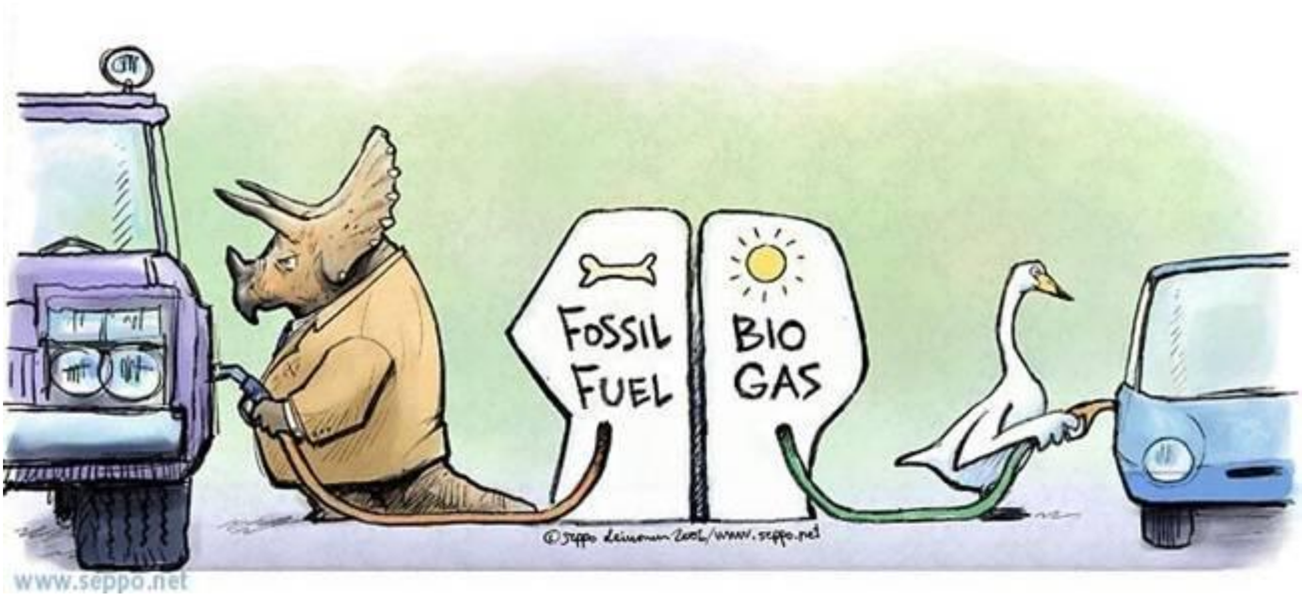
Mapping Biogas in the Nordic Countries

Report to Nordic Energy Research

norden

Nordic Energy Research



30 November 2010

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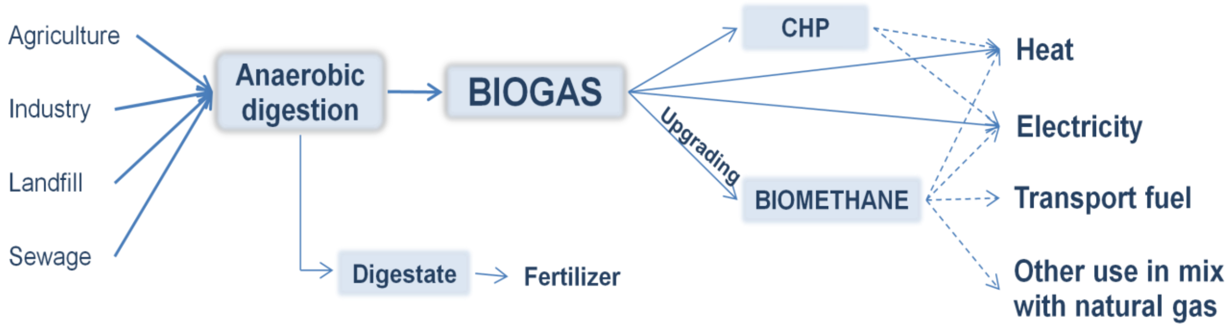
Executive summary

Biogas has received increased focus in recent years as a valuable potential energy contributor to reducing climate gas emissions. Much of the biogas can be produced by capturing methane currently released into the atmosphere and using this to replace fossil fuels would lower total emissions even more. Biogas is fuel in combined heat and power (CHP) production or it can be upgraded to natural gas specifications and used in electricity/heat production, in transportation (CBG) and in gas grids, alone or blended with natural gas.

Figure 1 Schematic representation of the biogas value chain



Source: Sund Energy, 2010

Europe has in the past few years given renewed attention to biogas and, as technology improves, costs are reduced. Combined with higher willingness to pay for mitigating climate emissions, this could increase the role of biogas in future energy mix. In parallel, many countries plan to support natural gas vehicles, making associated technologies cheaper as well. Perspectives for biogas could then improve even further.

In the Nordic region, biogas use is very small in the total energy picture and it differs substantially between countries. The two largest producers, Denmark and Sweden, are very different biogas users: Denmark puts most biogas output into CHP plants, while Sweden prefers upgraded biogas as vehicle fuel. Finland and Norway both have low biogas production compared to potential, while Icelandic output is almost negligible. Biogas could increase significantly or it could remain a small part of the Nordic energy mix. This overview is to illustrate regional potential, values of using more biogas and possible barriers to development, some of which could be lifted politically.

To realise its potential, biogas needs to be lifted to political attention. Better emissions' accounting will also reveal the value of reducing emissions of methane from agriculture/ waste streams and of carbon dioxide (CO_2) from transport, making biogas a potentially significant lever in meeting climate goals despite currently small market shares. This is important, because on the environmental arena there is competition from many renewable sources, carbon capture and storage (CCS) and other measures. From an economic viewpoint, some biogas plants are already competitive, but profitability without political support should be the target for all plants in the long run. On the demand side, biogas availability is essential both at national and at local/ filling station level.

In summary:

- The socioeconomic potential of biogas is large and its role in the energy mix could grow if benefits for energy and the environment are seen in combination
- The necessary technologies are already developed and continuously improved, choices depending on the feed stocks for and the use of biogas
- Demand-driven markets will unleash larger biogas volume compared to the current supply-driven approach once the business models become economically sustainable
- There is high learning potential from collaborating with other countries, including on value and technology improvement
- Synergies and learning among the Nordic countries should be prioritised, breaking down silos of thinking, increasing cooperation and even developing joint solutions

Introduction/background

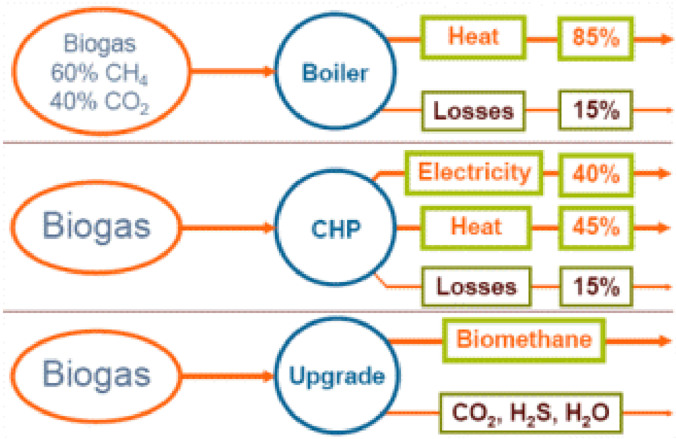
Biogas has received increased focus in recent years as a valuable potential energy contributor to reducing greenhouse gas emissions, mainly methane (CH_4). The Nordic Council of Ministers' Working Group for Renewable Energy has initiated this study. The focus of the report is to map current activity and use of biogas in the Nordic region and discuss possible future scenarios in order to identify opportunities for synergies between the five countries. The share of biogas in the energy mix is low and differs substantially among the Nordic countries, so better cooperation may enhance feasibility of the production, distribution and consumption of biogas in the region.

Biogas - what is it?

Natural gas, mainly methane, is a product of natural sediments from millions of years ago. Like oil, gas is trapped in geological formations and it can be extracted from these and burned for energy. Natural gas has low density compared to oil and is valued based on energy content/ calorific value. Biogas is similar, but the timing is different: waste from animals, people and organic matter naturally emits methane in months, rather than millions of years. This methane can be captured by covering it and is of sufficient quality for burning as fuel in CHP units, the main biogas use today. The by-product of anaerobic digestion, digestate, is often used as a natural fertiliser.

The "young" gas can also be upgraded technically to natural gas characteristics, for fuelling vehicles and blending with distributed natural gas. Upgrading is costly and removes unwanted elements, such as CO_2, particles and other gases. The extent of this removal determines calorific content. There is a trade-off between upgrading costs and gas worth, as the quality and energy content vary with substrate source. Upgraded biogas often still has lower calorific value than natural gas, delivering less energy per cubic metre of gas and impacting value and versatility.

Figure 2 Biogas uses and efficiencies



Source: University of Southampton at Biogas Markets, London, 2009

Biogas combines energy and environmental values in a unique way that is increasingly in focus throughout the world. The feedstock is usually available domestically and the gas is used in power and heat production (replacing coal or natural gas), in transportation (replacing oil products) or in gas distribution networks (replacing natural gas). In addition, capturing methane that would be otherwise emitted from agriculture, landfills and other sources enhances the environmental profile of biogas.

Note on data

Biogas represents a very small share of total energy use in most countries, so it often does not appear in official statistics, neither for volume nor prices. Mapping is therefore difficult and it seems many previous analyses have chosen to look at technology and number of plants, rather than energy mix and value. This study will look at current and possible future production, distribution and consumption of biogas. We also discuss prices and different forms of policy support. As governments are increasingly emphasizing the other side of sustainability (not only environment-friendly, but also economical), financial support will fade as volumes grow and costs fall. Enova, the state agency supporting biogas projects in Norway, mentions this in describing the incentives for 2010: the criteria are unchanged, but there is closer control of data on energy volumes and costs. This would make the biogas sector consumption instead of production driven.

