IEA Bioenergy Task 37

Country Reports Summary 2014

This publication contains a compilation of summaries of country reports from members of IEA Bioenergy Task 37 (Energy from Biogas). The individual country reports include information on the number of biogas plants in operation, biogas production data, how the biogas is utilised, the number of biogas upgrading plants, the number of vehicles using biomethane as fuel, the number of biomethane filling stations, details of financial support schemes in each country and some information on national biogas research and development projects. The publication is an annual update and is valid for information collected in 2014.

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IEA Bioenergy

IEA Bioenergy Task 37 - Country Reports Summary 2014

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Note: Australia became a member of IEA Bioenergy Task 37 in January 2015 and therefore is not included in this 2014 Country Reports Summary.

1. Introduction

The International Energy Agency acts as energy policy advisor to 28 Member Countries plus the European Commission, in their effort to ensure reliable, affordable, and clean energy for their citizens. Founded during the oil crisis of 1973-74, the IEA's initial role was to co-ordinate measures in times of oil supply emergencies. As energy markets have changed, so has the IEA. Its mandate has broadened to incorporate the "Three E's" of balanced energy policy making: energy security, economic development, and environmental protection. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world, especially major producers and consumers of energy including China, India, Russia and the OPEC countries.

Activities within IEA are set up under Implementing Agreements. These are independent bodies operating in a framework provided by the IEA. There are 42 currently active Implementing Agreements, one of which is IEA Bioenergy. IEA Bioenergy is an organisation set up in 1978 by the International Energy Agency (IEA) with the aim of improving cooperation and information exchange between countries that have national programmes in bioenergy research, development and deployment. IEA Bioenergy's vision is to achieve a substantial bioenergy contribution to future global energy demands by accelerating the production and use of environmentally sound, socially accepted and cost-competitive bioenergy on a sustainable basis, thus providing increased security of supply whilst reducing greenhouse gas emissions from energy use. The work of IEA Bioenergy is structured in a number of Tasks, which have well defined objectives, budgets, and time frames.

IEA Bioenergy Task 37 addresses the challenges related to the economic and environmental sustainability of biogas production, by anaerobic digestion, and utilisation. While there are thousands of biogas plants in OECD countries, operation in the vast majority of cases can only be sustained with the help of subsidies to be able to compete with the fossil energy industrial sector. There is a clear need to enhance many of the process steps in the biogas production chain in order to reduce both investment and operating costs. Publications from Task 37 provide important information intended to be used to improve both economic and environmental performance of the biogas value chain where the end product can be heat, electricity or vehicle fuel, or combinations of these products. The other product from a biogas plant, the digestate, is a very important contributor to the overall sustainability of the biogas value chain and is also addressed in various Task 37 publications.

The Task 37 working group meets twice each year to discuss the progress of the work programme. At these meetings, the national representatives also present the latest information within the field of biogas from their respective countries. These presentations are available for free download at the homepage of Task 37 (http://www.iea-biogas.net/country-reports.html). This current publication is the second annual summary of Task 37 country reports collated from the presentations made at meetings and from additional background details provided by the national representatives. It is hoped that this publication will ease the dissemination of national biogas information to third parties.

The way information is gathered, recorded and reported varies from one member country to another and as a consequence direct comparison of country data is not always straight forward. Direct comparison is hampered by countries using different units to compile the available biogas statistics. The largest difference is how the biogas production is expressed. The following three methods exist: i) the energy content in the produced biogas from different plant types independent of the utilisation; ii) the energy content in the produced and utilised energy (such as electricity, heat and vehicle gas); iii) installed capacity for energy production. While every attempt has been made to harmonise data in this publication, the different ways original data have been collected for national databases has made harmonisation and subsequent comparison difficult or even impossible in some cases.

Biogas production is presented for the following plant types:

- Waste water treatment plants
- Biowaste – co-digestion or monodigestion of food waste and other types of biowaste
- Agriculture – digestion at farms (mainly manure and energy crops)
- Industrial – digestion of waste stream from various industries (e.g. food industries).
- Landfill – landfills with collection of the landfill gas

2. Austria

To meet the European Union 20-20-20 goals, Austria has to increase the amount of renewable energy to 34 % of total energy consumption. The Energy Strategy Austria envisages biogas to contribute to these targets by delivering electricity or biofuel. The focus lies on upgrading biogas to biomethane with two options. The first option is the addition of 20 % of biomethane to natural gas to reach 200,000 cars by 2020. The second option is increasing the amount of biogas produced to 10 % of the gas demand, which corresponds to 800 M Nm³ biomethane annually in the country.

The renewable energy law foresees the construction of power plants to obtain an additional 100 MWe out of biomass by 2015. It has to be mentioned that the energy strategy was set up in 2010 when market conditions were quite different from more recent years. In the past few years prices for raw materials have increased tremendously and the plans to increase the number of biogas plants have fallen behind schedule. Currently much effort is being invested to save existing biogas plants from bankruptcy.

2.1 Production of biogas

Today the main production of biogas is derived from energy crops, sewage sludge and landfills (see Table 1). The annual biogas production corresponds to 1.5–2.5 TWh. Current trends are that high prices of biogas feedstock (e.g. maize) lead to severe difficulties to operate the plants economically. This has led to keen interest to investigate the possibility to use alternative substrates. In total 368 biogas plants exist in Austria, but only 337 plants had a contract with OeMAG in 2013.

Table 1: Status of biogas production in Austria, contract with OeMAG (values from 2013)

Plant type	Number of plants with electricity generation	Energy production (GWh/year)*
Waste water treatment plants and landfills	44	26
Agriculture and biowaste	293	544
Total	**337**	**570**

* = Produced energy as electricity excluding efficiency losses.

Source: Ökostrombericht 2014, Energie-Control Austria

2.2 Utilization of biogas

In Austria biogas is utilised mainly for electricity and heat production. Even though the aim is to upgrade more biogas to biomethane for use as a vehicle fuel, this change is taking place rather slowly. There are around 7,700 natural gas vehicles (NGVs) and about 180 compressed natural gas (CNG) filling stations. Three of the filling stations are situated at biogas upgrading plants.

Table 2: Utilization of biogas in Austria (values from 2013)

Utilisation type	GWh
Electricity	570
Vehicle fuel	7 *
Flare	13 *

* = installed capacity

Source: Ökostrombericht 2014; Franz Kirchmayr (Arge Kompost & Biogas)

There are 11 biogas upgrading units in operation. All commercial technologies are represented (amine scrubber, water scrubber, membrane and PSA). The upgrading plants are rather small, 600-800 Nm^3/h, and have a combined capacity around six million Nm^3 biomethane annually.

2.3 Financial support systems

Support is provided for electricity production via the Green Electricity Law (Ökostromgesetz 2012).

Feed-in tariffs for 2013 are:

0.1950 EUR/kWh up to 250 kW_e,
0.1693 EUR/kWh from 250 - 500 kW_e
0.1334 EUR/kWh from 500 - 750 kW_e
0.1293EUR/kWh for higher than 750 kW_e
+ 0.02 EUR/kWh if biogas is upgraded
+ 0.02 EUR/kWh if heat is used efficiently

It is required that a minimum of 30% manure is used as a substrate to qualify for the feed-in tariff. If organic wastes are used, the feed-in tariff is reduced by 20%.

Older biogas plants, when subsidies are running out, can apply for an extended period of subsidies, up to a total of 20 years. Furthermore, a supportive measure for existing plants (built before 2009), of up to 0.04 EUR/kWh_e can be granted to assist with procurement of substrate.

Some investment grants exist, but they are dependent on local conditions.

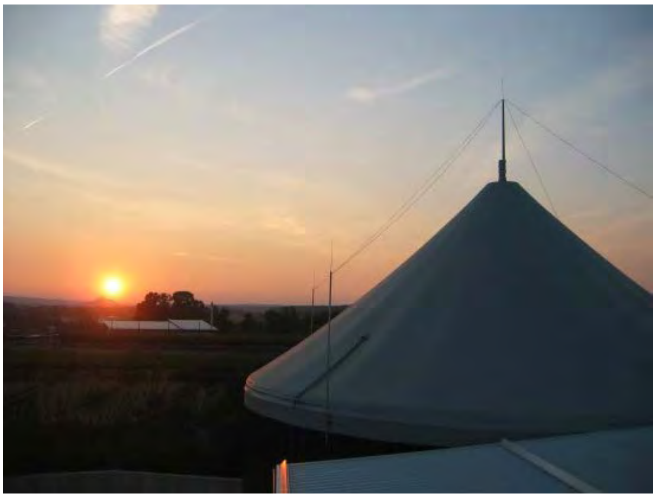


Figure 1: Biogas plant in Strem nearby Güssing

2.4 Innovative biogas projects

Graskraft Reitbach (http://www.graskraft-reitbach.at/)

In 2004 the agricultural cooperative Eugendorf started to produce renewable energy and to recycle nutrients. In the state of Salzburg, an alpine region, 65 ha of grassland are used for biogas production. In two digesters, each 750 m³, the substrates hay, fresh grass and grass silage are digested. A total of 40 Nm³ per hour of biogas with a methane concentration of 56% are produced. In the beginning a 100 kW CHP unit was installed to produce electricity. In 2007 a 1.6 km long district heating grid was installed. Public, industrial and private buildings are provided with heat by this grid. Due to an increased demand of renewable heat, two additional biomass boilers were installed. In 2008 the cooperative grew by 6 members, and as a result gas production could be increased to 100 Nm³/h. At the same time the project developer, Energiewerkstatt, and the regional energy supplier, Salzburg AG, decided to implement a biogas upgrading system (PSA). In this unit 40 Nm³ biomethane are produced and distributed by the on-site biomethane fueling station. The off-gas with a methane content of 18% is mixed with the raw biogas and used in a gas turbine to produce 65 kW electricity and 130 kW heat. In 2008 the project was awarded the national Energy Globe Austria Award.

Figure 2: The biogas plant Graskraft Reitbach.

Research project TherChem

The aim of the project is to develop a process to enhance the digestability of brewery residues. The higher biogas yield will be realised by increased bioavailability of the difficult to degrade components of the lignocellulose complex. By using a specific catalyst higher gas yield can be achieved. This catalyst will be recycled by microbiological processes in the last step. It is intended that the process should be based on the following criteria: low energy demand and low temperature level (depending on the existing infrastructure of the brewery). For demonstration reasons a 20-ft container including pretreatment facility and anaerobic digestion system was constructed. In further tests additional hard to degrade substances (e.g. wheat brewers spent grains, maize straw, wheat straw, grass cuttings and bagasse) for biogas production are to be tested. More information can be found here: **www.therchem.eu**.

3. Brazil

On September 30, 2014, the Electric Energy National Agency (ANEEL) issued Resolution No. 1807. The Resolution approved the auction for the procurement of energy from solar photovoltaic, wind and biomass. The bioenergy may be generated from municipal solid waste, biogas from landfills and sewage sludge treatment plants, as well as biogas plants treating animal waste.). The electricity sold in this auction will be subject to supply contracts with a duration of twenty (20) years. Expressed in Euro per MWh, the submitted price to generate electricity from biogas was 53.82 €/MWh (assuming 1 Euro = 3.14 BRL). This auction was the first to allow different KWh prices for each type of renewable source of electricity; in effect allowing for differences between the generating costs for solar, wind and bioenergy. Although this auction had been designed to increase the competitiveness of alternative sources in the wider energy market, the KWh value established did not stimulate planning and building of new biogas plants.

Another initiative under development is the creation of legislation (in the form of a Resolution) that will allow the development of the biomethane market in Brazil. Development of draft legislation is being carried out by the government's National Agency of Petroleum, Natural Gas and Biofuels (ANP - http://www.spectrumasa.com/wp-content/uploads/INSTITUTIONAL-FOLDER-LR.pdf). Through public consultations, information is gathered that will help to formulate a standard definition (a Normative Resolution) for biomethane produced from biodegradable materials originating from agroforestry and organic waste and intended for nationwide use as a fuel for vehicles, commercial shipping and for residential use. The standard will include obligations regarding quality control to be met by the various economic agents who trade biomethane throughout Brazil.

