapter we highlight two cases that are typical for Denmark and the Netherlands, respectively. Each case is selected based on the differences between the two countries, the lessons that can be learnt from these differences, and the opportunities for cooperation. The Danish case is a holistic approach to biogas, with biogas as a key ingredient of a circular agriculture. The Dutch case is about the role of gasification as 'working horse' for the realisation of the Dutch 2 bcm ambition in 2030.

4.2 Danish case: digester as integral part of agricultural nutrients cycle

One of the most striking differences between the Danish and the Dutch approach of biomethane is the answer to the question: 'biomethane is the solution for …?'. In Denmark, the story of biomethane is firmly grounded in agriculture, see Figure 1. The digesters being a solution to an environmental problem in the early '80s and onwards. Not shown in the figure is the use of CO_2 from the biogas plant for food grade gas for soft drinks[8].

Figure 1 - Green gas value chains in Denmark[9]



Biogas production for waste treatment

The biogas story of Denmark started in 1985, when government set rules to regulate the amount of cattle and pig manure to be used on the agricultural lands. Following an alarming news broadcast on dead fish caused by nitrification of the water, the National Association of Land Conservation managed to have nitrate use regulated by government. A maximum was set for the amount of nitrogen allowed per ha. Manure is only allowed to be spread in springtime when crops are growing. It caused a redistribution of manure from cattle and pig farmers to the crop fields, and a need for storage capacity arose.

8 In the Danish outlooks, the CO_2 will play an important role (through methanation) in the integration of windpower derived hydrogen to the Danish natural gas grid, which serves as a huge battery infrastructure. In the future, Power-to-Gas (PtG) will play a role in greening the aviation and shipping sectors as well.

9 Presentation by Mr. Jonas Jürgens, Danish Energy Agency, Denmark/Spain meeting 3rd of June, 2021.

The positive side effects of biogas

Digestion of organic matter is a key element in the Danish circular economy: it is a form of waste treatment, produces soil enhancers, and of course biogas for energy. In the case of co-digestion, instead of directly using manure on the agricultural land, digestate is used with positive effects for the local community and the environment. The local community has a means for circulation of organic waste. The digestate has a smaller CO_2 footprint and a reduction of the bad smell of livestock manure. The risk of leaching of nitrates into the aquatic environment is reduced. And the digestate, being a better fertilizer than manure, can be used on lands to increase the yield of crops. See Figure 1.

"Biogas should not only be compared with inflexible renewable energy suppliers. Biogas production is a multifunctional technology to handle organic residues and make the food production more sustainable." Bruno Sander Nielsen, COO from Danish industry association Biogas Denmark.

The realisation of co-digestors for large scale production

A large part for the realisation comes from the boundary conditions: regulation, finance and support. Regulations were set on the quality of biogas, which is important for a good operation of the plants. The feed-in tariffs in combination with the obligation for the TSO/DSO to connect the biomethane plant to the grid, gave opportunity for the biomethane producers to feed in the biomethane, removing the earlier constraint from the use of the heat of the CHP plant that was used to convert the biogas into electricity. Biogas producers only need to pay to connect to the regional grid (4 bar): compression and redistribution of gas (and electricity) is paid for by society. With a four months grid storage capacity, the switch to biomethane was essential to be able to monetize the advantage of utilizing biogas/biomethane as a storable energy carrier. Biomethane is also seen as one of the solutions to store renewable wind power through Power-to-Methane processes.

"Denmark is heading towards a 100% renewable gas supply. In 2030, we will have 70% biomethane in the gas grid." Kristian Havskov Sørensen, Chefkonsulent, Danish Energy Agency

Biomethane is produced from waste, hence the costs of waste affect the cost of production. Where at the start a gate fee was part of the income for the biogas plant, but with a growing demand for biomass the price rises and subsidies become even more important. Considering the support: the local community is supportive, because of the benefits the plant reaps for them. Other than for windmills, the Not-In-My-Back-Yard (NIMBY) effect consists mostly of fear during the construction phase with the risk of bad smelling, but there is none during normal operation. Operation of a biogas plant delivers positive effects for the local community as mentioned in the positive side effects of biogas.

The optimal size of the digester depends on the opportunity for economy of scale and the transport costs and hence distances of the feedstock and of the digestate. Denmark is focusing on and investing in innovation, which also led to professionalisation and scaling up, as large dedicated companies have the power to go into innovation and reduce cost per produced m^3. A collaboration between stakeholders within Agriculture, Environment and Energy considered moving from laboratories to the market, back in the early 1990's, as necessary for scaling up. As a way to reduce the financial risk of investing in new and less proven solutions, local biogas plants could get up to 40% of construction costs, provided they try something that hasn't been tried before. Ministries were facilitating knowledge sharing between the biogas plants, even tracking the progress. The support strategy led to dedicated integrated digester companies like Nature Energy, that cover the whole Design-Build-Own-Operate chain, with own funding, standardized concepts and high environmental standards, thereby also realising a substantial lowering of overall project risk and of production costs of the biogas.