Accounting of greenhouse gas emissions

Greenhouse gas emissions are increasingly counted for the entire lifecycle of energy, rather than just from end use. Biogas production often avoids methane emissions (20-24 times more potent than CO_2 over 100 years, 80-100 times in a 25-year perspective) from manure, wastewater sludge or landfills. If biogas also replaces fossil fuels in CHP or transport, recent research shows over 100% reductions in greenhouse gas emissions. Feeding biogas into the natural gas network is thus termed "decarbonising the network" even if biogas has more CO_2 than natural gas. Biogas life cycle analyses reveal differences depending on the choice of feedstock. If agricultural waste or sewage sludge would have otherwise emitted methane, climate accounting is more favourable than if the biogas is made from something that would otherwise cause no emissions. In transport, lifecycle analyses for vehicle emissions show that fuels perceived as "clean" (e.g. electricity and hydrogen) have higher emissions than petrol. Meanwhile, biogas as vehicle fuel could be counted as negative emissions.

The EU has adopted biomass emission standards that are comparable to traditional fuels. Biogas reduces emissions from waste by 80%, from wet manure by 84% and from dry manure by 86%. Only bio fuels that reduce emissions by at least 35% are approved (EU Directive 2009/28/EC on renewable energy promotion, article 17). So far, there is no mechanism for considering negative emissions in greenhouse gas accounting and auditing, so the concept is not backed up by financial incentives. In the future, as countries try to reach "climate neutral" status, having such negative elements will help in meeting the goal compared to cutting absolutely all current fossil greenhouse gas emissions. This issue should be brought up to EU's attention in order to put in place incentives for being more than climate neutral by increasing negative emissions.

Policy justifications for biogas use

Biogas can be found in all countries, but it is always a small part of the total primary energy mix and has a different "image" from natural gas. Biogas potential varies and is often greater with political support, based on different justifications. Interestingly, these are country specific, depending on energy alternatives, political focus/ preference and even individuals' skills:

- **Environmental:** By making CO_2 negative fuel, biogas provides a faster way to become climate neutral than the ongoing pressure for efficiency/reduced consumption. Before climate change concerns, in the 1980s, biogas was already promoted in Denmark for improving local ground water, surface water and air quality, while at the same time boosting the agriculture sector.
- **Economical:** Domestic production is often seen more favourably than oil and gas imports, especially when imports have been seen as very costly during the last few years
- **Security of supply:** Domestic sources are always perceived as more secure than imports; especially natural gas has had at times an image of being less secure, although this is gradually changing with the current oversupply and with new pipelines being built in Europe.

Although most countries do not place an exact value on secure supplies, reducing vulnerability to insecure and possibly expensive imports is seen as important. This has given biogas added value in countries such as Germany and the Netherlands. Also, as some of the countries are realising that conversion to electric cars could take time and is not guaranteed, taking up vehicles using natural gas or biogas is starting to be seen as easier to achieve. Going forward, one could also see biogas in ships and airplanes, with improved technology and continuation of current policies. This growing interest could reduce costs significantly, with positive effects on production and use in many countries.

Who is doing it?

Biogas is not a mature industry and still seems to be dominated by enthusiasts with different backgrounds, drivers and ambitions. There are farms wanting a higher income from manure, engineers wanting a new area of focus after seeing a large potential and regulators fascinated by the upside for society. Typical for this situation is that there is not much comparable data or quality control thereof, harmonisation of terms or quality requirements, with more focus on number of plant rather than energy supplied. However, this is now improving with the growing interest in biogas in many countries. Increased dialogue between the different groups will bring forward a more harmonised "language" of data and standards, while larger volumes will position biogas into the overall energy picture in a better way. In the past, biogas groups have been focusing on rapid growth but, going forward, it will be easier to see contributions to primary energy, final energy, environment and perhaps even security of supply. The rising number of international conferences is helping in this respect.

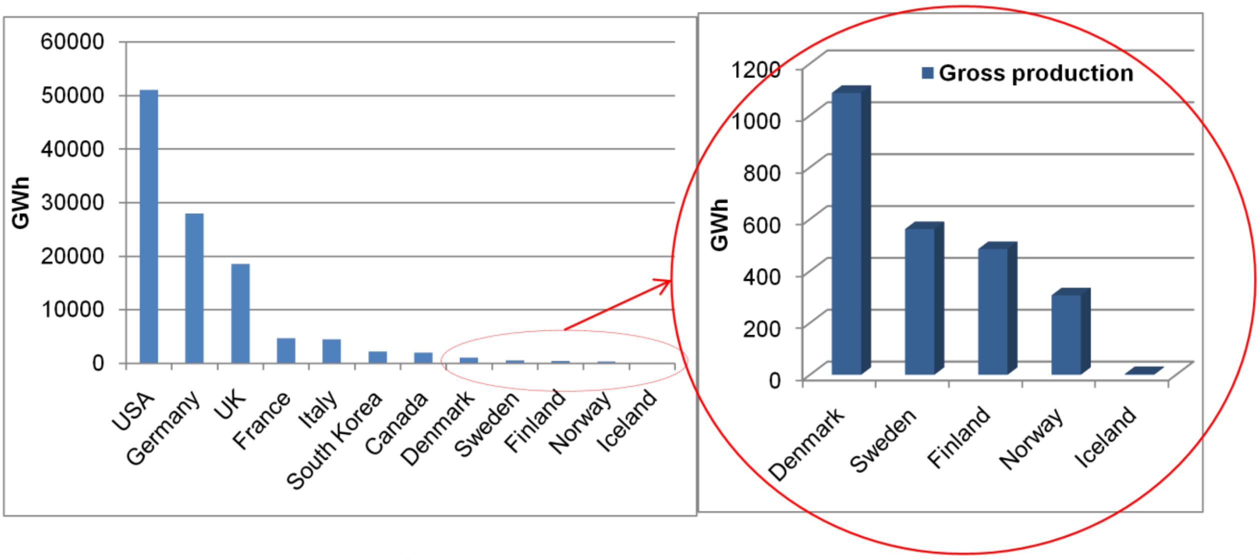
International perspectives

There is a global interest in renewable energy, despite the economic downturn and still incompatible views on climate change mitigation options among countries. In 2010, new renewable generation capacity installed globally (dominated by hydro, wind and solar power) is expected to be higher than new fossil fuel capacity. Compared to other renewable energy sources, biogas has several added advantages, including the associated reduction in methane emissions and the possibility to generate on demand (a growing need with more intermittent electricity sources like wind and solar). Biogas from agriculture substrates improves land management, resulting in less nitrogen and phosphorus spillover into ground and surface waters. Biogas is also better received by people, as it is relatively affordable and it boosts local economies.

UN institutions have been advertising the contribution biogas can make to sustainable development for more than two decades and mechanisms such as CDM now grant certified emission reductions for biogas projects in developing countries. The International Energy Agency also has a dedicated task force (37) to enhance international cooperation on biogas technology and create industry standards. In countries with predominantly rural settlements, biogas is mostly sourced from agriculture substrates, while developed countries often make better use of landfill and sewage sludge gas.

While biogas is produced in most countries, there are also some truly global leaders, with three countries responsible for most of the world's production. By far the largest market is the USA with more than 50 TWh. Germany and the United Kingdom are also significant producers, although even combined their output is below the USA. The Nordic countries are also present in the global biogas picture, but with comparatively low levels of production, as illustrated in figure 3. The data should be interpreted with caution and regarded as an indication of order of magnitude, since it is not fully comparable with alternative national data sources and it dates from 2007. The 2008 update is expected in December 2010.

Figure 3 Production of biogas in selected countries and the Nordic region



Data: UN Data, December 2009 (data for 2007)

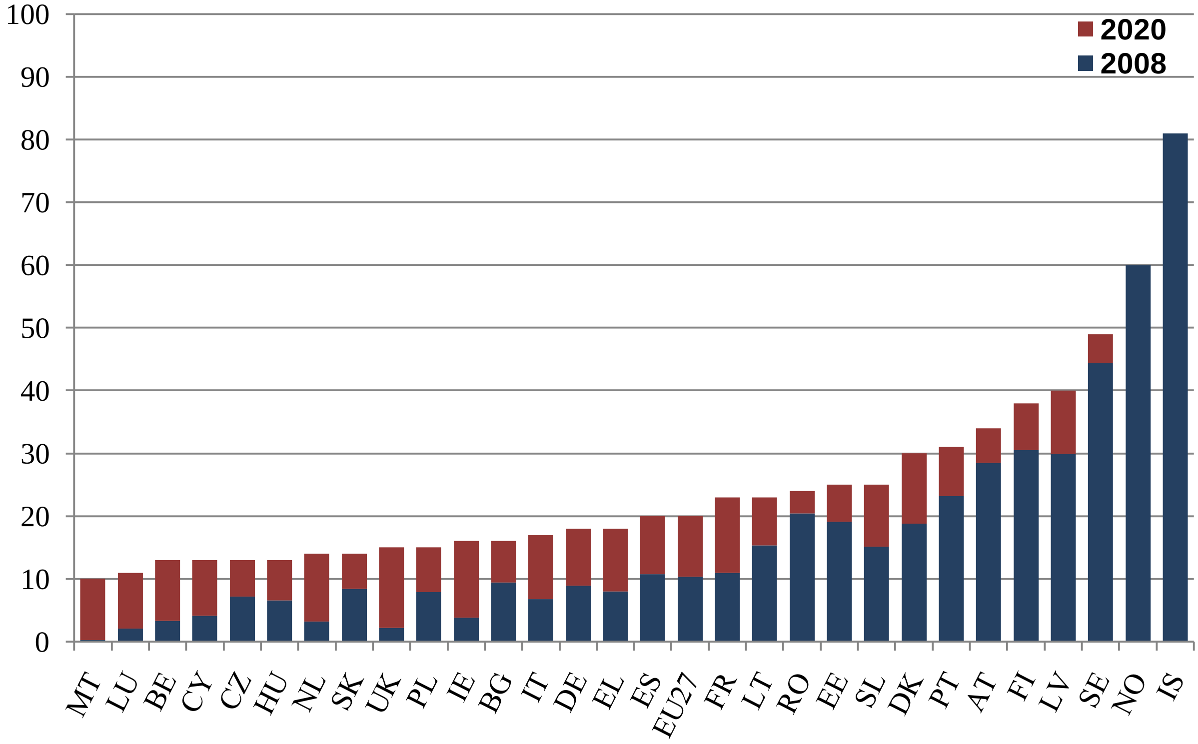
Short historical evolution of biogas use