3.1 Production of biogas

According to the Electric Energy National Agency (ANEEL) in 2014 the production of electricity from biomass corresponded to 8.75% (representing an increase of 0.29 of a percentage point compared with the previous year) of the Brazilian electricity production. This correspond to an installed capacity of 12,303 MW. This includes 3 new biogas plants in 2014 and in total 25 biogas plants connected to the electricity grid. However, according to the data of electricity production in 2014, the potential decreased by around 12% compared to the previous year. This reduction can be attributed to the decay curve of biogas in landfills. The majority of the biogas plants are located on agricultural properties to process residues and on landfills (see Table 3).

Table 3: Status of biogas production used for electricity production (values from 2014)

Plant type	Number of plants	Energy production (GWh/year)*
Sewage sludge	5	42
Biowaste	1	1
Agriculture	9	10
Industrial	2	8
Landfills	8	552
Total	**25**	**613**

* = Produced energy as electricity excluding efficiency losses.

3.2 Utilization of biogas

Most of the biogas is used for electricity and heat production, while biogas use as a vehicle fuel is rare. However, one project developed by ITAIPU Binacional, the Itaipu Technology Park Foundation, Scania, Haacke Farm and the International Center on Renewable Energy-Biogas/CIBiogás-ER demonstrated the viability to use biomethane as a vehicle fuel (read more under biogas projects, 3.4).

3.3 Financial support systems

The financial support systems shown below were used to stimulate biogas in Brazil:

- The program is financed with funds from BNDES, Rural Savings Booklet (MCR 6-4) and Constitutional Funds, which are obtained by public resources taxes and driven by the national economy. The target group is farmers and their cooperatives, including transfer to associates, with the credit limit of one million U.S. dollars per beneficiary per crop per year. This figure can be received regardless of other credits that the producer or the cooperative has a right to and is based on controlled rural credit resources. The interest rate is 5.5% a year.
- PRONAF ECO: Credit to projects with renewable energy technology in waste treatment and effluent treatment stations. The target group is family farmers under PRONAF. The credit limit is R$ 50,000 per beneficiary. The interest rate is 2% a year. Deadline: 10 years with up to 5 years of grace.
- National Policy on Climate Change: Reduce emissions of greenhouse gases from 36.1 % to 38.9 % by 2020. Budget: R$ 6 Billion. One of the goals is to use anaerobic digestion to treat 4.4 million m³ of agricultural residues, leading to 6.9 million tonnes reduction of CO_2 emissions.
- Support for exploitation of biogas through permanent structures:
    - Brazilian Association of Biogas and Biomethane.
    - International Center on Renewable Energy – Biogas (CIBiogás).
- Brazilian Association of Biogas and Biomethane: Founded in December 2013 by 18 public and private institutions from all segments of biogas in Brazil: including research, production, processing, distribution. The association aims to be a channel for dialogue with civil society, the federal and state governments, municipalities and agencies responsible for planning Brazilian energy.
- International Center on Renewable Energy – Biogas:
    - Mission: Develop biogas as a product and develop its applications.
    - Vision: To be a reference on biogas energies by 2023.
    - Main Structure:
        - Demonstration Units: Demonstrates full-scale viability of biogas.
        - Methodology: Territorial Management; the economics of the biogas; distributed generation; small power circuits; energy parks.
        - Technology: Digesters; gas holders; pipelines; filters; monitoring; electric and thermal energy; vehicular use; macrophyle; energy forests.
        - Capacity: Disseminate expertise in renewable energy.
- National Program on Biogas and Biomethane: Aims to institutionalize the process of production and use of biogas and biomethane in the country, in order to achieve more significant goals for the participation of these energy sources in the Brazilian energy matrix. Supported by the Brazilian Association of Biogas and Biomethane.
- Biogasfert Network: This project is a cooperation between the Itaipu Binacional and the Brazilian Agricultural Research Company (Embrapa). Budget: € 2,25 Million. The main challenge of the project is develop technologies for production and use of biogas and fertilizer from treatment of animal waste under the ABC Plan (Low Carbon Agriculture Plan). Embrapa is responsible for 10

action plans which are related with biogas production, fertilizer, GEE emissions, methane reforming. Itaipu and CIBiogás will coordinate 2 action plans which are related with spatial modeling of potential production of biogas and fertilizer, pipeline sizing, filters and equipment for use of biogas.

3.4 Innovative biogas projects

A project developed by ITAIPU Binacional, the Itaipu Technology Park Foundation, Scania, Haacke Farm and the International Center on Renewable Energy-Biogas/CIBiogás-ER demonstrated the possibility to use biomethane as a vehicle fuel. The bus used in the project was a Scania Euro 6 bus from Sweden. This was the first Scania Euro 6 bus designed to run 100% on compressed natural gas operated with biomethane from food production in Brazil.

The biomethane used in the bus was produced in one of the CIBiogás-ER Demonstration Units, Haacke Farm, located in St. Helena, 100 km from Foz do Iguaçu, Paraná State. The Farm has 84,000 hens and 750 beef cattle. 960 Nm^3 of biomethane is produced every day in the biogas plant at the farm that is digesting the animal waste. The role of CIBiogás-ER was to enable the use of biomethane to run the Scania Euro 6 bus, as well as the production of biomethane including infrastructure, filtering systems, compression, transportation and distribution to the filling station built at the Itaipu technology Park.

The bus covered 2,800 km on pure biomethane over a period of 19 days at ITAIPU Binacional, avoiding the emission of about 400 tonnes of CO_2 equivalent, when compared to a diesel-powered bus.

To seal this so important moment for sustainable mobility in Latin America, the International Center on Renewable Energy-Biogas, Scania and the Itaipu Technology Park Foundation signed a Cooperation Agreement to develop and implement joint activities involving education, science and technology.

Figure 3: The first Scania Euro 6 bus operated with biomethane from food production in Brazil

4. Denmark

The ”Green Growth” initiative, which formed the basis for a political agreement in June 2009, includes the objective that 50% of the livestock manure is to be used for green energy in 2020. This requires a significant acceleration of the current development in biogas deployment. In March 2012, the Danish Government entered into a broad energy policy agreement for the period 2012–2020. The agreement includes several elements and calls for a significant enhancement of the share of renewables in the Danish energy supply. The main aim is to make Denmark free from fossil fuels by 2050. Biogas is a key area of the 2012 energy agreement.

4.1 Production of biogas

154 biogas plants are in operation in Denmark, with a yearly production of 1.2 TWh of biogas. Animal manure is the most important biogas feedstock, with a high future potential. According to the Danish Biogas Association, roughly 7% of the animal manure is today supplied to biogas plants in Denmark. The aim is to increase it to 50% by 2020. Along with manure, organic wastes from industry and sewage sludge also make a significant contribution to the biogas production today.

Table 4: Current biogas production in Denmark (values from Energistatistik 2012)

Substrate/Plant type	Number of plants	Production* (GWh/year)
Sewage sludge	57	250
Biowaste	-	-
Agriculture	67	861
Industrial	5	51
Landfills	25	56
Total	**154**	**1,218**

* = produced raw biogas expressed as its energy content from the different plant types
Source: Danish Energy Authority (2014)

In 2012 the Danish Energy Agency predicted a 4-fold increase (to 4.7 TWh) of the total biogas production by 2020. The Biogas Task Force concluded in 2013 that the increase will only be a doubling, to around 3 TWh by 2020. A limited number of biogas projects, representing an increase of about 400 GWh have already reached a final decision. According to the Danish Energy Agreement, the main driver of this expansion is the increased support for the use of biogas for electricity production and upgrading to biomethane, which was approved by the EC in November 2013. The first priority is to use easily available waste materials, in line with the new “Resource strategy - Denmark without waste” adopted by the Danish Government in 2013. For environmental sustainability reasons, the Danish politicians have indicated that biogas in Denmark should not be developed based on energy crops, and have therefore introduced limitations for the share of energy crops used for biogas production. Instead the interest in using deep litter and straw in the production of biogas in Denmark is growing.

Recent estimations (AgroTech, 2012- quoted by Biogas Task Force, 2014) of the biogas potential in Denmark show that the maximum potential for biogas production in Denmark lies between 12 and 22 TWh, depending on time horizon and share of energy crops. From these data, Biogas Task Force has estimated the biogas potential in 2020 to be around 13.5 TWh. The agricultural sector has a very high biogas potential, estimated at 6 TWh, primarily based on the 37 million tonnes of animal slurry which were produced in 2012.

4.2 Utilization of biogas

Today biogas is mainly used for heat and power production in Denmark. The Danish government believes that biogas will be an important vehicle fuel in the future, especially when replacing fossil fuels used by heavy duty vehicles. At a biogas conference in Skive in January 2013, the Danish climate- and energy Minister Martin Lidegaard said: “I believe that gas is one of the main solutions for the future of transport”.

The general interest for using biogas as a fuel for cars is increasing. The first four Danish biogas upgrading plants are in operation and a number of biogas upgrading projects are at various stages of planning. There are seven biogas filling stations and more are about to be established. Currently, around 80 CNG cars are in operation in Denmark.

In 2013 there was only one small biogas upgrading plant in operation in Denmark that was supplying biomethane to the natural gas network. In 2014, four new biogas upgrading plants were taken into operation. The use of biogas as a transport fuel is only at its beginning, and established almost entirely through certificates. At the end of 2014 there were 10 filling stations for compressed natural gas (CNG).

Table 5: Utilization of biogas in Denmark (values from 2013)

Utilisation type	GWh	%
Electricity*	1023	79
Heat	250	20
Vehicle fuel	<5	< 1%
Flare	<15	< 1%

* = including efficiency losses
Source: Danish Energy Agency (S. Tafdrup) 2014

The Danish Energy Agency has set up a number of scenarios for 2035 and 2050, respectively, as part of analyses of the future energy system. The scenarios reflect the energy policy objectives for a 100% renewable energy system in 2050. The presumption is that fossil fuels will be phased out of the Danish electricity and heat supply by 2035. In all scenarios, wind has a central role. A key difference between the scenarios is the quantity of biomass used for energy supply. Biomass is the only "permissible" fuel in 2050 and the scenarios range from the use of 28 TWh up to 200 TWh of biomass. This reflects the political choice between a fuel-based system with high imports of biomass and an electricity-based system that limits the use of biomass to a level comparable to what Denmark can supply from its own resources.

The scenarios are based on the energy projection from 2012, which assumes that there are 5 TWh of biogas available in 2020 and 12 TWh of biogas in 2050. It is also assumed in the two scenarios that the 12 TWh of biogas in 2050 will be upgraded through methanation to increase the available upgraded biogas to 18 TWh. This limited amount is targeted for those applications where the benefits are greatest: meaning transport, industry and quickly adjustable power generation equipment.

4.3 Financial support systems

An improved financial support package for the biogas sector was adopted and approved by the EC in 2013. Removal of the restriction that the support cannot be given for both investments and operation was also approved by the EC in 2014.This consolidated the confidence in the future of biogas and consequently boosted the deployment of biogas in Denmark. The main elements of the Danish support system for biogas are:

- 0.056 EUR/kWh for biogas used in a CHP unit or injected into the grid (115 DKK/GJ).
- 0.037 EUR/kWh for direct usage for transport or industrial purposes (75 DKK/GJ)

These tariffs include natural gas price compensation of maximum 0.012 EUR/GJ (26 DKK/GJ) and temporary support of 0.005 EUR/GJ (10 DKK/GJ) up to 2016. It is also possible to apply for investment grants for plants digesting mainly manure. Support for upgraded biogas supplied to the natural gas network in calendar year 2013 was 111.6 DKK per. GJ. The support is payable to both upgraded biogas supplied to the natural gas grid and to purified biogas entering a town gas grid. This support is provided with effect from 1 December 2013. In the energy agreement, new support frames for biogas to transport and other applications were also agreed.