Biogas, part of circular agriculture and circular economy

Biogas is a way to handle manure and organic residues to turn the food production into a more sustainable system. Denmark is a frontrunner in the circular economy. What was formally known as waste has been turned into the nutrients that will produce next year's food and feed. Food production can be conventional livestock, but also organic food production. For example organic food production needs a lot of clovergrass to get access to the nitrogen. Digesting the clovergrass in a biogas plant first and then using the digestate gives climate and environmental benefits. The biogas that can be used in the energy, transport and chemistry sectors is 'only one of the products'.

"We collect and deliver biomass from businesses, agriculture and households and return the degassed biomass to the agriculture that recycles nutrients. This is circular economy at its best." Oliver Vindex Nielsen, Chief Business Development, Nature Energy.

Take aways for the Netherlands

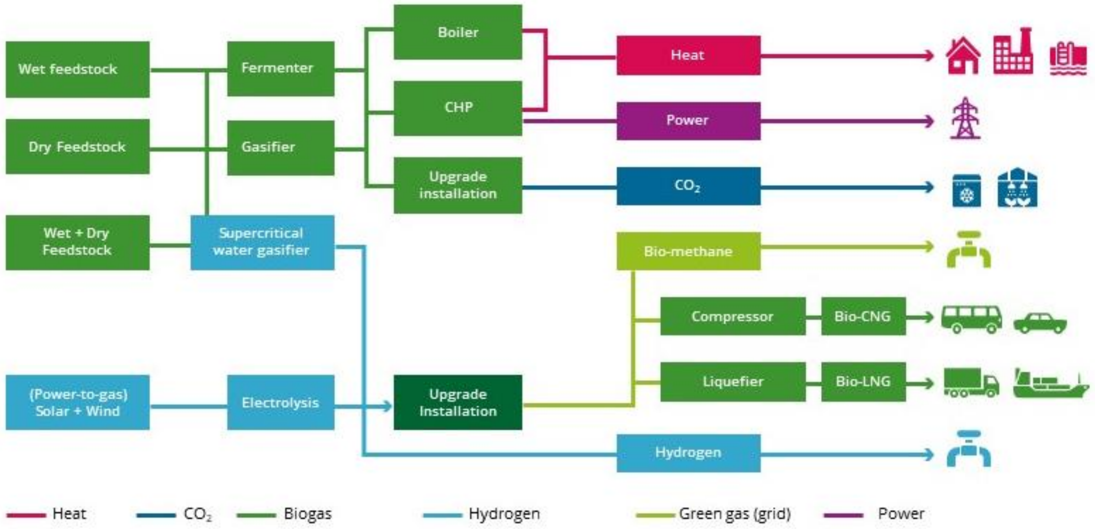
The Danish approach of digesters as integral part of the nutrients cycle of agriculture and part of the circular economy, converting local organic wastes into useful products for society is interesting. This could be a way out of the debates in the Netherlands about the future of agriculture, on the challenge to further professionalise the Dutch biogas sector, and on the challenge to realise the ambitions of the Dutch 2 bcm roadmap.

4.3 Dutch case: biogas part of silver buckshot for renewable energy target

The Dutch approach to biogas is primarily based on the targets for renewable energy (which are part of the climate targets), and the strong intent to do this at the lowest cost for society. Biogas production thus being in financial competition with other renewable energy techniques, like solar-PV and wind.
And, also important, in alignment with the Eurostat rules of counting towards the renewable energy target, i.e. the production must be comparably measured, and used for energy (not feedstock).

Other values for society attached to biogas, like the energy system values of green molecules compared to green electrons, and sustainability values for agriculture, are recognized but not yet monetized. Imported to note also is the energy intensive nature of the Dutch industry, with a strong base in relatively cheap natural gas, and a history that goes back to the discovery of the large natural gas field below Slochteren, in Groningen. Whereas biogas/biomethane is the Danish silver bullet to green the national gas consumption, the potential of biogas/biomethane in the Netherlands from domestic organic waste streams adds up to about 10% of the current natural gas consumption. Making biogas part of the Dutch silver buckshot for renewables and decarbonisation, not a silver bullet. However, there is no silver bullet for the Dutch energy transition challenge. Thus, biogas is receiving attention in the national policy, as are other techniques like offshore wind and solar-PV.