Manure and wastewater have been used for energy purposes for millennia, with the earliest records of biogas utilisation dating from about 2000 years ago in Asia. By the 1800s, China and India burned biogas for heating water. Improved technology boosted production before the First World War and Germany was already feeding bio methane into the gas distribution network in the 1920s. Since 1949, compressed biogas was used as car fuel. After the Second World War, comparatively cheap oil made biogas unprofitable and many plants were closed down until the oil crisis in the early 1970s. As oil got costlier in the aftermath, biogas to heat, electricity or CHP became popular and production started to grow again. Technology improvements over the last decades and efforts to reduce greenhouse gas emissions are currently giving more weight to biogas in the energy mix.

European perspective – great variation

The EU has pledged to meet 20% of total final energy consumption from renewable energy sources and to reduce greenhouse gas emissions by 20% compared to the 1990 level by 2020. EU policy is also intended to lower overall energy consumption and the volume of imported fossil fuels, improving trade balances and security of supply. As seen in figure 4, all EU27 countries have to increase their share of renewable energy. Although Norway is part of the EEA and thus bound by the European directives, the country does not have a similar stretch target. This is partly explained by the high share of hydro power and very low use of fossil fuels for electricity or heating. Iceland is in a similar situation as Norway, already having a very high share of geothermal and hydro energy.

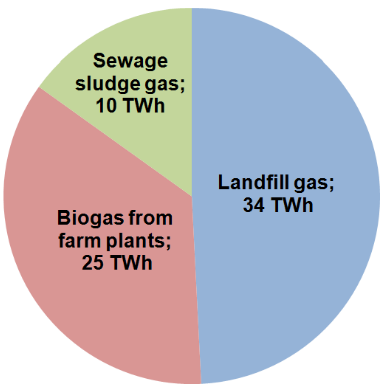
Figure 4 Status and target of renewable share in total energy for EU27, Iceland and Norway (%)



Data: Eurostat, Statistics Norway and Statistics Iceland, 2010

Biogas is one of several energy forms that are encouraged, both with preference in the energy system (gas pipelines and electricity grid feed-in) and reduced investment risk. The 2020 targets for renewable energy will likely support biogas in many countries in all areas of use: electricity/ heat production, transportation and blending in natural gas networks. However, each country has different incentives and preferences depending on their energy mix and alternatives for renewable energy. In 2007, overall production was almost 70 TWh, half of which came from burning landfill gas. Biogas from agricultural substrates accounted for another third of total production and the remainder was obtained by processing sewage sludge.

Figure 5 Biogas production by feedstock in the EU27



Data: EurObserv'er, 2008 (latest available, data for 2007)

Biogas in Germany

Germany is building a mature biogas industry, with leading companies across the value chain. Production has seen a bottom-up development and there will be approximately 6000 biogas plants in operation by the end of 2010. Farmers are incentivised to use agricultural substrates and produce electricity and heat from biogas. Under the current Renewable Energy Source Act (EEG), the use of energy crops and manure in biogas production is rewarded with 4-8 €c/kWh and bonuses are allocated for landscape work substrates, for innovative technologies (such as biogas upgrading), for burning the biogas in efficient CHP units, etc. Overall, feed-in tariffs are 8-30 €c/kWh.

Biogas upgrading to natural gas characteristics is also encouraged. Natural gas network operators have to connect plants to the grid and cover half of the associated cost, as well as take care of odorization, quality control and compression of the bio methane. An alternative to injecting bio methane in the natural gas network is to set up off-grid gas filling stations for vehicles. Germany has 45 operational bio methane feed-in projects and 60 more are planned or under construction, expecting a total annual feed-in capacity of 0.65 bcm by 2012. The potential estimated by the Wuppertal Institute for 2020 is 12 bcm, more than 10% of Germany's total natural gas demand. Biogas use already reduces Germany's annual greenhouse gas emissions by about 15 $mtCO_2$ equivalent.

Biogas in the United Kingdom

The United Kingdom is the largest European user of landfill and wastewater-based biogas, while anaerobic digestion on farms is only also taking off now. Plants with a capacity below 5 MW which generate electricity from agricultural substrates are eligible for feed-in tariffs of 9-11.5 £p/kWh for a duration of 20 years, while heat from biogas and bio methane will receive feed-in tariffs starting with June 2011 via the Renewable Heat Incentive. Farm plants above 5 MW are entitled to two tradable Renewable Obligation Certificates per MWh of electricity delivered to the grid. Moreover, biogas used in CHP is exempted from climate change levies.

Two projects –a brewery and a wastewater treatment plant– are currently injecting upgraded biogas into the natural gas network, both operational since October 2010. Interest in bio methane is likely to increase with the launch of a green gas certification mechanism. National Grid presented a baseline scenario where more than 5 bcm of bio methane would be injected into the gas grid in 2020. An optimistic scenario places the figure at 18 bcm, almost half of all residential demand for natural gas. Liquefied biogas for commercial fleets is also being tested.

As domestic natural gas production is rapidly declining, the United Kingdom investigates the possibility of using biomass for thermal gasification in order to supplement biogas potential by producing large volumes of biogenic synthesis natural gas (bio-SNG). There is a large biomass potential in the United Kingdom, but bio-SNG will have to compete with other uses of biomass. Bio-SNG is not within the scope of this report.

Mapping biogas in the Nordic countries

Similar to the EU, Nordic countries are aiming to increase biogas use as part of a renewable energy drive. As shown in this section, they have taken different approaches to realise the potential of available biogas resources. Historically, the availability of biogas substrates has been the strongest driver for development: if raw material is available, countries find a way to use it. However, production is now increasingly expected to be demand-driven, with markets wanting more biogas in their energy mix and with production scaled and suited to meet this demand. The following sub-chapters describe particularities of the biogas value-chain in the Nordic countries.

Production

In Denmark, biogas has a flavour of added income to farmers and production pushes demand, which is preferred as CHP to avoid costs of upgrading and transportation. More than 50% of the Danish production is based on manure in combination with organic waste from the food and meat processing industries, while the rest is split between sewage sludge and landfill gas. There is still large potential for increasing biogas production from manure in Denmark (only 5% is currently used), but as slaughter house activity is gradually decreasing through relocation to e.g. Germany and biogas production is planned to increase substantially up to 2020, it will be necessary to replace industrial organic waste in the co-digestion mix with new raw materials like energy crops.

In Finland, landfill gas is the main source of biogas, with more than 30 plants throughout the country. Up to mid-2010, investment in biogas plants had been frozen for years awaiting decision on feed-in tariff regimes. The number of farm scale plants is small in Finland and with existing support the perception is that they will stay uneconomical. Nearly all biogas is used for heat and electricity production, but Finland has a natural gas network in the south which could take up bio-methane.

Iceland's biogas production is practically negligible (one landfill gas plant) and the potential is also limited. Biogas cannot compete with geothermal heat and hydro power, but it could cover part of the local energy demand in large farms.

Norway has been behind in biogas production, but it is now growing in several areas. The fact that there is a very limited natural gas activity in the country is one of many factors holding biogas back and in addition the tax system leads to waste being exported to Sweden and Denmark (this inconsistency is now gradually removed). Another reason for limited production of biogas in Norway is that the country is rich in resources and economically, making drivers such as security of supply and domestic economy less powerful than in other countries.

In Sweden, according to the Energy Agency, biogas production is nearly 1.4 TWh but the potential is ten times larger, with considerable untapped resources in agriculture. The government is actively supporting research and development in the sector, while in transportation there is an initiative to convert tractors to use bio-methane. Heat is the main end product of biogas in Sweden, but demand for transport is growing, determining producers to increase capacity. The lack of a widespread network for distribution is identified as an obstacle for growth. Sweden is in general ambitious in using renewable energy (including bio fuels), with an overall target of 49% of final energy consumption for 2020, the highest in the EU27. As electricity is mostly climate neutral, the focus is now on the transport sector.

The Faroe Islands have not reported biogas consumption. In Åland, there are some investments in biogas production based on manure and organic waste, but volumes are very small. Greenland does not have biogas production so far, but a pilot plant is expected in 2011 to run on waste from fishing and hunting in Uummannaq. A doctoral thesis from 2009 has assessed the feasibility of biogas from shrimp manufacturing waste in Sisimiut.

Overview of biogas production technologies

Biogas is the result of anaerobic digestion, whereby organic matter with more than 50% moisture content is decomposed in the absence of oxygen at temperatures of 10-100°C. This occurs naturally in peat bogs, swamps and ruminant intestines, or in manufactured digesters. The feedstock is determinant of process duration and wood is for example unsuitable for biogas production due to high lignin content and long decomposition times. The output is a burnable gas made of mostly methane and CO_2, as illustrated in Table 1. If oxygen is present, such as in thermal biomass gasification, the associated process known as aerobic digestion has as output synthesis natural gas (syngas), not biogas.