- €10.6/GJ in basis subsidy for combined heat and power heating (direct and indirect subsidies)
- €10.6/GJ in basis subsidy for upgrading and distribution via the natural gas grid
- €5.2/GJ in basis subsidy for industrial processes and transport

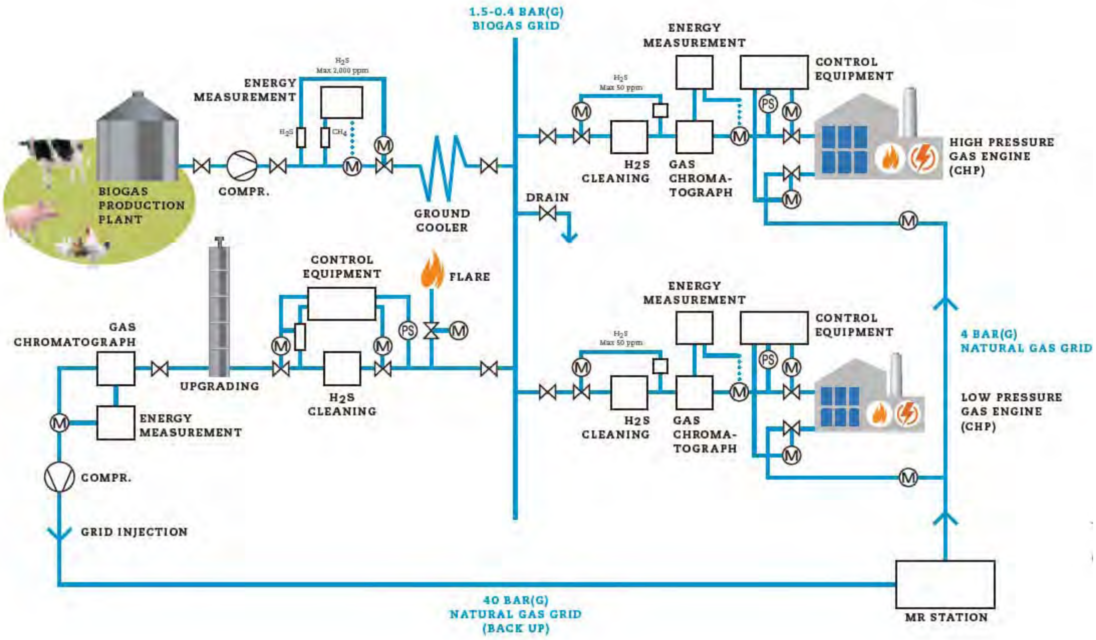
In addition:

- €3.5/GJ for all applications – scaled down with increasing price of natural gas. If the natural gas price the year before is higher than a basis price of €7.1/GJ the subsidy is reduced accordingly.
- €1.34/GJ for all applications – scaled down linearly every year from 2016 to 2020 when the subsidy expires.

4.4 Innovative biogas projects

Solrød Biogas (http://www.solrodbiogas.dk/en.aspx)
Solrød Municipality has started construction of a biogas plant which will produce 5.4 mil. Nm^3 biomethane per year from seaweed, citrus peel and animal slurry. The seaweed is collected on beaches along Køge Bay. Removal of seaweed and utilisation in biogas plants has several benefits: it eliminates odour problems along the coast, resolves the municipality's nutrient reduction requirements for Køge Bay (100% in the case of phosphorus, and 72 % of the requirement in the case of nitrogen), and lowers the municipality's CO_2 emissions by 40,500 tons per year (equivalent to half). Solrød biogas plant is different from most of the Danish biogas plants because of the feedstock mixture, where out of 154,400 tons, manure represents only about a third of the total. This means that the biogas plant can achieve relatively high gas production because the co-substrates have high methane potential. The methane gas will be used for electricity and heat using a gas engine. The investment costs are 85 million DKK, of which 3.6 million DKK is EU funding. The plant is expected to start operating in summer 2015.

Biogas grid in Ringkøbing-Skjern
Ringkøbing is the Danish Municipality with most animal slurry. The aim is to establish approximately 60 small biogas plants as well as one or two large plants. The small biogas plants will each produce biogas equivalent to about 650,000 Nm^3 of methane a year, and the two larger plants will each produce biogas equivalent to about 10 million Nm^3 of methane a year. A biogas grid, approximately 150 km long will transport biogas from the biogas plants to 10 CHP plants in the municipality. The plan is to establish an upgrading plant with a capacity of about 2,600 Nm^3 of methane per hour to balance biogas production and biogas consumption. The biogas project design is illustrated below in Fig.4. The planning of the first four biogas plants is ready, and building work is expected to start at the beginning of 2015.



Estimated costs:
Decentralised/centralised biogas plants: EUR 67 million
Biogas grid including compressor stations: EUR 25 million
Upgrading plant: EUR 7 million
Conversion of engines/new biogas engines: EUR 15 million
Total costs excl. VAT: EUR 114 million

Figure 4: The biogas grid in Ringkøbing-Skjern

5. Finland

The government target in Finland is that about 10 % of gas used will be from biomass based gas, mainly SNG, by 2025.

5.1 Production of biogas

In 2013 the total energy production from biogas was 589 GWh from 82 different biogas production sites. Biogas production has slightly (ca 2 %) increased since 2012. Two co-digestion plants and one sewage digester started production in 2013. Landfills continued to be the major gas producers even though the production has decreased about 5 % since 2012.

Table 6: Status of biogas production in Finland (values from 2013)

Plant type	Number of plants	Energy production * (GWh/year)
Sewage sludge, municipal	16	126
Biowaste,codigestion	11	124
Agriculture	12	4
Industrial wastewater	3	7
Landfills	40	295
Total	**82**	**567**

* = Produced energy as electricity and heat excluding efficiency losses. [a]Vehicle fuel production 11 GWh is added to total energy production. Source: Huttunen and Kuittinen, 2014, Suomen biokaasulaitosrekisteri n:o 17, University of Eastern Finland

It has been estimated that theoretically up to 4–6 TWh/year biogas could be produced from waste and manure, but there are no official targets for biogas production. The biogas yield from grass silage is about the same amount, but present use is negligible and there are no major investment plans for crop digesters. In 2014, about 20 co-digestion plants were under construction or in the planning phase. In addition, wood based bio- SNG production by gasification could significantly add to the gas supply in the future.

5.2 Utilization of biogas

Biogas is mainly used for heat and electricity production in CHP plants located at the biogas production sites, or transported by pipelines for use in industrial processes. The number of biogas upgrading units has increased from three to nine, and upgraded biogas is used as vehicle fuel or injected into the natural gas grid. The usage of biogas as a vehicle fuel has increased above 1 % of total biogas use for the first time.

In August 2014 nine upgrading plants were in operation phase. Water scrubbing technology is used in all except one of the installations. One plant uses membrane technology. In August 2014, 23 public filling stations for biomethane/CNG and three private fuelling stations were operating, mainly in the southern part of Finland. A few biogas upgrading and filling stations also exist outside the grid. The share of biomethane in the methane/CNG mix sold for transportation was approximately 27 % in 2014. In total about 1,800 gas vehicles were in operation in August 2014. The price of biomethane is about half that of the price of petrol.

Table 7: Utilization of biogas in Finland (values from 2013)

Utilisation type	GWh	%
Electricity*	151	22
Heat	404	58
Vehicle fuel	11	2
Flare	126	18

* = excluding efficiency losses

Source: Huttunen and Kuittinen, 2014, Suomen biokaasulaitosrekisteri n:o 17, University of Eastern Finland

5.3 Financial support systems

The Energy Market Authority of Finland supports new biogas plants, which produce more than 100 kVA, with a feed-in tariff. It guarantees a minimum price of 83.5 EUR/MWh for electricity, but when the combined capacity of the generators exceeds 19 MVA no subsidy is paid. If the generated heat is utilized, 50 EUR/MWh heat premium on top of basic subsidy is paid, provided that the total efficiency is at least 50% or at least 75% if nominal generator capacity exceeds 1 MVA. In the feed-in tariff system, an electricity producer whose power plant is approved in the system will receive a subsidy (feed-in tariff) for a maximum of twelve years. The subsidy varies on the basis of a three-month electricity market price or the market price of emission allowances. These subsidies are paid up to the amount confirmed in the acceptance decision. When the price of electricity is below 30 EUR/MWh, the subsidy to be paid amounts to the target price less 30 EUR/MWh. A subsidy is not paid when the price of electricity is negative.

Feed-in-tariffs have been applied since March 2011 and since then 170 K€ has been paid for biogas production (two plants) while during the same period 84.4 M€ has been used for wood based bioenergy and 56.5 M€ for wind energy.

Investment grants are paid by the Ministry of Employment and Economy to biogas plants which produce energy and do not meet the requirements of feed-in tariff, but this kind of grant is not meant for residential buildings, farms or plants connected to the above-mentioned installations. A maximum of 30 % of acceptable investment costs are supported provided that there is still money available in the budget for the investment year. The Ministry of Agriculture and Forestry supports biogas plants built on farms aiming at producing their own electricity and heat. More than half of biomass must be from their own farm and more than 50 % of the energy produced must be used by the farm. Part of the support is money and part of it is loan.

There is no excise tax on biogas.

5.4 Innovative biogas projects

The Kuopio biogas plant is the most recently started co-digestion plant in Finland. One of its special features is a system used for processing packed biowaste from grocery stores and supermarkets. The role of biogas technologies in waste treatment continues to increase, and a major breakthrough seems to be ongoing. However, even though two co-digestion plants started operation in 2013, and several plants were under construction or in planning phase, the number is still relatively low especially considering that one of the first biogas plants in the world for treating MSW was built in Finland (Stormossen) about 25 years ago. In the waste sector, besides digestion plants, major investments have been realized in last 2-3 years in waste combustion plants. In order to promote the biogas sector, contractors are increasingly providing comprehensive operation contracts, which mean that they also take responsibility for the operation of the plant, including also responsibility for organising digestate utilisation with third parties.

Figure 5: Biogas plant in starting phase in Kuopio. The plant has capacity of 60,000 tonne/year of sewage sludge, source separated biowaste, biowaste from grocery stores and supermarkets, and food industry wastes. Biogas production is about 34 GWh / year, and the biogas is delivered through a 5 km pipeline to Kuopio Energy that produces heat and electricity for Kuopio city.

6. France

The vision of the French Environment and Energy Management Agency is to produce 70 TWh biogas annually by 2030 and that 600 biogas plants will be built every year. 50% of the biogas produced shall be injected into the grid, 30% shall be used to generate electricity and the remaining 20% shall be used to produce heat. In 2050, the aim is to produce 100 TWh.

6.1 Production of biogas

In France there are 256 biogas plants and 245 landfills. Only 90 of the 245 landfills are valorizing the biogas (see Table 8). The number of farm AD plants is expected to double by the end of 2013.

Table 8: Status of biogas production in France (values from 2012)

Plant type	Number of plants	Electricity production (GWh/year)	Heat production (GWh/year)
Sewage sludge	60	97	540
Biowaste from MSW	11	51	15
Industrial	80	7	350
On-farm and centralized plants	105 (90+15)	260 (120+140)	390 (190+200)[1]
Landfills with biogas valorization [2]	80	858	296
Total	**336**	**1,273**	**1,591**

[1] heat recovery = 210 GWh/year (90 GWh/year on farm + 120 GWh/year centralized plants)

[2] source ADEME : ITOM, les installations de traitement des ordures ménagères en France – Résultats 2010, octobre 2012

A recent study financed by ADEME on *The estimation of feedstock for AD use* shows that the potential resources for AD will give a probable potential of 56 TWh by 2030. Based on its own calculation, an estimation of ADEME expects a theoretical production of 70 TWh by 2030.

6.2 Utilization of biogas

In France there is a strong development of on-farm and centralized biogas plants and for landfills to recover biogas for electricity generation (today only 90 out of 245 landfills utilize biogas). Around 120 on-farms AD plants were built by the end of 2013 and nearly 15 centralized units. In addition, 60 WWT and 80 agrofood industries AD plants are currently operating.

In 2010, a study showed a relatively low energy recovery from biogas, around 60% of raw energy, the main part coming from landfills (*Market study on anaerobic digestion and biogas valorization in France*, Ernst & Young, May 2010).

Regarding Table 8, 44% of the energy recovery is transformed into electricity and 56% into heat.

There are only four biogas upgrading plants in operation, but more than 400 applications to inject biomethane into the natural gas grid, which indicate a significant increase of the number of upgrading plants in a nearby future. Today, all the biomethane produced is injected into the natural grid or sold as fuel for vehicles.

More than 13,500 vehicles, of which 3,500 are trucks, are in use in France with a daily consumption of 265,000 Nm^3. 37 public filling stations and around 130 private filling stations are in operation (http://www.afgnv.info/Mise-a-jour-des-stations-GNV-en-France_a101.html).