Figure 2 – Green gas value chains in the Netherlands[10]



Innovation: the key to 70 PJ in 2030

The government, in cooperation with the biogas sector, made a roadmap for the production of 2 bcm (70 PJ) of biomethane in 2030. In the roadmap, a vision is stated to enhance the production of biomethane along different parallel routes. The most important is the investigation of new instruments to support the business case of biomethane production (such as a quota system obliging energy suppliers to supply a certain percentage of biomethane and adjustments to the current subsidy scheme (SDE++)). Other routes are the further professionalisation of the sector, which is represented by different organisations, the upscaling of digestors, the further development of small scale mono manure digesters, nutrient recovery[11], and to stimulate innovation in gasification. Gasification, both super critical water gasification (SCW) of wet organic waste streams and thermal gasification of dry woody waste streams, is seen as a way to scale up and reduce costs. A co-benefit in the Dutch context is also the absence (SCW) or reduction of the digestate volume as compared to co-digestion, as in some of the agriculture-intensive regions in the Netherlands there is a surplus of manure[12]. The storyline behind the roadmap is: we need green molecules, not only green electrons. The Dutch energy system in 2050 still needs 40-60% molecules and these need to become green.

Breaking down all organic waste with super critical water gasification

Super critical water gasification uses high temperatures (>375 °C) and high pressure (>221 bar) to convert the wet (organic) waste feedstock into syngas[13] and other components. Other than with digestion, the process breaks down all organic compounds including cellulose and lignin. As a result a high conversion can be reached, and minerals and other inorganic compounds can be taken as separate output products. The process of gasification, being a thermo-chemical process, is much faster than that of digestion. At the back-end, the syngas can be upgraded to biomethane, and still at high pressure, can be then fed into the national high pressure gas grid (at 90 bar).

10 Groengas Nederland : Groengasketen (in Dutch)

11 See e.g. Green Mineral Mining Centre

12 This is also the rationale behind the Dutch Jumpstart Programme that stimulates mono manure digestion.

13 Syngas consists of CO, CO_2, CH_4 and H_2 in different compositions, depending on the feedstock and the process conditions.

"Super critical water gasification can break down all hydrocarbon based waste streams. We provide a solution for complicated waste streams and turn it into a valuable product for a circular economy." Wout de Groot, Director business development, SCW Systems.

SCW Systems[14] develops this technology with a team of engineers, researchers and operators at their site in Alkmaar. SCW Systems combines research with demonstration at the same time. In the research centre their team tests different feedstocks and the optimal process conditions. Their technology provides a means to take care of (wet) organic waste streams that are now seen as a burden. These include organic sewage slurry and manure. But even complicated organic waste such as plastic waste from hospitals could be broken down in the gasification process. The minerals are part of the output in the brine at the end of the process. One of the research programs will be on valuation of nutrients and minerals. Currently SCW Systems is developing a mineralization process to capture and convert the biogenic CO_2 into useful resources.

"The Netherland is truly a frontrunner when it comes to gasification. There is a lot of knowledge and knowhow in the companies in the Netherlands." Dinand Drankier, project leader biogas, Dutch Ministry of Economic affairs and Climate.

With the 18.6 MW demo-installation SCW Systems show the continuous production of biomethane that is fed into the high pressure national gas grid. The demo-installation consists of 4 reactors, of which the first is now being commissioned. Scaling up is an important phase in this innovation, to learn and integrate engineering solutions that will increase and proof the robustness of the installation at industrial scale. An important part of the strategy is that the units of the demo plant are already at the final industrial scale. Larger future installations will consist of multiple parallel units. The planning is scale up to 100 MW in Alkmaar, to build a 350 MW facility in Delfzijl (Groningen) and one in Zuid-Holland.

Currently SCW holds two patents for these engineering solutions. Along with the demonstration plant, a research team performs tests on various waste streams and the conditions required to get the desired output. SCW aims to unlock a large variety of potential waste streams for the production of biomethane, whereas also hydrogen production is a future possibility[15].

Gasification of woody waste streams for green molecules

The other Dutch branch of innovation in the field of gasification of biomass focusses on dry waste streams as feedstock, not only 'woody' waste streams but also other dry waste streams. The technical approach is different from the large scale fluidized bed gasifiers that are known from the coal industry, which have difficulties with tar production using biomass as a feedstock.

One technique is developed by Torrgas[16], it is a two-step process, using torrefication of the biomass followed by further gasification. The produced syngas is shifted towards biomethane or towards hydrogen. Pure chaincarbon is one of the products, as is biogenic CO_2. The technology is scalable to 100 MW per gasifier. There are also other developments of gasification techniques, for example MILENA-OLGA, developed by TNO.

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14 See: SCW Systems : clean energy technology for more information.

15 Note that the Netherlands is working on the realisation of a national hydrogen backbone, re-using parts of the already existing natural gas transport grid. The backbone will connect the main industrial areas and the underground storage facilities (salt caverns) in the northern part of the country and will also connect to Belgium and Germany.