Table 1 Methane, CO_2 and energy content of biogas, landfill gas and natural gas

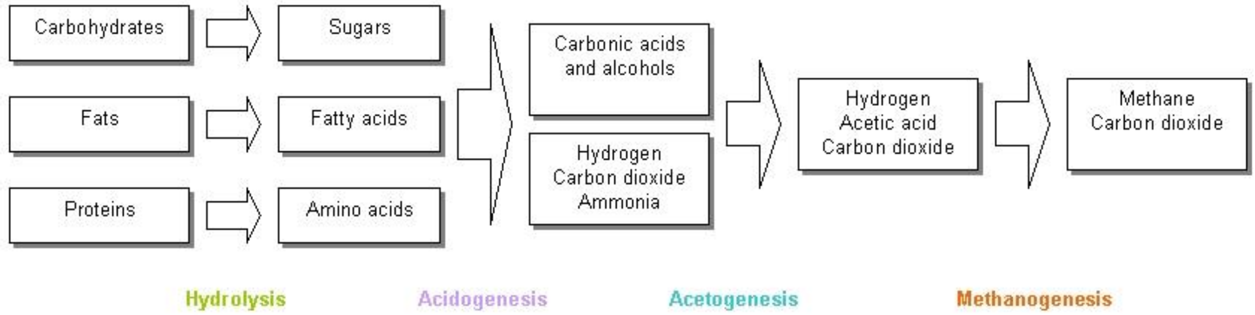
	Biogas	Landfill gas	Natural gas (Danish)	Natural gas (Dutch)
Methane (%)	60-70	35-65	89	81
CO_2 (%)	30-40	15-50	0.67	1
Lower heating value (kWh/ Nm^3)	6.5	4.4	11	8.8

Data: IEA Bioenergy –Task 37

Substrates suitable for biogas production are organic waste streams (landfill waste, sewage sludge from wastewater treatment, industrial organic waste from the food industry), agricultural by-products (manure and bio waste) and dedicated crops (energy and catch crops). The CH_4 content of these sources is higher with lower moisture, but anaerobic digestion is most suitable for substrates with at least 70% water content (wastewater, food waste and certain livestock manures). Anaerobic digestion takes place in a four stages:

- Hydrolysis: Bacteria digest carbon hydrates, proteins and fats into sugars, fatty acids and amino acids
- Acidogenesis: Bacteria convert the products of hydrolysis into carbonic acids, alcohols, H_2 and CO_2
- Acetogenesis: Bacteria convert the products of acidogenesis into acetic acid, H_2 and CO_2
- Methanogenesis: Bacteria convert these products into biogas

Figure 6 Transformation stages in the anaerobic digestion process



Source: Clarke Energy, 2010

The solid by-product of anaerobic digestion is known as digestate. Digestate produced during acidogenesis contains lignin and cellulose and retains moisture, while digestate resulting from methanogenesis is a sludge rich in nitrates and phosphates that can be used as natural fertilizer and soil conditioner. Digestate could regulate the nitrogen cycle and enhance the sustainability of intensive agriculture.

There are many types of farm scale digesters and the functioning principle for four main technologies used for manure processing is outlined:

- *Covered lagoon digester*, suitable for liquid manure with less than 3% solid concentration. The manure is stored in a covered lagoon and biogas can be extracted after decomposition through a suction pipe. The process requires large volumes and a warm climate, but has low capital cost.
- *Complete mix digester*, suitable for liquid manure with solid concentration between 3% and 10%, which converts organic waste to biogas in a heated tank. It requires mechanical or gas mixers to keep the solids in suspension, so it needs large volumes and has high capital cost.
- *Plug-flow digester*, suitable for liquid manure with solid concentration between 11% and 13% and typically made of a manure collection system, a mixing pit and the digester. The mixing pit, a container with airtight expandable cover, is used to add water to reach optimal consistency. The slurry is kept between 25°C and 40°C, which is optimal for methane production.
- *Fixed film digester*, basically a tank filled with plastic media which support a thin layer of anaerobic bacteria called bio film. As the waste manure passes through the plastic media, biogas is produced. This technology is best suited for deluted waste streams.

Centralised anaerobic digestion, pioneered by Denmark, uses several different substrates in co-digestion to optimise feedstock composition and digestate quality. Larger reactors also increase the stability of input flows across the seasons and improve scale economies. Co-digestion usually takes place in wet systems. Dry continuous digestion in plug-flow systems is also possible, reducing the energy use of the biogas plant.

Landfill and sewage sludge gas are also the result of anaerobic processes. Landfill gas occurs naturally in a process known as wet organic waste decomposition and can be collected via wells drilled into the landfill and a piping system that connects the wells.

Production costs

The cost of producing raw biogas varies greatly, as estimated in a 2007 study based on Swedish sources and performed by Østfoldforskning in Norway. Biogas plants have been classified in three categories in this report and results are summarised in table 2. Cost differences are mainly due to different complexity levels between the categories and thereby investment cost. Production costs also vary within each category, due to plant size.

Table 2 Costs associated to biogas production in Sweden (2007)

Plant type / SEK/ kWh	Capex	Opex	Total
Liquid waste, simple technology (e.g. larger plants for sewage sludge)	0.05 – 0.08	0.06 – 0.11	0.11 – 0.19
Semi liquid waste, complex technology (e.g. household waste that requires pre-treatment)	0.12 – 0.44	0.34 – 0.66	0.46 – 1.10
Semi liquid waste, simple technology (e.g. farms)	0.22 – 0.39	0.06 – 0.07	0.28 – 0.46

Data: Østfoldforskning, 2007: Bioenergi i Norge – potensialer, markeder og virkemidler

E.ON and others (2007) have estimated the production cost at between 0.13 and 0.40 SEK/kWh for manure and industrial waste. The span is due to scale economies in the digesting process.

Upgrading

Germany, Sweden and Switzerland have many biogas upgrading plants and they are all using bio-methane actively in both transportation and gas network distribution. Sweden has 38 feed-in projects and 466 GWh of bio-methane production in 2008. Utilisation is predominantly as vehicle fuel, but also in the gas grid in the south west. The preferred technology is water scrubbers, but pressure swing adsorption and chemical scrubbers are also used. These technologies are described briefly in the overview below.

Far behind but second in the Nordic region is Norway, where several players are growing their activities. There are currently 3 upgrading plants, but growth is expected in the future. However, it must be kept in mind that even doubling bio-methane volumes would still not give 1% of primary energy demand. The single largest potential is from agriculture in Rogaland. Finland has brought to bio-methane quality only 0.4 GWh of biogas in one plant in 2008, while Iceland also has only 1 upgrading plant. Denmark has so far assessed upgrading as uneconomical, using raw biogas only directly (mostly) in CHP units.

Overview of biogas upgrading technologies

For some applications, such as vehicle fuel or for grid injection, it is important to have high energy content in the gas. Bio-methane with natural gas specifications is necessary to make the two gases substitutes. This is achieved by upgrading the biogas, a process which adds to biogas costs before its utilisation. It is important to have an optimised upgrading process, which gives high methane content in the upgraded gas and is energy efficient. Minimising methane and CO_2 emissions from the process is also important.

The energy content of upgraded biogas becomes comparable to natural gas after removing CO_2, water, hydrogen sulphide, nitrogen, oxygen, ammonia, siloxanes and particles. Efficiency and flexibility increase substantially by using natural gas instead of biogas in CHP, but the additional value with upgrading needs to be worth the upgrading cost. Several mainstream techniques for upgrading biogas are in use:

- *Pressure Swing Adsorption,* the separation of CO_2 by adsorption on a surface under high pressure
- *Membranes* made of dry materials permeable to CO_2, while only little methane passes through
- *Absorption*, whereby the raw biogas meets a counter flow of liquid in a column. CO_2 is more soluble than methane. The liquid leaving the column contains an increased concentration of CO_2, while the gas has higher methane concentration. Examples of absorption technologies are water scrubbing, organic physical scrubbing and chemical scrubbing

Among the new developments in upgrading technology, the most successful are:

- *Cryogenic upgrading*, which makes use of the distinct boiling/sublimation point of component gases, particularly for the separation of CO_2 and methane
- *In situ methane enrichment*, whereby CO_2 is removed from the sludge, leading to increased methane concentration
- *Ecological lung*, whereby an enzyme is used to dissolve CO_2 from the gas

Upgrading costs

The cost of upgrading biogas to bio-methane is dependent on the specific technology used, but the most important cost determinant is plant size. Other important factors weighing on the economics of upgrading are plant efficiency, the location and availability of a secure biogas supply with low logistics cost and the proximity to natural gas pipelines or markets.

Bringing raw biogas to the same methane content as natural gas has a cost of between 0.10 and 0.20 SEK/kWh, as estimated by the IEA biogas taskforce in 2009. E.ON places the upgrading costs for Sweden in 2007 at between 0.09 and 0.28 SEK/kWh, while other studies show spans from 0.10 to 0.40 SEK/kWh. The cost of getting raw biogas up to natural gas specifications is additional to the biogas production costs in table 2. The seller of bio-methane to natural gas networks is responsible for gas quality and thereby for the cost of upgrading raw biogas. This is important, as the choice of upgrading technology influences final bio-methane quality and thereby its suitability for different uses. For example, biogas from landfills is more costly to upgrade to vehicle quality than biogas from covered plant.