6.3 Financial support systems

In France there is a feed-in-tariff system for electricity produced from biogas with the following properties (energy efficiency bonus and manure bonus included, tariffs revised yearly, values of 2013):

0.8580 to 0.14521 EUR/kWh$_e$ for landfills
0.1182 to 0.2110 EUR/kWh$_e$ for AD plants

There are also upgrading tariffs as follows:

45 to 95 EUR/MWh for biomethane from landfills (depending of volume, values of 2011)
69 to 125 EUR/MWh for upgrading the biogas to biomethane from AD plants (depending of volume and the nature of the feedstock, values of 2011)

Some subsidies are possible and attributed by the French Agency for Environment and Energy Management through two financial funds: the Waste Fund and the Renewable Heat Fund. So the subsidies depend on the nature of the investment and limited in amount or by the percentage of aid.

Other subsidies can also be applied, including regional (Regional Councils) or European (FEDER) funds.

Figure 6: Biogas unit in Chaumes en Brie, France, owned by Bioénergie de la Brie Co. The plant produces biomethane and various products from agro food biowastes and manures. The biomethane is injected into the natural gas grid and feeds 5 cities located close to the unit.

7. Germany

The share of renewable energies in energy generation is to be raised to 40-45 percent by 2025, to 55-60 percent by 2035, and to 80 percent by 2050. The reform of the Renewable Energy Sources Act (EEG) should play a key role in the success of the energy reforms. The introduction of specific growth targets for different technologies is a new development for the German renewables support scheme. The annual growth of biomass including biogas is limited to a maximum of 100 MW compared to 2,500 MW for onshore wind and solar power.

7.1 Production of biogas

Compared to 2013 there was only a slight increase in production of energy from biogas. However, because of the regulations of the EEG 2014 with limitation of growth rate, the contribution of biogas in the energy supply will therefore diminish considerably in the future. The 7960 biogas plants in the agriculture sector make the biggest contribution to biogas production today with electricity and heat supply of 25,120 GWh/year and 10,550 GWh/year, respectively (Table 9).

Table 9: Status of biogas production in Germany (2014)

Substrate/Plant type	Number of plants	Energy production *) (GWh/year)	
		Electricity**	Heat
Sewage sludge	1400	1310	1740
Biowaste	180	850	360
Agriculture	7960	25120	10550
Industrial	80	450	190
Landfills	400	540	90
Total	**10020**	**28270**	**12930**

* = Fuel not included

** = excluding efficiency losses

Source: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety; German Biogas Association; DWA

Based on data from the Agency of Renewable Resources (FNR) and the German Biomass Research Center (DBFZ) the technical primary energy potential for biogas production in 2020 (Status 2014) amounts to 123 TWh/y with the following proportions: biogas crops from 1.6 million ha arable land 94 TWh/y, animal manure 19 TWh/y, municipal wastes 7 TWh/y and industrial wastes 3 TWh/y. 76 TWh/y (62%) of this potential was used in 2012.

7.2 Utilization of biogas

According to information from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, in 2013 the main part of the biogas was used for electricity and heat production, while biogas utilization as a vehicle fuel is rare (Table 10). The share of energy consumption in Germany for electricity, heat and fuel amounted to 4.7%, 1% and 0.1%, respectively.

Table 10: Utilization of biogas in Germany (values from 2013)

Utilization type	GWh/year	%
Electricity*	28,270	68
Heat	12,930	31
Vehicle fuel	350	1
Flare	-	-

* = excluding efficiency losses

In 2014 a total number of 151 biogas upgrading plants were in operation with a feed-in capacity to the gas grid of 93,650 Nm^3/h biomethane (Dena, 2014). Compared with data from the previous year (Table 11), the number of plants increased by 25%. Amine scrubbing, water scrubbing and pressure swing adsorption (PSA) are the most commonly applied technologies. Due to the reduction in the feed-in tariffs, the number of new biogas upgrading plants will presumably be smaller than the 20-30 plants/year during the last years. Surveys have revealed that at least five of the projects under construction or in planning are not realized due to the 2014 EEG reform and/or a continuation of the projects are not yet finally clarified.

Table 11: Biogas upgrading in Germany (values from 2013)

Upgrading technology	Number of plants	Capacity N m^3/h raw gas
Amine scrubbing	39	44,430
Water scrubbing	36	53,750
Pressure swing adsorption (PSA)	30	29,990
Organic physical scrubbing	12	11,450
Membrane separation	3	900
Total	**120**	**140,520**

Source: Fraunhofer IWES, 2013

Based on data from Erdgas Mobil GmbH in 2013 about 170 filling stations with 100% biomethane have sold 300 TWh biomethane. This corresponds to 20% of natural gas consumption by the 95,000 registered gas vehicles in Germany.

A Power to Gas (P2G) plant connected to a biogas plant was developed in the Audi e-gas Project in Werlte (Federal state of Lower Saxony) by Audi in cooperation with the Solar Fuel GmbH, the centre for solar power and hydrogen research (ZSW), the Fraunhofer Institute for wind energy and energy system technology (IWES) and the EWE energy AG. Since the autumn of 2013 about 3,840 Nm^3/day of methane are fed into the gas grid. CO_2 is supplied from a local biogas plant digesting organic wastes. Under the responsibility of CUBE Engineering, IDE Kassel, e-on Mitte and MicrobEnergy GmbH an existing biogas plant has been extended by an additional fermenter and electrolysis system for methane production in a three year project. The entire biomethane produced by the plant will be fed into the natural gas grid.

7.3 Financial support systems

On 1 August 2014 the new Renewable Energy Sources Act (EEG) entered into force. In line with the Coalition Agreement, funding will be largely restricted to waste and residues. For this purpose, the higher support levels for the substance tariff classes I and II, i.e. especially for renewable raw materials, will be abolished. Furthermore, due to the high cost of biogas processing, the gas processing bonus for new installations will be also abolished. In order to stay within the deployment corridor, the support rates for new biogas installations will be reduced to a greater extent if the annual biogas deployment exceeds 100 MW. The incentive for more flexible power generation on the market will be increased for existing and new biogas installations. In relation to the substrate category and the plant size the following feed-in tariff are set out (Table 12).

Table 12: Feed-in tariffs of electricity, Amendment of the Renewable Energies Act (EEG, 2014)

Substrate category	Feed-in tariffs Euro Cent/kWh	Electric power Up to
Biomass Ordinance [1)]	13.66	150 kW
	11.78	500 kW
	10.55	5 MW
	5.85	20 MW
Biowaste [2)]	15.26	500 kW
	13.38	20 MW
Animal manure [3)]	23.73	75 kW

1) dated 21 June, 2001, amendment article 12, dated 21 July, 2014

2) 90% by weight biodegradable waste (waste entry 20 02 01), mixed municipal waste (waste entry 20 03 01) or market waste (waste entry 20 03 02)

3) at least 80% by weight, poultry manure excluded

7.4 Innovative biogas projects

Integrated optimization of the biogas process chain" (Gobi)

Scientists from the University of Hohenheim and the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB together with industry partners explore sustainable biogas production in which all process steps from the crop production to recycling of residues are examined. The Federal Ministry of Research is funding the project "Integrated optimization of the biogas process chain" (Gobi) for three years that includes

- Development of optimized cultivation methods for biogas crops
- Treatment of silage effluents for producing organic basic chemicals
- Nutrient recovery from digestate and production of tailor-made fertilizers
- Process-related optimization and identification of involved microorganisms
- Life cycle analysis and computer based process optimization

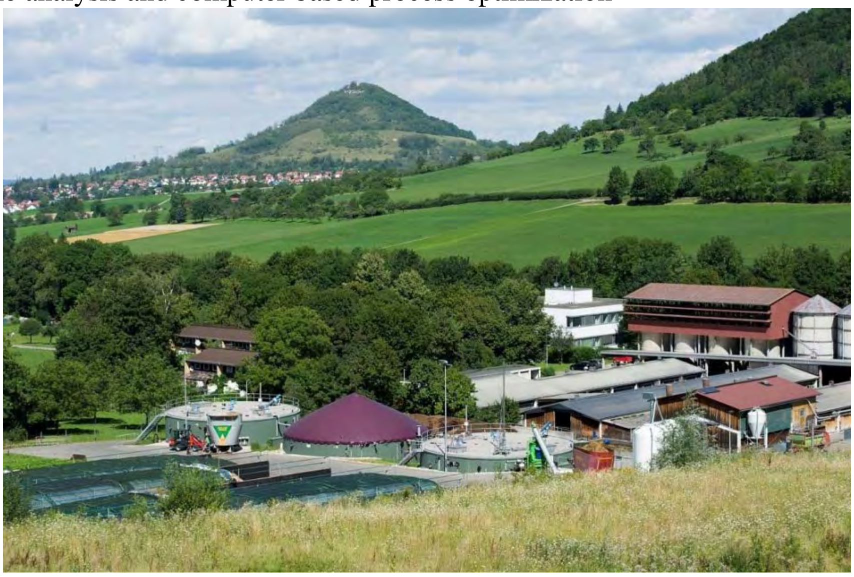


Figure 7: Experimental biogas plant of Hohenheim University

Power to Gas for small-scale Biogas plant

This project includes the methanation of hydrogen from surplus electric power using the carbon dioxide from biogas. The carbon dioxide is methanized directly without prior separation of methane so that the biogas upgrading step is not necessary. The goal is to achieve a high methane content (above 90%) in the product gas, even with varying CO_2 concentration in the biogas. The product gas from the methanation is stored and converted to electricity and fed into the public power grid for demand-driven supply. The characteristics of project are listed below:

- Fraunhofer IWES with partners will test the direct methanation
- Raw gas capacity of up to 50 m^3/h
- Biogas plant is located on the premises of the Hessian biogas research centre
- Research on this topic under real agricultural biogas plant conditions
- First successful project concerning the direct methanation of biogas
- Application of the power to gas technology for small-scale biogas plants

Figure 8: Test platform Eichhof, Hessen

8. Norway

The main energy sources used in Norway are petroleum and hydropower. Close to 60% of the energy consumption in Norway is based on renewable sources, mainly hydropower and wood.

In a report to the Storting (Parliament) (St.meld. nr. 34 (2006-2007)) a national goal to increase the amount of energy from biomass has been set. Underlying this goal is the recognition that increased use of bioenergy will reduce the emissions of GHG and local pollution, and at the same time reduce the nation's dependency on petroleum and virgin sources of plant nutrients.

A national strategy on increased development of bioenergy was presented by The Ministry of Petroleum and Energy in 2008. This strategy suggests a conservative estimate of 14 TWh available bioenergy that can be realized annually by 2020.

Energi21 - A collective R&D strategy for the energy sector in Norway:
The Energi21 strategy sets out the desired course for research, development and demonstration of new technologies for the 21st century. The strategy has been revised at the request of the Ministry of Petroleum and Energy as part of the effort to boost value creation, facilitate energy restructuring with the development of new technology and to cultivate internationally competitive expertise. (www.energi21.no).

According to the Report to the Storting No 39 (2008–2009), 30% (4–5 million ton/year) of manure is to be used for biogas production together with 600,000 ton of food waste (i.e. approximately 60% of available food waste) by 2020. The main incentive for this goal is to reduce emissions of GHG from agriculture by 500,000 tons of CO_2- equivalent. The Norwegian government presented a national sector-spanning biogas strategy in October 2014. The strategy claims that biogas is an instrument that will contribute to a national reduction of emissions by 2020 and to the objective that Norway shall be a low-emission society by 2050. A considerable technical potential for production and use of biogas has been identified, but high costs are challenging. To increase production and use of biogas, the government aims to stimulate technology development and reduce costs. The new biogas strategy presents instruments within:

- Research and development, and pilot plants
- Incentives for increased production and use of biogas
- Incentives to increase supply of feedstocks
- Incentives to ensure information dissemination

8.1 Production of biogas

In 2010 approximately 0.5 TWh of biogas was produced. For comparison, during the same year 118 TWh of hydropower and 1,000 TWh of natural gas (excl. LNG) was produced.

Table 13: Status of biogas production in Norway (data from 2010)

Substrate/Plant type	Number of plants	Production (GWh/year)*
Sewage sludge	25	164**
Biowaste	11	63
Agriculture	4	3
Industrial	3	n.d.
Landfills	85	270
Total	**129**	**500**

* = produced raw biogas expressed as its energy content from the different plant types
** = 2008

The realistic potential for biogas production is estimated to be 2.3 TWh in 2020: 32% from manure, 22% from industry waste, 14% biowaste from households and 7% biowaste from catering and trade, 12% landfill, 7% straw, 6% waste water sludge. (The Norwegian Environment Agency, 2013. Report TA3020)

At present only 0.5 TWh is used, and specific plans are available for another 0.3 TWh. This leaves a remaining realistic potential of 1.5 TWh for biogas production in Norway by 2020.