16 See: Torrgas opens worlds first Modular Bio-Syngas Plant for more information.

One other technique is developed by BioenergyNederland[17]. The company has selected their specific gasification technology looking for techniques that are able to handle local woody waste streams as feedstock, at low cost and without tar issues. The waste streams are chips, coming from forestry and from used construction wood. The properties of the developed gasification technique result in units that produce a clean gas with very low tar levels. As a result the units are relatively small when compared to large scale fluidized bed coal gasifiers.

“The economy needs green molecules. Our technology can provide these, using local waste streams as feedstock. It is the best solution to use waste wood streams locally and produce valuable feedstock streams for the region.” Jeroen de Swart, CEO, BioenergyNederland.

BioenergyNederland has one installation up and running (24/7 production) in Amsterdam. It consists of 2 units, 6 MW each, producing electricity and heat, where the heat is used in the district heating network of Amsterdam. The company is working towards a larger scale facility of 60 MW in Delfzijl (Groningen) that will produce biomethane that will be fed into the gas grid. Hydrogen production will be demonstrated in the Amsterdam plant in 2022. Challenges for innovation are the valuation of the biochar and of the nutrients in the waste water stream. A challenge for policy support is the valuation of negative greenhouse gas emissions using biochar for soil improvement.

Take aways for Denmark

Gasification is seen in Denmark as not feasible under current framework conditions (though pyrolysis will play a role in greening the agricultural sector in Denmark through carbon sequestration and biofuel production). The successful innovations in the Netherlands of both supercritical water gasification of wet waste streams and low-tar gasification of dry waste streams might shed new light on this. Gasification might provide a new parallel way for using biomass waste streams, for example of straw, but might also be combined with digestors. Recirculation of the nutrients is an important condition. The possible use of biochar in agriculture might be interesting also.

[17] See: Bio Energy Netherlands for more information.

5 Opportunities for cooperation

5.1 Introduction

From the research for this project, from discussions, and from own knowledge from earlier projects, we selected the opportunities listed here for cooperation between Denmark and the Netherland in the broad field of ‘biogas’. The opportunities will be discussed, supplemented, and prioritized in the round table event, where the business leaders and strategic stakeholders can discuss and agree where and how to move forward.

Wouldn’t it be great to build a living and lively cooperation programme between Denmark and the Netherlands on the further development of ‘biogas’, as follow up of the Royal Business Digital Conference that was the trigger for this project?

5.2 Overview of opportunities and topics for cooperation

1. **Digester part of sustainable agriculture.** Digesters as one of the key elements of a sustainable circular agriculture, by closing of local nutrient and biomass waste streams, and solving nitric leakage issues. The Danish approach may provide a solution to the current Dutch debates on the future of agriculture. It would fit into the MoU between Denmark and the Netherland ‘On cooperation in climate adaptation and mitigation of agriculture and food systems’, signed 25th of March 2021, by the Minister for Food, Agriculture and Fisheries of Denmark and the Minister of Agriculture, Nature and Food quality of the Netherlands.
2. **Combination digester and gasifier.** Combined use of a digester and a gasifier in one demo site, provided the nutrients can be reused in (local) agriculture. The gasification technique of BioenergyNederland is one of the promising techniques.
3. **Optimisation and valuation.** Valuation of rest- and side streams from digesters and gasifiers, and optimisation possibilities for existing plants. Also the valuation of bioCO_2. What can the Dutch and the Danish learn from each other in this respect?
   The cooperation could be structured as a knowledge exchange platform, resulting in tangible results.
4. **Biorefineries**. Biorefinery concepts, extracting valuable components from the biomass feedstocks, and using the side streams of the refinery as feedstock for biogas production. Part of this can be the research into the production of sea weed, extraction of proteins, and production of biogas, but there are more. For example the developments at Cosun (biorefinery with sugar beet as feedstock, extraction of specific sugars and pectines, extraction of fibers). Possible interested parties from the Dutch side might be Cosun, and DSM.
5. **Gas cleaning.** Gas cleaning techniques and optimisations (biomethane, hydrogen).
6. **New feedstocks**. New sustainable feedstocks, like e.g. bioplastic waste streams, for the digesters and/or gasifiers.
7. **Power2Gas**. In the Danish context Power2Gas is seen as power to methane, using H_2 from elektrolysers and CO_2 from digesters, with the methane grid and its underground storages to solve unbalances between power production and demand. In the Dutch context, with the development towards a hydrogen backbone, production of green hydrogen from electricity seems more realistic. However, in the Netherlands the production of biohydrogen by the gasifiers might be an opportunity.
8. **Biomethane as part of circular water cleaning sector**. Water cleaning sector and biomethane: in the Netherlands, this sector is a key player in the climate agreement, producing biogas, electricity and — more and more often — biomethane, from the sewage slurry. This fits into a programme of broader valuation of components, like alginate (fibers) and struvite (i.e. phosphorus). In Denmark, this seems to be an opportunity.