Distribution

In principle, transportation costs are incurred at all stages in the value chain: from feedstock source to biogas production site, to CHP unit (often located near feedstock)/ upgrading plant, and finally to market. This array of costs depends on the water content of feedstock, transported volumes, distance to the next value-chain level and is difficult to estimate as such. Some general considerations relevant for the Nordic perspective can be made, though.

First, agricultural feedstock for biogas is usually largest in areas far from markets, increasing transportation costs and even rendering biogas projects unfeasible. The lack of local markets for power and especially for distributed heat in combination with low volumes often leads to biogas being flared. Many farms never get connected to the electricity or gas grid, instead using biogas for own needs and replacing fossil fuels. When production is centralised, micro-grids can be feasible for distributing heat and power to local communities.

Second, upgrading plants need to be located close to natural gas grids or filling stations for gas to vehicles in order to make feed-in feasible. Due to small volumes, transportation is done by truck as compressed gas in bottles (CBG) or as liquefied gas (LBG), as well as by pipeline in the local or main distribution grids. The alternatives for transporting bio-methane have been analysed, concluding that compressed gas by truck is the most economical solution for volumes of about 10 GWh annually. Local gas networks are economical for larger volumes, e.g. a 50 km gas pipeline becomes feasible above annual capacities of 100 GWh (10 mcm). In general, it is economical to transport the gas in existing pipelines when this is possible. Swedish studies indicate a cost of transport and distribution of about 0.20 SEK/kWh, assuming a compressed state and a maximum distance of 50 km from upgrading site to market (Energy Markets Inspectorate, 2009).

Sweden has natural gas distribution mainly along the west coast, but also in Skåne and in Stockholm. 36% of Swedish biogas is upgraded and injected into the national gas network, which is supplied by Danish gas. In Finland, there is a natural gas network in the south, connected to the Russian and Baltic networks. There are extensive networks for natural gas distribution and for district heating in Denmark. However, biogas has not yet been upgraded to natural gas specifications in Denmark. This is in part due to own natural gas resources, but biogas upgrading costs are also seen as prohibitively high.

Denmark is now looking at the possibility of establishing national or regional pipelines for distributing raw biogas, to circumvent high upgrading costs. Since biogas output is insufficient for an extensive network running parallel to the existing natural gas network, two options are analysed. First, as domestic natural gas production is declining, peripheral pipelines could be cut off from the main grid and supplied exclusively with biogas. Alternatively, the entire natural gas network could be supplied with biogas quality gas, by downgrading natural gas at a fraction of the cost of upgrading biogas. However, calorific value is lower with lower methane content and more pipeline capacity would be needed to deliver the same amount of energy. Moreover, appliances would have to be checked if gas with a different composition were used.

Economics

Biogas competes with other fuels and needs to be economic to consumers as well as producers. Most biogas still has government support of some kind, normally as top up on the electricity price, but also as financial support for building plant. Based on the previous overview, the total cost of production and delivery of biogas to the customer can be approximated with the sum of production, upgrading and distribution costs. As seen in table 3, the total cost of biogas varies greatly, with the cost of the cheapest option is one third of the cost for the most expensive solution analysed.

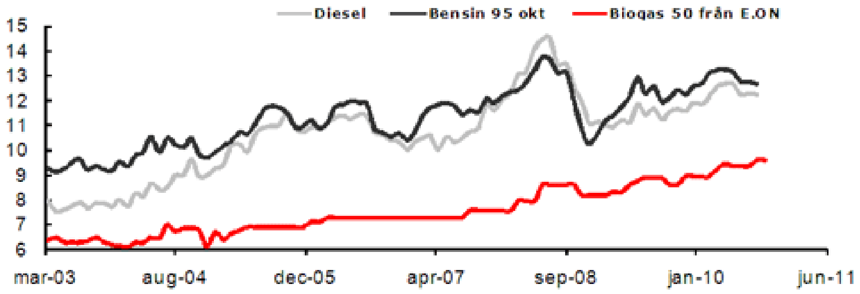
Table 3 Total value-chain cost of biogas

Plant type — SEK/kWh	Production	Upgrading	Distribution	Total cost
Liquid waste, simple technology	0.11 – 0.19	0.10 - 0.20	0.20	0.41 - 0.59
Semi liquid waste, complex technology	0.46 – 1.10	0.10 - 0.20	0.20	0.76 - 1.50
Semi liquid waste, simple technology	0.28 - 0.46	0.10 - 0.20	0.20	0.58 - 0.86

Data: Østfoldforskning, 2007; IEA Bioenergy –Task 37, 2009; Energy Markets Inspectorate, 2009

Biogas – cheaper than conventional fossil fuels

Biogas for vehicles is competitive from a fuel cost perspective, as can be seen in a longitudinal comparison by E.ON Sweden. The pump prices for diesel, petrol and gas with at least 50% bio methane are expressed in SEK/energy content of one litre of petrol. Moreover, there seems to be some room for profitability between the pump price and total cost for most sources of biogas.



The slightly higher price of eco-fuel cars compared to petrol and diesel cars and problems with fuel availability are slowing demand growth.

Government support

From an overall perspective, it appears that countries that are more concerned about their economy and have less own oil and gas have been more focused on developing own energy to lower import costs, grow their economy and in addition have the potential to reduce emissions. This is more evident in the two Nordic countries with nuclear power, Sweden and Finland.

Supply-oriented governments have usually responded to the industry's call for policy support, driven by the expensive development and take up of new renewable technology and by the lack of economies of scale. As the financial schemes have often taken long time to develop and pass into law, in public presentations given by the industry the focus is often on how to get more government support to expand production. Little is said about how biogas should be used, how it can compete in relevant markets and why governments should support it.

In Denmark, policy support is basically directed through generation of electricity of biogas (from livestock and organic materials) and through energy and CO_2 tax exemption of heat produced based on biogas. The goal is to collect and convert to green energy 50% of the country's livestock manure by 2020, compared to only 5% in 2010. New biogas plants receive 20% investment support when several farmers cooperate and up to 60% community guaranteed loans. CHP plants that use 94% to 100% biogas as feedstock receive a feed-in tariff on electricity produced of DKK 0.772/kWh, plus exemption of energy and carbon taxes for the produced heat. When biogas makes up only part of the CHP feedstock, plants receive a premium of 0.405 DKK/kWh for the share of electricity generated with biogas plus the tax exemption for heat. Energinet.dk buys biogas electricity and sells it on Nord Pool, with the difference between Nord Pool price and the feed-in tariff also paid by consumers.

In Finland, new biogas plants receive grants covering 15-50% of initial capital expenses. Moreover, recent legislation has set up a feed-in tariff regime for electricity from biogas. Producers are guaranteed a price of 8.35 €c/kWh for power generation and 13.35 €c/kWh for CHP with at least 50% efficiency. Farmers argue that small biogas plants are still not economical, even with the new level of support. The authorities expect 50 GWh of additional annual output from landfill gas because of the new scheme.

Iceland has no subsidies for biogas. Biogas cannot compete with geothermal heat and hydropower, but it could be a viable fuel for off-grid farms, especially if capital expenses are partly covered by the state.

In Norway, governmental support to renewable projects is managed by Enova. The authority provides 40% investment support for small-scale plants, with 8 projects in the start-up stage and 28 other under planning. 80 million NOK were allocated during 2009 and 2010 for 7 larger projects with an expected annual output of 140 GWh. Electricity production and economic projects on a stand-alone basis are not supported. In general, agriculture projects are not economic, as there is no alternative cost related to emitting methane, but waste projects could be (typically from household waste, sewage, fish industry and poultry). Support to transport is managed by a new authority, Transnova. In 2012, Norway and Sweden are expected to create a common market for green electricity certificates.

Sweden has a functional market for green electricity certificates, which also supports biogas. Moreover, the fuel is exempt from energy taxes. Partial grants are given for investment in biogas production, distribution and use as vehicle fuel, as well as for electricity and heat production. Biogas upgrading can receive up to 30% investment support in rural areas. Swedish authorities also finance innovation in the sector. SEK 106 million has been allocated this year to support 11 biogas projects, of which three in transportation.

Support scheme uncertainty: Case of Lyse Energi in Rogaland

Lyse Energi is the public energy company of Rogaland, established in 1909 and owned by sixteen municipalities. It operates mainly hydropower, then lately gas, wind and telecom. Lyse has recently invested in biogas, as Rogaland has the highest potential in Norway according to the national authority responsible for renewable projects, Enova. The area is well suited for production of biogas because of good access to raw material, as well as a distribution system for and use of natural gas. The total consumption of natural gas in 2009 was 620 GWh (1100 customers). The area has a 50 kilometre high-pressure gas net with a capacity of 15 TWh and a 450 kilometre low-pressure distribution system.

Lyse Energi works with IVAR (also owned by the region's local authorities), which provides it with output from a local sewage plant in Mekjarvik. Wastewater sludge from 220000 people is turned into biogas, upgraded and then put into the gas network. Lyse Energi and IVAR also plan to produce 80 GWh of biogas annually from household, industry and agricultural waste by building Hå Biopark. However, the project was postponed indefinitely in August 2010 due to lack of government support. Hå Biopark needs 50% investment support and a production support of 1.3 NOK/kWh to be realised.