8.2 Utilization of biogas

The production and use of biogas has until recently been low, but is currently increasing significantly. A considerable amount of the biogas energy is used internally at the production plants. The remainder is upgraded to fuel, or it is used for electricity or heat production. Some is still being flared. Statistical data on the use of biogas are not available.

Norway has less than 10 upgrading plants. Today almost 1,000 vehicles, including approximately 400 buses run on methane and 24 filling stations exist (http://www.ngvaeurope.eu/european-ngv-statistics).

8.3 Financial support systems

The two strongest incentives for increasing the available substrates are the Landfill guidelines that banned landfilling of biodegradables from 2009, and a delivery support system that gives approximately 3.5 EUR per ton of manure delivered to biogas plants.

To stimulate production of biogas, different schemes for investment aid are available, depending on size of plant.

The use of biogas is stimulated by

Tax-exemption on road use

Investment aid for infrastructure related to sustainable mobility solutions

8.4 Innovative biogas projects

Efficient slurry-manure digester
A cost efficient anaerobic digestion reactor for slurry manure has been developed by Telemark University College and the R&D institute Tel-Tek. The reactor is of the anaerobic baffle reactor (ABR) type. Norwegian farms typically have between 2000 – 3000 m^3 slurry manure per year. Manure must be collected and stored in the winter period. Producing biogas will reduce the emission of methane from storage, reduce odours, and make organic nitrogen available for the plants as ammonium. By having a high rate reactor of the ADR type it can be small enough to be prefabricated and transported by lorry to the farm. Prefabrication is a key technology to keep the investment cost low. The reactor is constructed in

high density polyethylene. The reactor design has been tested extensively on both pig and cow manure in laboratory and at small pilot scale. Due to the cold weather in Norway extensive care has been taken in the design to reduce heat losses. The first full scale pilot/demonstration plant was started in November 2014 on a pig farm. At present the reactor is running at 4.6 days hydraulic retention time. In the laboratory hydraulic retention times below 1 day have been tested with good results. Granular sludge used in the ADR ensures a high solids retention time. The biogas will be used in a boiler producing hot water for the farm's floor heating and radiators. The reactor design has also been used for different types of industrial waste water with good results.

Figure 9: Romerike Biogas plant was operative by the end of 2012. The plant recovers biogas and fertilizer from source separated food waste from the households and businesses in Oslo. (Photo: Oslo Waste-to-Energy Agency)

BiogasFuel – Biogas from organic residues and livestock manure as a vehicle fuel

The transport sector is responsible for about one third of the total emissions of greenhouse gases (GHG) in Norway. Thus one way of reducing the GHG emissions would be to substitute fossil fuels in the transport sector. One possible fossil fuel substitute is biogas which is already used in buses in Norway. Biogas is produced during microbial anaerobic degradation of organic substrates. However, nationwide implementation of biogas production is hampered by several challenges. Some of these challenges are addressed in this project, the overall goal being to maximize biogas yields to improve the role of biogas as a vehicle fuel. This research project will focus on (1) increased process understanding and control by detailed characterization of the microbial community in biogas reactors, (2) studying the start-up and stable operation of two new commercial biogas plants, one mesophilic and one thermophilic, in regard to performance and microbiology, (3) optimizing biogas production from blends of food residues and livestock manure, (4) studying unconventional substrates for biogas production which have the potential to realize the utilization of biogas as a fuel at large scale, and (5) utilization of the digestate as a soil amendment in agriculture. The three year project is financed by the Norwegian Research Council and project partners. The project will be carried out at Ås campus where a new dedicated biogas laboratory will be used for biogas production in laboratory scale reactors. Biogas microbial communities will be analyzed by state-of-the art high throughput sequencing tools. The project is led by the Norwegian University of Life Sciences (UMB) and is conducted in close collaboration with Bioforsk, Cambi, The Norwegian Farmers' Union, Oslo Waste-to-Energy Agency, FREVAR and Waste Management Norway. Oslo Waste-to-Energy Agency and FREVAR are owners of two new biogas plants that will supply buses with biogas, and their participation yields a valuable link from research to application in this project.

9. Republic of Ireland

The biogas industry has not yet taken off in the Republic of Ireland. There are a number of reasons for this including for the relatively low level of renewable energy feed in tariff (REFIT) as compared to that available across the border in neighbouring Northern Ireland. This has led to a situation whereby biogas developments are more profitable north of the border and as such developers are more likely to situate north of the border. At present there is trade of biomass across the border, South to North. Another reason for the relatively low level of development of biogas facilities in the Republic (South) is the ongoing discussion on the processing standards for various categories of substrates.

A Government Bioenergy Strategy is due to be released by the end of 2014. It is hoped (and expected) that this will include targets or strategies for increased biogas production, for biomethane grid injection and for use of biomethane as a transport fuel.

9.1 Production of biogas

The exact number of biogas plants in the Republic of Ireland is hard to access in detail. Many waste water treatment facilities have digesters but as they are in private ownership the data is somewhat hard to collate. There are approximately 8 landfill gas projects and 14 industrial facilities including for wastewater sludge treatment. The IrBEA state that there are numerous other facilities at an advanced state of desktop development. Cre (Composting and Anaerobic Digestion Association of Ireland) provided the data on landfill and wastewater facilities in Table 14.

Table 14: Biogas production in the Republic of Ireland (values from 2012)

Plant type	Number of plants	Installed capacity
Sewage sludge	14	n.d.
Biowaste		
Agriculture	8	2.7 MW_e
Industrial		
Landfills	8	29 MW_e
Total	**30**	

Source: Cre and IrBEA

The facilities at present are dominated by provision of electricity and/or heat. This is reflective of the REFIT scheme. However there is a viewpoint that if the biogas industry is to take off in the country it is likely to require gas grid injection to facilitate better returns on the biogas produced.

A Bord Gais report (http://www.bordgais.ie/corporate/media/15665_BG_RenewGas_Final1.pdf) suggests that a realistic biogas industry could be based on 5% of cattle, pig and sheep slurry, 75% of poultry slurry, 50% of slaughter waste, 25% of food waste and 100,000 ha of grass land (2.2% of agricultural land). The report suggests that biogas should be upgraded to biomethane and gas grid injected. This would require approximately 180 rural digesters, 4 slaughter waste digesters and 4 municipal digesters; all at a scale of 50,000 tonnes/year of substrate. The investment cost was estimated at ca. € 1,400M. This scale of investment could facilitate substitution of 7.5% of current natural gas demand and provide for ca. 5% of energy in transport (Singh et al. (2010) Renewable and Sustainable Energy Reviews 14(1) 277-288).

There is one biogas upgrading plant in Ireland under construction which has a gas grid injection point.

In the last two years a number of companies have invested in natural gas vehicles (NGVs). Initial trials by Bus Eireann in Cork and Celtic Linen have been very positive. This industry is expected to grow rapidly.

A market for gaseous transport fuel initially based on natural gas will facilitate gas grid injection of biomethane.

9.2 Financial support systems

Support to biogas in the Republic of Ireland includes:

- A landfill levy of €75/t is in place as of July 2013. Also as of July 2013 there is a requirement to provide collection of source segregated food waste for population centres in excess of 25,000 persons. By July 2015, this will be required for populations of 500 persons. These regulations provide an incentive to digest the organic fraction of municipal solid waste.
- REFIT for biogas to CHP was 7.2c/ kWhe in 2007 and was raised to 12c/kWhe in 2008.

As of May 2010, the tariffs are indexed and offered on a 15-year basis and include:

- AD CHP equal to or less than 500 kW: 15 c/ kWhe
- AD CHP greater than 500 kW: 13 c/ kWhe
- AD (non CHP) equal to or less than 500 kW: 11 c/ kWh_e
- AD (non CHP) greater than 500 kW: 10 c/ kWh_e

Figure 10: Biogas plant McDonnell Farms Limited. Primary Digester and first covered storage digester. David McDonnell milks 300 dairy cows in Limerick and also operates a free range poultry farm. In 2009/2010 he installed the most modern farm digester in Ireland which has a capacity of 250 kWe. (Source: SEAI (Sustainable Energy Authority of Ireland) Anaerobic Digestion: A case study – McDonnell Farms Biogas Limited, Shanagolden, Co. Limerick))

9.3 Innovative biogas projects

Science Foundation Ireland (SFI) Marine Renewable Energy Ireland (MaREI)

The SFI MaREI Centre (http://marei.ie/) is a cluster of key university and industrial partners dedicated to solving the main scientific, technological and socio-economic challenges related to marine renewable energy. These challenges will require innovative solutions to reduce time to market and reduce costs to a competitive level. They cover all aspects of technology development and require solutions to the engineering problems, energy conversion and storage transmission and integration as well as the enabling ICT technologies and environmental aspects. MaREI will deliver significant economic and societal impacts, leveraging from existing internationally recognised groups in Irish universities working in the Marine Renewable Energy (MRE) sector. MaREI will develop an innovation environment that will yield intellectual property and high potential start-up companies, and lead to jobs in the Irish economy through the outputs from the targeted projects with the industry partners. Within SFI MarEI, eleven researchers from the Environmental Research (ERI), University College Cork (UCC) are investigating “Smart Marine Energy: Marine Renewable Gas and Energy storage”. The objectives of this research include:

- The biomethane potential from various types of macro-algae harvested at different times of year

- Optimum methods of generating biomethane from macro-algae including co-digestion with suitable substrates
- Cogeneration of hydrogen and methane from macro- and micro-algae
- Investigation of microbial ecology of algae digesters
- Design and fabrication of "in –situ" and "ex –situ" biomethanation processes
- Optimal applications of Power to Gas systems

Advanced technologies for biogas efficiency sustainability and transport (ATBEST)
The ATBEST initial training network (http://www.atbest.eu/) develops innovative research and training for the biogas industry in Europe. Twelve early stage researchers and 2 experienced researchers have been recruited from ten countries (Poland, Italy, Spain, India, Germany, Greece, Lebanon, China, the UK and Slovenia). These fellows are based in eight different training sites. ATBEST is a multidisciplinary collaboration between internationally-renowned research teams and industrial partners. The aim is to establish long-term collaborations and develop structured research and training relevant to industry and academia along the biogas supply chain. ATBEST is led by Queens University Belfast and has three partners from the Republic of Ireland.

The Animal & Grassland Research and Innovation Centre Teagasc, Ireland are investigating synergies from co-digestion of grass silage with other feedstocks. Their objectives are to: identify the optimal growth stages of grass and legume silages and the optimal mixture with cattle slurry for biomethane production; identify the optimal slurry type and the optimal mixture with grass silages harvested at different growth stages for biomethane production; undertake a full cost analysis of biogas/biomethane production system.

The Environmental Research Institute (ERI) in University College Cork (UCC) Ireland is evaluating innovative biomethane systems with life cycle assessment. The main focus in its evaluation lies in efficient digestion systems and upgrading of biogas with external hydrogen from surplus electricity. In this scenario, the storage capability of biogas functions as a "battery" of the electricity grid.

Bord Gais (The Irish Gas Grid) is investigating the optimal model for rolling out a biomethane industry in Ireland incorporating novel innovative technologies and novel biogas substrates.

10. Republic of Korea

Total energy production has been steadily increased over recent years; renewable energy accounted for 3.2% (8.9 MTOE) in 2012 of which 1.3 MTOE was bioenergy (8.0% from biogas plants and 8.7% from landfill gas). Landfill gas utilisation has dominated biogas production over the last decade while biogas plants have started to make a significant contribution only since 2010. The "Bioenergy Strategy 2030" targets bioenergy production to increase by a factor of more than 4.

10.1 Production of biogas

A total of 82 biogas plants are now in operation and produce almost 2,578 GWh per year. Landfill biogas contributes 52.4 % (1,350 GWh/yr), biogas from sewage sludge 37.6%, biowaste 9.6% etc. Biowaste mainly consists of food waste, food waste leachate, and digestible co-substrates. Table 15 shows Korean biogas production from different types of plants.