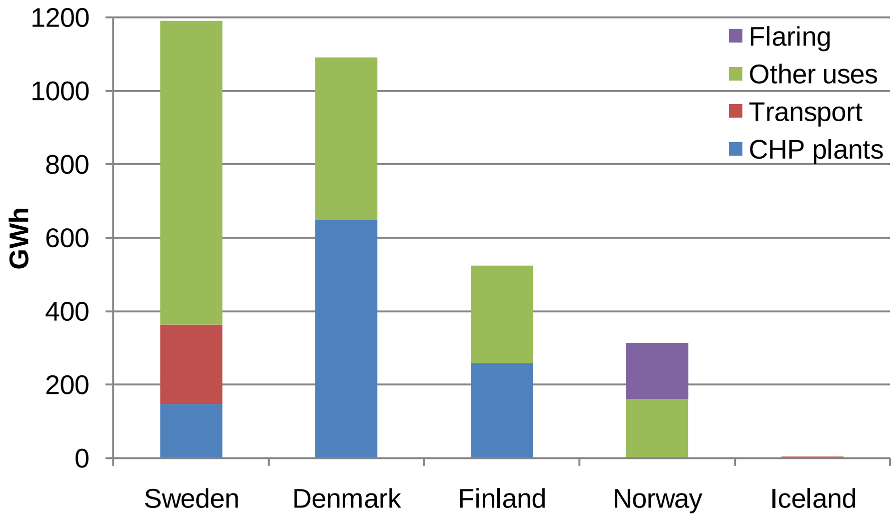
Lyse Energi mixes bio-methane (33%) with natural gas (67%) and sells it to 180 gas cars currently registered in Rogaland. In 2010, the company forecasts 8 GWh gas sales, of which 3 GWh biogas from three filling stations. In addition, 3 more stations are planned and a further 13 stations are under evaluation. In 2011, Lyse Energi plans to have 9 stations and to supply some 500 cars with 16 GWh gas, of which 8 GWh bio-methane.

Transnova, the state authority in charge of projects designed to reduce CO_2 emissions from transport in Norway, has so far supported Lyse Energi in their development of biogas filling stations, but this covers only about 25% of investments.

Consumption

As mentioned previously in the report, there are difficulties in finding consistent statistical data on biogas consumption, also for the Nordic countries. For example, IEA Energy Statistics for 2008 is one source that includes all countries (see figure 7), but the reported volumes are inconsistent. For example, the database suggests that Norway is the only country in the region which flares biogas.

Figure 7 Consumption of biogas in the Nordic countries



Data: IEA Energy Statistics, 2010 (data for 2008)
Note: Other uses include electricity and heat plants, direct use in industry, agriculture/forestry, as well as the commercial, public and residential sectors.

We have looked at several sources of data. The three EU member states have reported estimates for 2010 to the European Commission this summer. Consumption of biogas in different market segments (electricity production, heating and cooling, transport) is estimated as required by the EU Directive 2009/28/EC on renewable energy promotion for each year between 2010 and 2020. The data is only giving an orientation, especially for small sources like biogas.

The estimated share of biogas in renewable and in total energy consumption in 2010 is shown in table 4B. The transport sector in Sweden and CHP generation in Denmark are the only sectors where biogas has some relevance. We do not find comparable data for Norway and Iceland, but the share is probably lower in all segments.

Table 4 Estimated biogas consumption in 2010

A: GWh			
	Denmark	Finland	Sweden
Electricity production	194	40	53
Heating/Cooling	688	350	204
Transportation	0	0	467
Total	**882**	**390**	**724**

B: share of renewable and of total energy consumption (%)						
	Denmark		Finland		Sweden	
	Renewable	Total	Renewable	Total	Renewable	Total
Electricity production	**1.6 %**	**0.5 %**	0.2 %	-	0.1 %	-
Heating/Cooling	**2.4 %**	**0.7 %**	**0.6 %**	0.2 %	0.2 %	0.1 %
Transportation	-	-	-	-	**7.6 %**	**0.6 %**

Data: National Renewable Action Plans from Sweden, Denmark and Finland, 2010

Selected recent developments

Since biogas production is growing rapidly, but the latest available statistics only present data for 2008, this section looks at some of the most recent developments in the Nordic biogas industry. Without being exhaustive, the illustrations capture market trends and help identify critical steps that are needed to bring biogas closer to realising its potential.

In Sweden, the Energy Agency has recently published a report describing a national strategy for the biogas sector. Moreover, LNG vehicle filling stations are gradually being opened and Volvo is now testing dual-fuel trucks running on LNG/ LBG and diesel.

Gothenburg Energy (in partnership with E.ON) is building a large bio-SNG plant for gasification of bio fuels and waste from forestry. The synthesis gas will be purified and then upgraded to natural gas quality. The plant could be built in two stages, the first operational in 2012 and the second in 2016. Gothenburg Energy expects to deliver 1 TWh of bio methane annually by 2020.

Oslo is building a large biogas plant, based on landfill gas and built with financial support from Enova. The plant will be operational by 2012. The biogas will fuel buses and garbage collecting vehicles in the capital region. 14 buses are already running on biogas produced since 2009 at a wastewater treatment facility, but the number is expected to increase to about 150.

Another project supported by Enova is a CHP plant integrated with Norske Skog's Skogn plant near Trondheim, based on bio-SNG. This will be one of the first such plants in the world. Enova gave NOK 120 million to Fiborgtangen Vekst for the project. The annual output should be about 100 GWh power and 170 GWh heat. However, biogas support in Norway is not likely to increase before the following update of the national climate change strategy, scheduled for autumn 2011.

Why are biogas resources used so differently in Denmark and Sweden?

New energy forms are introduced to a society to meet a need for consumption, fix a problem or generate income to someone. The choice could depend on where the energy form exists, what the alternatives are and what focus the current government happens to have. The timing of different initiatives will also impact this. Seen from the outside, it seems that Denmark and Sweden have taken two different approaches, both valid and both fine, perhaps explaining the very different results.

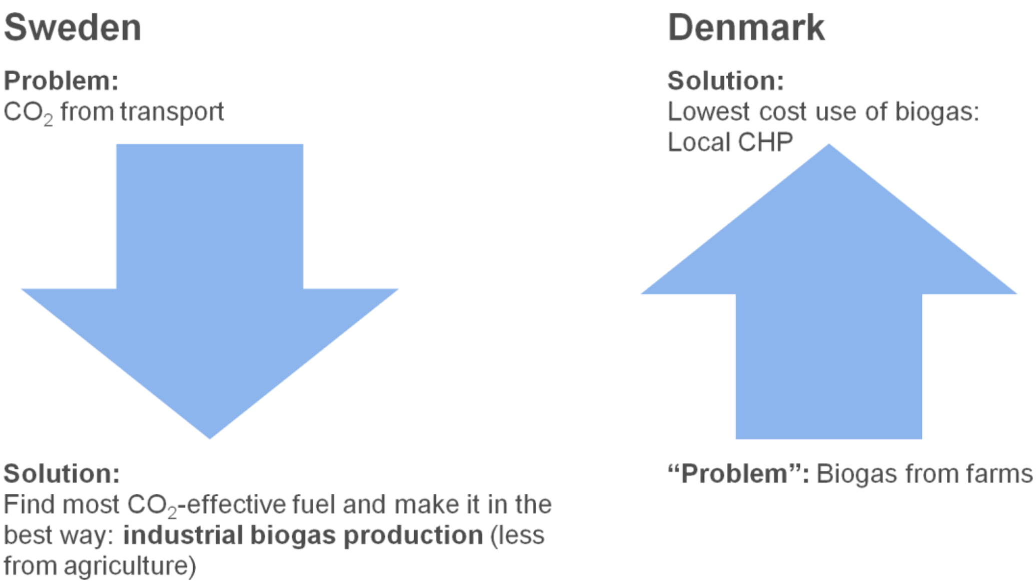
Last 30 years – reduce oil import dependency

Denmark has had a long tradition of developing own oil and gas, wanting to reduce imported oil and use more renewable energy. This is part of the reason why gas has replaced oil for heating a while ago and the high use of renewable energy in generating electricity, both bio and wind. Sweden has also wanted to reduce the dependence on oil, using gas for heating and developing nuclear energy. After the Chernobyl nuclear accident in the Ukraine in 1986, a moratorium was decided (although later dropped) and new energy forms developed –much based on biogenic sources. So the two countries had similar goals, both with some focus on and government support to bio fuels.

Last 10 years – reduce CO_2 emissions

Denmark supports the production of several types of biogas, mainly from the agriculture sector. Producing heat for local communities is seen as the cheapest option for this energy to be used. The gas and power companies in Denmark may see challenges in biogas entering the natural gas system and promote electric cars as renewable solutions for transport. There is now very strong focus on such cars for the future in Denmark. As some of the electricity is renewable, this partly counts towards EU targets in transportation. This can be seen as a bottom-up, production driven strategy for biogas. Also, as Denmark is a smaller country than Sweden, the short driving range of electric cars may be seen as less problematic.

Sweden, with no oil or gas of its own, has been even more disciplined in the use of biogenic energy forms. The approach seems to have been an acknowledgement that there is a large CO_2 problem in transport which needs to be fixed. At the same time, imported fuels would be reduced significantly. Of bio fuels available for transport, biogas is seen as more favourable, while other biogenic sources are available for electricity and heat generation. Biogas is thus chosen as a significant contributor to the greening of transportation, and given priority to this. In early phases, especially on the west coast, there has been some cooperation with natural gas, as biogas (when upgraded) and natural gas are interchangeable in gas-fuelled vehicles. Some advantages of this are that it is easier to convert for the public –very similar cars, and sometimes, even existing cars – and clear environmental benefits.



Plans for biogas in the Nordic countries to 2020

The overall renewable share in total energy consumption is expected to rise in all the Nordic EU countries from 2010 to 2020, but at different pace according to the EU burden sharing agreement and different preferences for meeting the binding 2020 targets.

Denmark envisions a rise in biogas to electricity production from about 200 GWh for 2010 to about 2500 GWh in 2020. This makes biogas a substantial contributor to the electricity production in Denmark, with 6.3% of total energy production compared to 0.5% in 2010 (see table 5). Denmark also expects to almost triple the use of biogas in heating and cooling, from 0.7% of total energy consumption in 2010 to 2.2% in 2020. Production is expected to increase especially in the second half of the decade.

Sweden reported less ambitious biogas plans to the EU. Actually, the communication indicates no increase in biogas use to electricity and heat production by 2020. Biogas to transport (the main policy focus) would increase from 460 GWh in 2010 to 1100 GWh in 2020, raising its share of total energy consumption from 0.6% to 1.3%. On the contrary, Biogassportalen.se forecasts a doubling of total biogas production to 3 TWh already by 2012, based on 50 planned and ongoing projects, even though the use of the additional biogas is not certain.

Finland's biogas electricity and heat production is expected to double by 2020, but from a negligible share in 2010, so it would remain below 1% of the total energy mix.

Corresponding data for Norway and Iceland is not available, since the two countries are not bound to report to the European Commission on their renewable action plans. Nevertheless, both countries seem to expect growth in the sector.

Table 5 Planned biogas consumption in 2020

A: GWh and percentage increase compared to 2010						
	Denmark		Finland		Sweden	
	GWh	Increase from 2010	GWh	Increase from 2010	GWh	Increase from 2010
Electricity	2493	1185 %	270	575 %	53	0 %
Heating/Cooling	1925	180 %	700	100 %	128	-63 %
Transportation	0	0 %	0	0 %	1097	135 %
Total	**4418**		**970**		**1278**	

B: share of renewable and of total energy consumption (%)						
	Denmark		Finland		Sweden	
	Renewable	Total	Renewable	Total	Renewable	Total
Electricity production	**12.1 %**	**6.3 %**	0.8 %	0.3 %	0.1 %	-
Heating/Cooling	**5.4 %**	**2.2 %**	0.8 %	0.4 %	0.1 %	0.1 %
Transportation	-	-	-	-	**9.3 %**	**1.3 %**

Data: National Renewable Action Plans from Sweden, Denmark and Finland, 2010

Scenarios for biogas in the Nordic countries to 2050

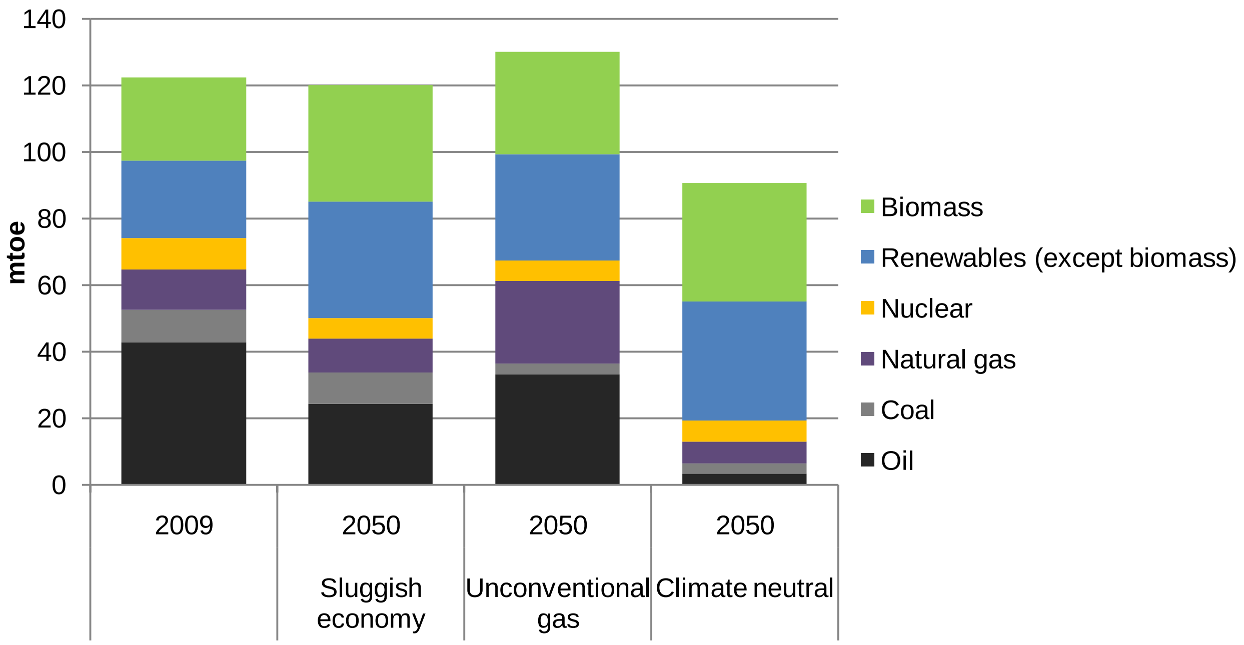
This chapter presents a qualitative foresight of the possible role of biogas in the overall energy mix in 2050. In one scenario, assuming climate change and the environment remain important policy areas, the Nordic countries set an ambitious goal to be the first climate neutral region in the world. This is realistic assuming all countries contribute to climate mitigation, not only the Nordic region. Effort sharing could the shape of a global CO_2 tax or simply of emission caps in each country, making energy with emissions more expensive. If a global carbon cost in a liquid market is expected, there will be a merit order of abatement. Sund Energy has recently developed a scenario where renewables and CCS act as main tools to achieve the climate neutrality goal by 2050. Elements of that scenario are included here to illustrate one possible role biogas could play in the future Nordic energy mix.

All Nordic countries benefit from large potential for most types of renewable energy resources for electricity generation: hydropower (most electricity in Norway), geothermal (most heat and electricity in Iceland), wind (large share of electricity in Denmark), biogenic fuels (particularly in Finland and Sweden, where the pulp and paper industry is well developed). In addition to opportunities for more wind electricity generation (both offshore and onshore), there are other technologies that could be relevant by 2050, such as tide, wave, fresh water – sea water osmosis and more. Nevertheless, many of these energy forms have a limit to how large a share they can have in the total energy picture, partly due to cost and partly due to space, running patterns and other constraints.

In meeting the climate neutral target, the mix of alternative reductions in greenhouse gas emissions should be optimised so as to be feasible, to maximise social acceptance and to minimise costs. With successful implementation of affordable or easy solutions, fewer of the more expensive/ difficult measures need to be taken. In theory, following a merit order of abatement whereby cheap solutions are adopted first, measures targeted at energy efficiency improvements are cost effective and happen as outcome of rational decisions, while more expensive solutions such as CCS are only needed to offset marginal emissions. In general, the more emissions are reduced in some areas the less effort is needed in others.

Other scenarios are of course possible and we illustrate three different pictures of energy use in 2050 in figure 8. With 2050 so far ahead, technologies, costs, energy sources and political preferences will change! Only during the last few months, several CCS and wind projects have been cancelled due to recession, low electricity prices and even low gas prices. With sustained lower gas prices, the energy mix would have more gas than in the climate neutral scenario, which could be a benefit for biogas. As there are many types of abatement, ranging from efficiency to renewable energy, it is impossible to assess today where exactly biogas could be in the merit order in 2050.

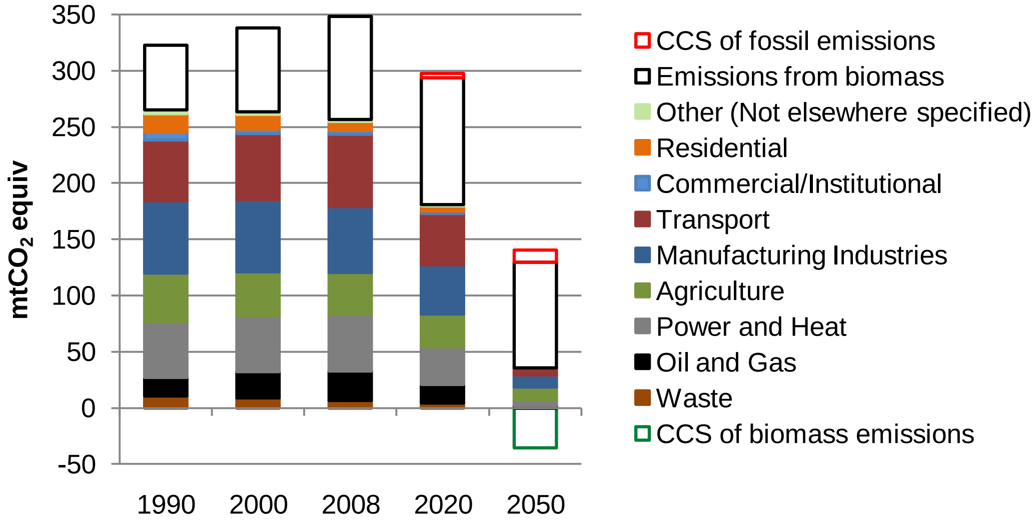
Figure 8 Total energy use in the Nordic region by source (2009 and foresight 2050)



Data: National statistics for 2009 base year and Sund Energy analysis for 2050 scenarios

Historical attempts at improving the energy and carbon efficiency of many small sources have often been unsuccessful. It is unrealistic to assume that all current emissions from fossil fuels could be entirely avoided in 2050, with transport being a particularly difficult sector. Counting some emissions as negative within the current accounting framework leaves room for fossil emissions which are extremely expensive or difficult to cut. CCS applied to large stationary biogenic sources is one way of having negative emissions, as seen in the climate neutral scenario for the Nordic region in figure 9. However, mobile emissions and those from small punctual sources are not suited for CCS. Biogas, instead, is well placed in this respect, as it avoids methane emissions, it replaces fossil fuels in the energy mix and it improves land use management – altogether giving negative climate gas emissions.