Table 15: Status of biogas production in Korea (values from 2013)

Substrate/Plant type	Number of plants	Production* (GWh/year)
Sewage sludge	38	969
Biowaste (co-digestion)	16	249
Agriculture	7	9
Industrial	-	-
Landfills**	21	1,350
Total	**82**	**2,578**

* produced raw biogas expressed as its energy content from the different plant types

** based on 2012 data.

Electricity generation from biogas plants amounted to only 39 GWh in 2012. The governmental goal is very slowly increasing; 64 GWh in 2020 and 161 GWh in 2030, respectively. There are 15 new biogas plants under construction to treat 4,764 tons of food waste and food waste leachate daily to produce 454 GWh biogas by 2017. The electricity generated from LFG reached 419 GWh in 2012. The total amount of electricity produced from all biogas sectors including LFG was 458 GWh in 2013 from 1,517 GWh biogas. The electricity production is expected to increase to 1,937 GWh in 2020.

10.2 Utilization of biogas

About 59% (1,517 GWh) of the biogas is utilized for electricity production. The main part (24%, 618 GWh) of the remaining biogas is used for heat generation. This part is decreasing every year to meet the increasing demand for biogas sale. Flaring biogas is still significant (11%). The utilization of biogas as vehicle fuel wasd only 1.0% of the total biogas production. The utilization of biogas in Korea is summarized in Table 16.

Table 16: Utilization of biogas in Korea (values from 2013)

Utilisation type	GWh	%
Electricity*	1,517	58.8
Heat	618	24.0
Vehicle fuel	26	1.0
Flare	280	10.9
Biogas sale	137	5.3
Total	2,576	100

* = including efficiency losses.

The number of buses using CNG as a vehicle fuel reached almost 31,000 and the number of gas filling stations reached 197 of which 6 are biomethane filling stations. However this figure covers only 0.2% of the total number of buses.

Biogas up-grading is carried out by water scrubbing or PSA at 3 wastewater treatment plants and 3 food waste leachate plants. 2 other food waste AD plants for biogas up-grading are now under construction. The biomethane is used mainly in city buses and municipal vehicles. The standard for vehicle fuel and grid injection is similar to Swedish standards. There is not yet any grid injection system operating in Korea.

10.3 Financial support systems

There are no tariffs or subsidies on biogas. However 10% VAT (Value Added Tax) and 2% tariffs will be charged when the mixture of CNG and biogas is sold. A FIT system had been implemented until 2011.

However the RPS (Renewable Portfolio Standard) system has been enforced since 2012. As “Mandatory Supply Quantity (MSQ)”, 2% of the total power generation should be supplied using the appropriate kind of renewable energy. There is a governmental target to increase MSQ up to 8% of the total power generation in 2020. The average REC price (non-solar energy) has been around 100 €/MWh in 2014.

A Renewable Fuel Standard (RFS) system for biogas is expected to be started in 2017.

Figure 11: Yangsan Biogas Power Plant that is producing 1.0 GWh electricity (with 2.3 million Nm^3 biogas) annually. (source : Kyungnam Province, Korea)

10.4 Innovative biogas projects

Animal Manure to Biogas Project

- The Ministry of Agriculture, Food, and Rural Affairs has financially supported enterprisers with 60% of the total construction cost of AD plants treating 70-100 m3 of manure per day.
- 6 AD plants are now under construction and 11 more AD plants will be built by 2020.

Organic Wastes to Energy Project

- The Ministry of Environment (MOE) established a center for Organic Wastes to Energy.
- The total budget for the research project 2013-2020 (7 years) is $74 million (MOE $56.5 million and Private $17.5 million) and the following research results are expected;
  - Construction of an AD plant for food waste with a volume of 1,800 m^3. Research on biogas up-grading, system development for odour control, O/M manual development for the AD plant and application of digestate.

11. Sweden

In Sweden there is a governmental aim to produce 50 percent of the energy from renewables by 2020 (this has already been reached), but there are no specific targets for biogas production. Sweden also has a governmental vision to have a fossil free transportation sector by 2050. The results from public inquiry of how to reach this vision are expected to be important for the future governmental support for biomethane production in Sweden.

11.1 Production of biogas

In Sweden the production of biogas has been fairly constant at around 1.3–1.7 TWh for several years. The main reason is the difficulties in showing a reasonable profit for new investments and new biogas plants. Biogas produced in new plants has been balanced by the steady decline in landfill gas production. Table 17 shows the Swedish biogas production from different types of plants.

Table 17: Biogas production in Sweden from different plants (values from 2013)

Plant type	Number of plants	Biogas production* (GWh/year)
Sewage sludge	137	672
Biowaste	23	580
Agriculture	39	77
Industrial	5	117
Landfills	60	240
Sum	**264**	**1,686**

* = produced raw biogas expressed as its energy content from the different plant types

Source = Produktion och användning av biogas år 2013, Statens Energimyndighet 2014

The potential to produce biogas from anaerobic digestion and gasification until 2030 has recently been evaluated (Dahlgren S (2013) "*Realiserbar biogaspotentiali i Sverige 2030 genom rötning och förgasning*", WSP). The potential depends mainly on the development of the financial support system, technical developments and the price of fossil fuels. The investigation was made for three scenarios with good, moderate or bad development of these parameters.

The potential to produce biogas from anaerobic digestion was shown to be 1–3 TWh in scenario 3 (poor development), 58 TWh in scenario 2 (moderate development) and 5–10 TWh in scenario 1 (good development). Today, more than 50% of the biogas produced is upgraded to biomethane and this proportion is expected to increase even more until 2030.

11.2 Utilization of biogas

In Sweden, around 50% of the biogas is used as vehicle gas. This part is increasing every year to meet the increasing demand from the increasing number of gas vehicles. The main part of the remaining biogas is used for heat production. The entire utilization of biogas in Sweden is summarized in Table 18 below.

Table 18: Utilization of biogas in Sweden (values from 2013)

Utilisation type	GWh	%
Electricity*	46	3%
Heat**	521	31%
Vehicle fuel	907	54%
Flare	165	11%

* = excluding efficiency losses.

** = including heat losses, e.g. during electricity production, and heat used by the biogas plant.

Source = Produktion och användning av biogas år 2013, Statens Energimyndighet 2014

In Sweden, nearly all upgraded biogas is used as automotive fuel, designated "fordonsgas" (vehicle gas), which means that the annual biomethane production in Sweden is around 900 GWh, according to Table 18. The biomethane is produced in 53 biogas upgrading plants with various technologies (~70% water scrubbers and, ~15% PSA, ~15% amine scrubbers). In one plant, with a capacity of 60 GWh, the biomethane is liquefied and sold as LBG (LiquefiedBioGas). Of the methane used as an automotive fuel, the biomethane share was 58% on energy basis in 2013. It is used by 47,000 gas vehicles, of which 2,200 are buses and 750 are heavy duty vehicles. Around 210 filling stations dispense vehicle gas, five of these also have liquid vehicle gas.

11.3 Financial support systems

Sweden has no feed-in tariffs, but instead uses other support systems, mainly focused on increasing the usage of biomethane as automotive fuel. The existing support systems are:

- No carbon dioxide or energy tax on biogas until the end of 2015. Corresponding to around 70 € / MWh compared to petrol and 56 € / MWh compared to diesel, and of which 24 € / MWh is from the carbon dioxide relief and the remaining part is from the energy tax relief.
- 40% reduction of income tax for use of company NGVs until 2017
- Investment grants for marketing of new technologies and new solutions for biogas during the period 2010-2016. Maximum 45% or 25 MSEK (~3 M€) of investment cost
- A joint electricity certificate marketed between Norway and Sweden. The producer gets one certificate for every MWh electricity produced from renewable resources and the electricity consumers must buy certificates in relation to their total use. Average price in 2013-2014 was around 20-22 €/MWh
- 0.2 SEK/kWh (~€ 0.02 / kWh) for manure based biogas production to reduce methane emissions from manure. Total budget 240 MSEK (10 years)

11.4 Innovative biogas projects

Catch crops as sustainable biogas feedstocks

Agriculture faces the challenge of increasing the biogas production without decreasing the production of food and fodder. Catch crops are normally grown in order to decrease the nitrate leaching from arable land. But can biomass from catch crops also be a sustainable feedstock in biogas production? The potential of using multifunctional catch crops/cover crops as biogas feedstock was evaluated in a field trial during 2013 by the Swedish University of Agricultural Sciences in collaboration with SB3 and SBI Jordberga Biogas.

•


Figure 12: One of 15 gas/electricity hybrid "tram-buses" that are 24 meters long in the city of Malmö. This is one of 2,200 buses in Sweden running on a mixture of 58% biomethane and 42% natural gas. 2,200 buses correspond to 16% of all buses in Sweden.

Nitrate losses from catch crop biomass can occur during winter, mainly in the form of gas emissions of nitrous oxide and nitrate leaching. The hypothesis is to enhance the nitrogen efficiency in crop production through harvesting of catch crop biomass as biogas feedstock in the late autumn, with the subsequent use of the digestate as a fertiliser the following spring for a new main crop. In the field trials, cover crops (*S. alba, R. sativus var. oleiformis, F. esculentum, P. tanaceti-folia, A. strigosa, V. villosa ssp. villosa, S. cereale*) were sown after harvest of green pea (*P. sativum*) in mid-July. Biomass yields of 3.1 – 4.6 tonnes dry matter per ha were obtained in early November. The nitrogen uptake was calculated to be 90 - 140 kg N/ha, with an estimated methane yield between 950 and 1,450 m^3 CH_4/ha.

It was concluded that biogas production and nitrogen management could be successfully combined through the use of cover crops as biogas feedstock. Nitrogen fertilisation of cover crops, after cultivation of green pea, as a means of increasing methane yield per ha could not be justified by the findings in this study. It was also concluded that in order to balance nitrogen management with sufficient yields per ha for economic harvest feasibility, further studies are needed.

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Development Project 7 (DP-7) at Linköping University Center of Excellence in Biogas Research: Enzymatic increase of sludge digestability
Financed through The Swedish Energy Agency, Linköping University and BRC partners and members.

A huge source of substrate for biogas production available in Europe is the sludge produced at waste water treatment plants, of which roughly 11 million metric tons of dry substance are treated by anaerobic digestion annually. However, the degree of digestion of sludge is often less than 50 %, partly because that the sludge is resistant to hydrolysis, the first step of the methanogenesis pathway. Notably, within the EU there was in 2011 a production 1,254 ktoe (kilo ton oil equivalents) of biogas from sewage sludge (EU

Biogas Barometer 2013). Thus, if the degree of digestion could be increased by 20 % (from 50 % to 70 %) this would equal an increase of biogas production by 242 ktoe (or equivalent to approximately 247 million litres of diesel).

An energy efficient way to specifically treat the substrate to increase the biogas production could be to add enzymes to make the organic content more accessible for biogas production. This however requires that the enzymes are active and have an appreciable life-time in the sludge and/or digester environment. The main goals of the project have therefore been to analyze and understand the activity, life-time and effect of enzymes in the biogas process at waste water treatment plants.

The conclusions from the projects were that the limited life-time of (the tested) enzymes makes it economically unfeasible to add enzymes to increase biogas production rate and yield. However, knowing the mechanism of the inactivation mechanism opens for the possibility to engineer or search for enzymes that are less susceptible to proteolytic degradation by the endogenous proteases present in the sludge or biogas digester.

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12. Switzerland

The Federal Council has adopted the energy strategy 2050 in order to guarantee security of energy supply in the long term. The thrust of this strategy is to gradually phase out nuclear power and, on the other hand, to develop hydro power as well as the new renewable energies (sun, biomass, biogas, wind, wastes and geothermal heat) and to improve energy efficiency of buildings, appliances and transportation. Energy supply difficulties could be overcome by fossil-fuelled power generation and by energy imports.

Concerning biogas, the energy strategy aims an annual electricity production of 1.6 TWh by 2050. In order to reach this goal, the focus is on coordinated energy research, integrating the following main priorities:

- Development of new processes and technologies
- Up-scaling or downsizing of close-to-market technologies
- Quality management
- Systems optimisation and integration

12.1 Production of biogas

In Switzerland there are around 610 biogas plants and six landfills, see Table 19. The total gross biogas production was 1,129 GWh in 2013.

Table 19: Status of biogas production in Switzerland (values from 2012)

Plant type	Number of plants	Biogas production* (GWh/year)
Sewage sludge	~465	550
Biowaste (co-digestion)	29	275
Agriculture	96	226
Industrial waste water	22	67
Landfills	6	11
Total	**616**	**1,129**

* = produced raw biogas expressed as its energy content from the different plant types

Figure 13: Biogas plant in Kägiswil, producing annually 1.5 GWh electricity and 1.7 GWh heat.

12.2 Utilization of biogas

The biogas is mainly used to produce electricity and heat in CHP plants, but the biomethane production is growing rapidly, see Table 20.

Table 20: Utilization of biogas in Switzerland (values from 2012)

Utilisation type	GWh
Electricity*	281
Heat	348
Biomethane	128
Flare	n.d.

* = excluding efficiency losses

There are 19 upgrading plants (mainly PSA units, amine scrubbers and organic physical scrubbers), two on agricultural sites, eight on wastewater treatment plants and seven at biowaste AD sites, with total biomethane production of approximately 128 GWh. The target is to inject 300 GWh into the grid by 2016. Today more than 11,000 vehicles run on methane and 140 filling stations are in operation (http://www.ngvaeurope.eu/european-ngv-statistics).

12.3 Financial support systems

In Switzerland there are feed-in tariffs for electricity according to Table 21 below.

Table 21: Feed-in tariff for electricity in Switzerland in Swiss currency (CHF).1 EUR ≈ 1.2 CHF

Power class	≤ 50 kW$_e$	≤ 100 kW$_e$	≤ 500 kW$_e$	≤ 5 MW$_e$	> 5 MW$_e$
Basic tariff [CHF/kWh]	0.28	0.25	0.22	0.185	0.175
Agricultural bonus [CHF/kWh]	0.18	0.16	0.13	0.045	0
Heat bonus [CHF/kWh]	0.025	0.025	0.025	0.025	0.025
Maximum [CHF/kWh]	0.485	0.435	0.375	0.255	0.20

There is also a fund for biomethane injection which is a voluntary support program by the Swiss Gas Association with the objective to inject 300 GWh biomethane annually within 6 years. Also projects aimed at reducing GHG emissions can receive financial support.

12.4 Innovative biogas projects

Biogas Zürich – An innovative energy concept
The new biogas digester of the company Biogas Zürich AG started operation in July 2013. It is a thermophilic installation for biowaste, built on the former composting site close to the wastewater treatment plant "Werdhölzli" of the city of Zurich, which already had digesters for sewage sludge. The separation of the two waste streams, sewage sludge and biowaste, allows using digestate from the new plant as fertiliser. In Switzerland sewage sludge must be incinerated.

The close proximity of the two biogas plants allows synergy in terms of heat production and utilisation, as well as gas upgrading and management of different waste streams.

For more information:

- Homepage of Biogas Zürich: http://www.biogaszuerich.ch
- Case Study "Biowaste and sewage sludge recovery: separate digestion, common gas upgrading and heat supply": http://www.iea-biogas.net/case-studies.html

Figure 14: Thermophilic biowaste reactor of Biogas Zürich (© Biogas Zürich)

13. The Netherlands

To meet the European Union 20-20-20 goals, the Netherlands has to increase the amount of renewable energy to 14 %, which can be compared to 2% in 2005. The ambitions of the Netherlands to increase the amount of renewable energy are expressed in the National Renewable Energy Action Plan. There it can be seen that the expected amount of energy from the feed-in of biomethane into the natural gas grid will increase to 6.7 TWh in 2020 if the required share of renewable energy should be reached.

13.1 Production of biogas

In the Netherlands today there are 252 biogas plants producing around 4 TWh of biogas. There are no data for biogas production from different plant types. Instead the installed capacity is given for production of heat, electricity and upgraded biogas in Table 22 below to give an indication how the production is divided.

Table 22: Status of biogas production in The Netherlands (values from 2013)

Plant type	Number of plants	Installed Heat capacity (MW)*	Installed electricity capacity (MWe)	Upgrading capacity (Nm3 biomethane /h)
Sewage sludge	82	8	46	470
Biowaste	11	2	11	3,892
Agriculture	105	18	129	606
Industrial	13	0	18	5,312
Landfills	41	0	15	1,625
Total	**252**	**28**	**219**	**11,905**

* = a large installed heat capacity is also available from the CHP units installed for electricity production, which is not included in this column.

Source: http://www.b-i-o.nl/

The development of biogas in the Netherlands has not been very strong during the last years, mainly due to the increasing costs of feedstocks. The development has been focused on energy utilization of industrial and municipal biowaste while the development in the agricultural sector was very slow. Due to changes in the feed-in tariff system (more money available) it is expected that new project will developed in agriculture in the future.

In the Green Gas Roadmap published in 2014, it is concluded that in 2020 digestion could potentially produce an estimated 1,200 million Nm^3 of biogas (63% CH_4 content), which corresponds to around 7 TWh. In 2030, this could potentially increase to 4,600 million Nm^3 biogas, which corresponds to almost 30 TWh.

13.2 Utilization of biogas

In the Netherlands, 78.5% of the produced biogas is utilized, corresponding to around 3 TWh, as either heat or electricity, as seen in Table 23.

Table 23: Utilization of biogas in the Netherlands (values from 2013)

Utilisation type	GWh	%
Electricity*	1,085	35%
Heat*	1,971	63%
Vehicle fuel	<1	0%
Flare	71	2%

* = excluding efficiency losses.

The gas grid in the Netherland only requires 88% methane which makes the biogas upgrading cheaper and suitable for technologies and designs adapted for producing lower biomethane qualities, such as membrane upgrading units with simple design. In 2012, the first biogas upgrading unit using cryogenic separation was taken into operation in the Netherlands. Today almost 7,000 vehicles run on methane and 186 filling stations exist (http://www.ngvaeurope.eu/european-ngv-statistics).

13.3 Financial support systems

A new support scheme was launched in 2014 (SDE+) with a budget of 3.5 BEUR. The interesting concept of the scheme is that it forces all renewables to compete with one another. In a staged application process with closing dates set at 6 dates throughout the year (see Table 24) projects can apply when the tariff fits their business plan. Since the tariff gradually increases during the year the scheme favours large scale facilities, unless the small facilities can demonstrate that heat is utilised. In Table 24 the tariffs are guaranteed minimum income, which means that the scheme only pays out if energy prices are lower than the prices in the table.

Table 24: Tariffs for the new 2014 SDE+ support scheme in the Netherlands

Phase	Opening	Max Electricity (EUR/kWh)	Max. Heat/CHP (EUR/GJ)	Max. Gas (EUR/Nm^3)
1	1 Apr.	0.07	19.4	0.483
2	12 May	0.08	22.2	0.552
3	16 June	0.09	25.0	0.621
4	1 Sep.	0.11	30.6	0.759
5	29 Sep.	0.13	36.1	0.897
6	3 Nov.	0.15	41.7	1.035

13.4 Innovative biogas projects

De Meerlanden Rijsenhout – producing five products from waste

De Meerlanden Rijsenhout is a waste collection and management company in the Haarlemmermeer-Bollenstreek-Aalsmeer region. It collects waste from 4,000 companies and 120,000 households, including 50,000 tonnes of organic household waste on annual basis. An innovative process transforms this waste into five new products: green gas, carbon dioxide, heat, compost and water.

Figure 15: The biogas plant owned by De Meerlanden Rijsenhout that is producing green gas, CO2, heat, compost and water

EcoFuels – the first biogas plant to utilise the carbon dioxide in the Netherlands
EcoFuels, a joint initiative of Laarakker Groenteverwerking (vegetable processing) and Delta Milieu Compost & Biomassa, produces green electricity and green gas at its location in Well, the Netherlands. Around 120,000 tonnes of biomass is processed every year, generating electricity for 5,500 households and gas for some 1,250 households. EcoFuels uses a thermophilic fermentation installation that was purposely developed and that is unique in Europe. Besides the generation of green energy, the plant has two major advantages. The puriefied waste water is re-used as rinsing water for the raw materials or irrigation of crops and the digestate can be applied as fertilizer in agriculture and horticulture. Furthermore, this plant is the first project in the Netherlands in which the separated carbon dioxide is ustilised; in this particular case as a fertilizer in horticulture

Figure 16: The biogas upgrading unit producing both biomethane and carbon dioxide at the Ecofuel biogas plant

14. United Kingdom

The UK government is still supporting the role out of AD in England and devolved administrations.

- In England, Defra set out in 2011 a vision for AD to generate 3-5 TWh of heat and electricity by 2020.
- Wales, as part of their 'One Wales Delivery Plan' has created a capital and revenue financial support package for local authorities who wish to adopt AD technology.
- Scotland has seen the introduction of food waste bans to landfill. This has driven up the AD capacity and this trend is expected to continue.
- Northern Ireland with its attractive government subsides (4 ROCs) for AD has seen an increase of farm fed (grass) facilities.

14.1 Production of biogas

Overall electrical capacity from biogas (sewage sludge, landfill gas and AD) equated to 1,389 MW in 2013.

There are today 80 AD plants treating food waste and 63 farm plants. The number of new plants has increased rapidly since 2005, along with gas production, and is predicted to keep on rising rapidly. The electricity generation from AD in United Kingdom increased by 26.5% during the period 2012-13.

Table 25: Status of biogas production in the UK (values 2013- Renewable electricity generation)

Substrate/Plant type	Number of plants	Electricity generation (GWh/year)
Sewage sludge	146	761
Biowaste	55	707
Agriculture	63	
Industrial	25	
Landfills	345	5,169
Total	**634**	**6,637**

The upward trend is expected to continue and the estimated total energy generated by AD biogas in 2030 could be around 23 to 37 TWh according to "Analysis of Characteristics and Growth Assumptions Regarding AD Biogas" published by the Department of Energy and Climate Change in 2011.

14.2 Utilization of biogas

The main use for biogas in the UK today is for electricity production with 6.6 TWh produced in 2013 from landfill, sewage sludge and Anaerobic Digestion (707 GWh from AD alone) via CHP.

The production of heat from biogas is still yet to fully mature in the UK with only 4 biogas plants currently accredited to receive RHI (renewable heat incentive) payments. Those 4 plants generated 729 MWh of heat between November 2011 and August 2014. It is noted that the RHI scheme is in its infancy and that accreditations should increase significantly in coming years.

Biomethane production is starting to grow within the UK. Progress into 2015 looks very encouraging with the likes of the Minworth gas to grid facility opening recently. The plant, which is the biggest of its kind in the UK, has capacity to convert 1,200 Nm^3 biogas an hour into 750 Nm^3 biomethane which will be injected into the natural gas grid. Overall, by the end of 2015 there is potential for 60 biomethane facilities to be either operational or under construction which represents over 2 TWh per annum.

In terms of fuel, around 2 million litres were produced for vehicles by the biogas industry during the period Jan 2014 – May 2014. The Gasrec Albury site is currently the only production site for Liquefied Biomethane in the UK and has an annual estimated capacity of between 4,000 to 5,000 tonnes (enough to fuel approximately 300 dual fuel trucks or 150 dedicated gas trucks).

14.3 Financial support systems

In the UK a range of financial support systems are available for Anaerobic Digestion operators. The Feed in Tariffs (FIT) provide a guaranteed price for a fixed period to small-scale electricity generators. FITs are intended to encourage the provision of small-scale low carbon electricity. Only AD facilities with less than 5 MW capacity and completed after 15 July 2009 are eligible for FITs.

Table 26: The Feed in Tariff with guaranteed price for a fixed period

Description	Period in which Tariff Date falls	Tariff (p/kWh)
Anaerobic digestion with total installed capacity of 250kW or less	1 April 2014 to 30 September 2014	12.46
	1 October 2014 to 31 March 2015	11.21
Anaerobic digestion with total installed capacity greater than 250kW but not exceeding 500kW	1 April 2014 to 30 September 2014	11.52
	1 October 2014 to 31 March 2015	10.57
Anaerobic digestion with total installed capacity greater than 500kW	1 April 2014 to 30 September 2014	9.49
	1 October 2014 to 31 March 2015	9.02

Anaerobic digestion is among the technologies that receives additional support in the form of multiple Renewable Obligations Certificates (ROCs): An anaerobic digester will receive 2 ROCs/ MWh until April 2015, this will then fall in line with DECC estimations of costs to 1.9 ROCs/MWh in 2015/16 and 1.8 ROCs/MWh in 2016/17.

The Renewable Heat Incentive (RHI) provides a fixed income (per kWh) to generators of renewable heat, and producers of renewable biogas and biomethane.