Figure 9 Scenario of Nordic evolution of greenhouse gas emissions to 2050



Source: Sund Energy study for TFI on role of CCS in climate neutral Nordic region by 2050, 2010

New technology development will continue to influence the mix of energy sources in the future, on both the renewable and the fossil front. On the one hand, better technologies for biogas upgrading will be developed and made commercial, improving efficiency and gradually making the sector economically competitive without government support. On the other hand, as an illustration, innovation in horizontal drilling has made unconventional gas profitable, opening up vast natural gas reservoirs for exploration. Sweden, which has domestic unconventional resources, might decide to expand its natural gas infrastructure to accommodate volumes of unconventional gas, improving at the same time the availability of bio-methane at filling stations (even though its share in total gas use would then likely decrease).

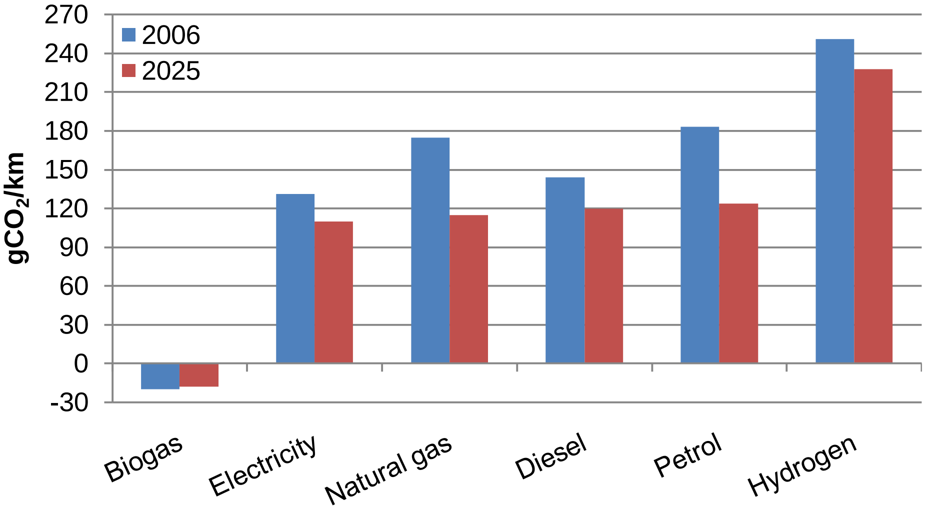
Regardless of technology improvements and market developments, there are also physical boundaries to how much energy each renewable resource can provide in each country. There is a limited amount of landfill waste, sewage sludge and livestock manure, for example, even though potentials are far from being reached in all Nordic countries. To overcome this problem of small localised supplies and enhance the competitiveness of biogas, having a strategy for how to use the scarce resource could improve scale economies. Denmark and Sweden have in part done this, supporting biogas use in CHP and transport respectively. The scarcity condition on becoming climate neutral is that energy efficiency will have to reduce energy demand to what can be supplied from renewable sources, except for fossil sources fitted with CCS and accounting of negative emissions from biogas and CCS for biogenic emission sources.

Both technology development and the use of renewable energy resource utilisation depend on clear and consistent regulatory frameworks. For example, taxes, tax rebates and subsidies are impacting energy preferences and levels of efficiency, albeit in different ways:

1) In Denmark, subsidies related to burning bio fuels for electricity generation have increased the generating capacity able to do this –normally coal generators– and bio fuels are used to maximise subsidies (with the option to burn coal for the rest of the time)
2) In Norway, tax rebates on heavy fuel oil for heating in some industry could keep oil as preferred fuel longer than otherwise and delay conversion to bio fuels
3) In Norway, the introduction of CO_2 separation and storage offshore has improved energy efficiency

Even with political support for technology development and specialisation of use to boost scale economies, biogas is unlikely to become a main contributor to electricity and heat production. It would probably not be the main vehicle fuel either, but it is important to acknowledge that it currently is the only one giving CO_2 negative emissions in transportation (see figure 9).

Figure 10 Comparison of emissions by transport technologies in Denmark (2006 and 2025)



Data: Danish Energy Agency, based on COWI update 2010

Since capturing CO_2 from vehicles is difficult, the only way to reduce emissions from transport is to change the fuel mix. Hydrogen cars are not well suited for the Nordic countries because of large territory and small population, making fuel distribution very difficult. Electricity from clean sources is more readily available, but as more capacity is built in the coming decades, biogas could also have an important role in 'decarbonising' mobility in 2050. Meanwhile, there are natural gas and other bio fuel solutions that could be a better bridge to this future than electricity with the current generation mix.

Summary and conclusions

Biogas production is growing in the Nordic region and this seems to be mainly supply-driven. There is very large potential for more biogas, but growth is slower to materialise than many had hoped. Although most governments have strategies to be greener and even specifically to use more biogenic energy sources, actions are lagging. There seem to be some barriers:

- **Production costs**: Perceived as high, there is often need for government support. Larger use, better prices and more predictable policies and market conditions could help.
- **Geography**: Most feedstock is far from people. To transport biogas some existing infrastructure may be helpful, but there are very different infrastructure options in the Nordic countries regarding:
  - Power – Once converted to electricity, biogas is delivered to the power grid
  - Heat – Either district heating or large buildings could switch to biogas
  - Gas for direct use – Upgraded, biogas can be put in the natural gas grid
  - Gas for vehicles – Biogas is upgraded and put into the NGV system
  - Import/export – Domestic volumes are too small to be traded even among neighbouring countries, unless bio methane is moved in mix with natural gas (in gaseous or liquid form)
- **Competition:** Biogas is not the only green fuel. It will not be straightforward for consumers which is the best fuel for them, even assuming they are willing to pay for cleaner heating and transportation
- **Immaturity:** The industry needs to break down the silos and improve in learning and data sharing
- **Political risk**: Government support has changed directions several times, turning the investment decisions made by biogas producers and users from profitable to loss making. For politicians it can be complex to decide which fuel to sponsor and for how long, and then to measure the impact on environment, economy and security of supply

The value proposition of biogas needs to be lifted to political attention. Compared to other energy biogas is small, but by reducing methane emissions from waste and agriculture and CO_2 emissions from transport it could have a significant contribution. Better accounting will enhance the environmental profile of the fuel. On the environmental arena there is competition from CCS and other measures, so economic sustainability should be the target for all biogas plants in the long run. Availability is also important, both at national and at local/ filling station level.

Synergies in the Nordic region

There are different approaches in the Nordic countries today and just that may give some relevant learning across the region with regard to technology, business models, infrastructure benefits etc. Since many countries are developing biogas technology, perhaps the strength of the Nordic countries could be to create innovative business models, either to reduce emissions from land/ waste and transport or to balance the energy system.

Potential next steps – further study to make it happen

There are large differences in biogas production and consumption in the Nordic countries. The area there seems to be most agreement on is that there is a very large untapped potential on the production side, in all countries. Based on this, we have the following recommendations on further studies and work:

- Technology for production and upgrading:
  - Play this down at first – build on long experience in other countries (within and outside the region)
  - Later, see if tailoring is needed for the Nordic countries (e.g. colder climate)
- Break down silos:
  - Combine positive elements across the value chain to make it happen! This requires more sharing, cross-disciplinary thinking and quantifying the market's willingness to pay (short and long term)
- Full picture analysis:
  - What are the benefits of biogas compared to other fuels, in heating, power, distribution (for direct use) and transportation? Don't let the strongest lobby win (electric cars, nuclear energy etc)
  - Climate, energy and economy impact not only farmers, but counties and countries as well
- Possible role and implications of bio-SNG:
  - What is the environmental and economic potential of synthesis gas compared to biogas?
  - Would large bio-SNG volumes (such as the planned investment in Gothenburg) improve or damage the profile and potential of biogas in the Nordic region?

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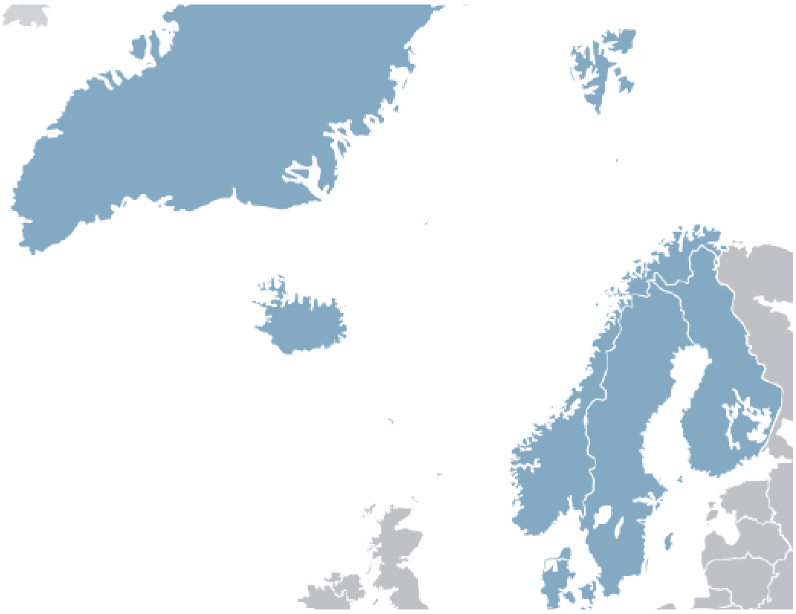
Abbreviations

CBG: Compressed biogas
CCS: Carbon capture and storage
CDM: Clean Development Mechanism
CHP: Combined heat and power
CH_4: Methane
CO_2: Carbon dioxide
CPI: Consumer Price Index
EEA: European Economic Area (EØS)
IEA: International Energy Agency
LBG: Liquefied biogas
LNG: Liquefied natural gas
Mcm: million cubic metres (of gas in standard conditions)
PSA: Pressure swing adsorption
SNG: Synthesis natural gas (syngas; bio-SNG)



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