Table 27: Renewable heat incentive for various sources

Tariff name	Eligible technology	Eligible sizes	Tariffs (p/kWth)
Biomethane injection	Biomethane	biomethane all capacities	7.5
Small biogas combustion	Biogas combustion	Less than 200 kWth	7.5
Medium biogas combustion (commissioned on or after 4 December 2013)		200 kWth and above & less than 600 kWth	5.9
Large biogas combustion (commissioned on or after 4 December 2013)		600 kWth and above	2.2

Renewable Transport Fuel Obligation (RTFO) is a requirement on transport fuel suppliers to ensure that 5 percent of all road vehicle fuel is supplied is from sustainable renewable sources by 2010. In January 2014 the certificates were worth an average of ~10 GBP/litre (~ € 11.96).

14.4 Innovative biogas projects

Cranfield University – Improving anaerobic digestion by injecting carbon dioxide

This WRAP funded project examined the potential benefits of enriching with CO_2 anaerobic digesters (ADs) treating sewage sludge or food waste.

The response of ADs to CO_2 enrichment was observed to be substrate dependent. Increases in CH_4 production of up to 138% over the 24 hours following CO_2 enrichment were recorded in sewage sludge units, while enhancements of CH_4 yield of up to 13% were recorded for food waste units. CO_2 reductions of 3-11% in food waste ADs and 8-34% in sewage sludge ADs were also estimated.

The substrate dependent impact of CO_2 enrichment in ADs could be associated with differences in methanogenic populations between food waste and sewage sludge. Methanosaeta was found to be the predominant methanogen in sewage sludge ADs (86.4%), while Methanosarcina was found to significantly contribute to archaea populations in food waste ADs. Importantly increased activity of Methanosaeta was found in sewage sludge ADs periodically enriched with CO_2 when compared to the control with no CO_2 injection.

CO_2 enrichment was applied in pilot scale ADs, with an estimated assimilation rate of additional CO_2 of 159 mg per litre of digesting material over 48 hours. When extrapolating to a large scale UK wastewater treatment works (WWTW) with 16 anaerobic digesters as an example, application of CO_2 injection could potentially reduce CO_2 emissions by over 2,400 tonnes CO_2 per annum. If the CH_4 enhancements obtained in laboratory scale tests in Phase 1 (Bajón Fernández et al., 2012) are parameterized between 13-96%, increases in electricity generation of 8.7 - 64.0 GWhe and in heat generation of 10.8-80.1 GWhth per annum are estimated when extrapolating to the large scale system described.

Full report available here: http://www.wrap.org.uk/node/16676

Striping ammonia from Chicken litter for digestion

Tamar Energy, a renewable energy company which focuses on anaerobic digestion, has recently completed the construction of a new AD process which utilises a novel piece of technology to strip ammonia from chicken litter prior to digestion.

They use Xergi's NIX technology which takes the litter, mixes it with CaO to help degrade the biomass by alkaline hydrolysis and improves the removal efficiency of ammonia. The litter is then treated in batches in a pressure vessel at 6 bar, into which steam is injected. The ammonia-rich off-gas is then passed through a column with sulphuric acid, producing an ammonium sulphate solution that can be supplied to agriculture. Capturing the N before digestion helps with AD process stability, and the steam/pressure approach also increases the biogas potential of the poultry litter by disrupting its structure and rendering it more readily digestible.

Results from field tests have concluded that:

- The target of 50% NH_4-N removal is achieved (60 % reached in third party testing)
- The target of 25% increase in methane production is achieved (30 % reached in this test)

More information is available from: http://www.xergi.com/index.php/News/ready-for-the-next-step-for-biogas-based-on-animal-manures.html

15. Summary and Conclusions

Biogas production in the IEA Bioenergy Task 37 member countries is clearly dominated by Germany with more than 10,000 biogas plants. None of the other member countries have each more than 1,000 biogas plants (see Figure 17).

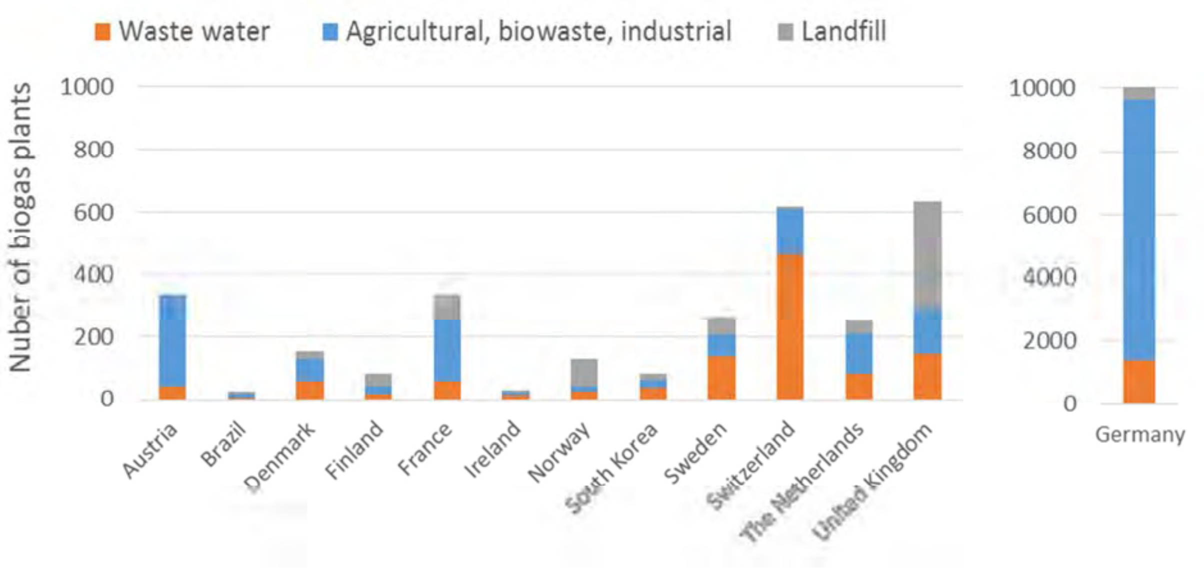
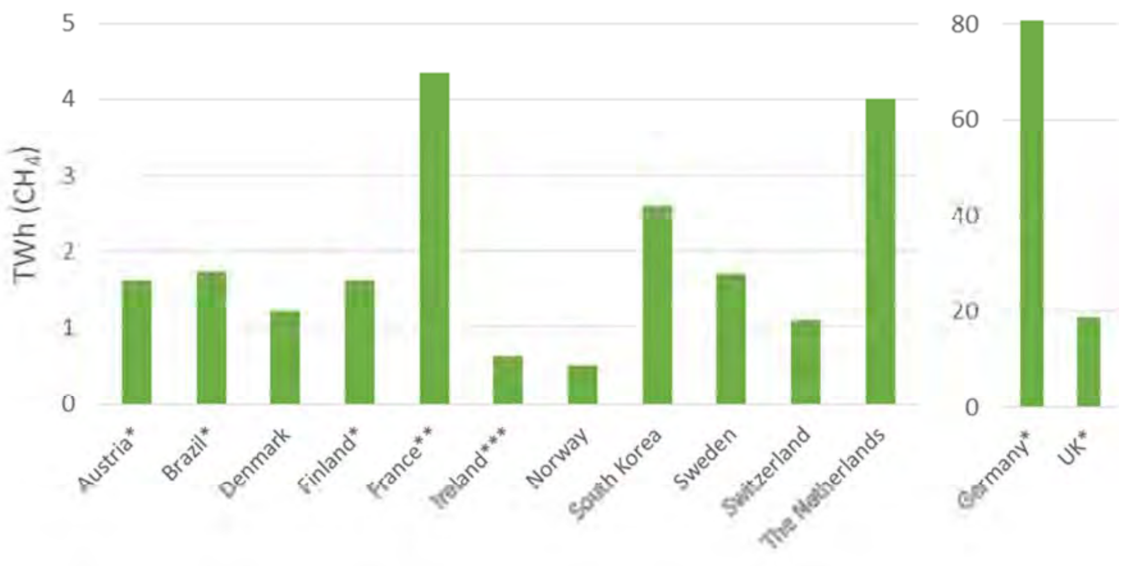


Figure 17: Biogas plants in the IEA Bioenergy Task 37 member countries.



* = Calculated from the reported electricity production and an assumed efficiency of 35%.
** = Calculated from the reported electricity production an assumed efficiency of 35% for landfills, agricultural and biowaste based plants and from the sum of reported heat and electricity production for industrial and waste water plants.
*** = Calculated from 80% of the installed capacity for electricity production and an assumed efficiency of 35%

Figure 18: Annual biogas production in the IEA Bioenergy Task 37 member countries.

The annual biogas production is around 80 TWh in Germany, 20 TWh in UK, 4 TWh in both the Netherlands and France and between 0.5-2 TWh in remaining countries (see Figure 18). The actual biogas production is not reported in all countries. In those countries where actual biogas production is not reported, in this report it has been calculated from the generated electricity by assuming a conversion efficiency of 35% and no additional losses. In countries like UK, Brazil and South Korea, the biogas produced in landfills is the largest source, while the landfill gas is only a minor contributor in countries like Germany, Switzerland and Denmark.

The biogas produced is mainly used for generation of heat and electricity in most countries with the exception of Sweden where approximately half of the produced biogas is used as vehicle fuel. Many countries, such as Denmark, Germany and South Korea, among others, show initiatives and interest in increasing the share of the biogas to be used as a vehicle fuel in the near future.

The amount of biomethane produced and the number of biogas upgrading plants is increasing. In Figure 19 below the distribution of around 330 biogas upgrading plants in the IEA Bioenergy Task 37 member countries and the technologies in use are shown.

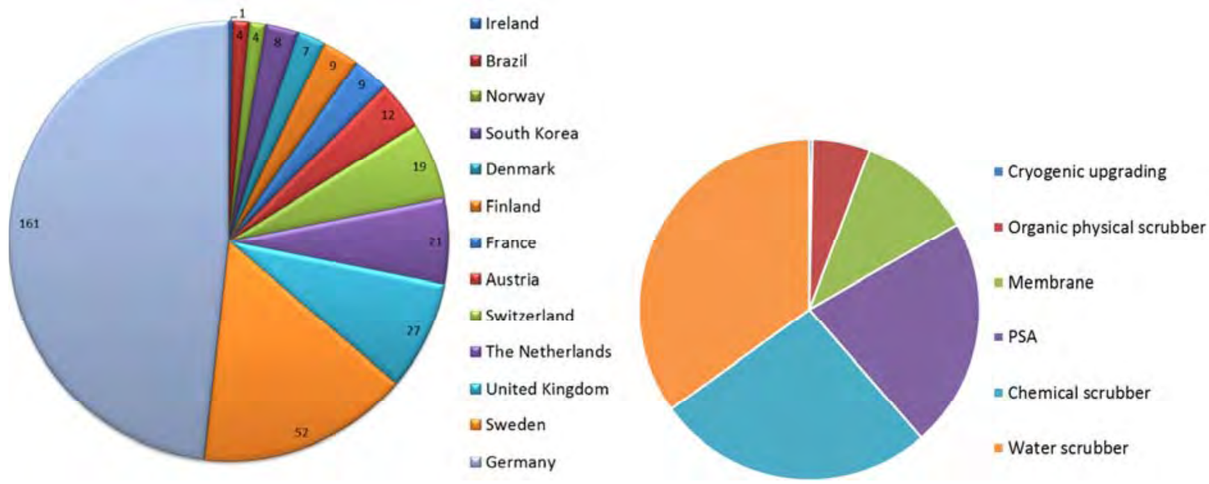


Figure 19: The location of the existing biogas upgrading units in the IEA Bioenergy Task 37 member countries. The labels are in the order from the smallest to the largest.

Financial support systems are very different from country to country. Various systems with feed-in tariffs, investment grants and tax exemptions exist. A clear correlation between the financial support system and the way biogas is utilised is evident in the Task 37 member countries. In UK and Germany with feed-in tariffs for electricity, this has led to most of the biogas being used to produce electricity, while the system with tax exemption in Sweden favours utilisation of the biogas as a vehicle fuel.

IEA BIOENERGY Task 37 – Energy from Biogas

IEA Bioenergy aims to accelerate the use of environmentally sustainable and cost competitive bioenergy that will contribute to future low-carbon energy demands. This report is the result of work carried out by IEA Bioenergy Task 37: Energy from Biogas.

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