

IEA Bioenergy Task 37

Country Reports Summary 2015

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 projects and production facilities. The publication is an annual update and is valid for information collected in 2015.



<http://www.iea-biogas.net/>



IEA Bioenergy

IEA Bioenergy Task 37 - Country Reports Summary 2015

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Coastal community on the islet of Foröya Vegsteinvika, in the world heritage of the Vega archipelago (Vegaøyen) on the Helgeland coastline, just south of the Arctic circle.

Norway's coastline is about 103,000 km, second only to Canada's. The country has more than 240,000 smaller and larger islands. The coastline is and has always been important for the fishing industry and Norway now see the large potential for marine algae production.

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IEA Bioenergy Task 37 membership summary

1. Introduction

The International Energy Agency acts as energy policy advisor to 29 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. The IEA now has four main areas of focus: energy security, economic development, environmental awareness and engagement worldwide.

Activities within IEA are set up under the Technology Collaboration Programmes, formerly Implementing Agreements. These are independent bodies operating in a framework provided by the IEA. There are 39 currently active Technology Collaboration Programmes (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 37¹. This current publication is the third 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.

¹ <http://www.iea-biogas.net/country-reports.html>

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. Australia

Renewable energy provided 13.5% of Australian electricity generation during 2014 with bioenergy contributing an estimated 7.9% to renewable generation². The majority of bioenergy comes from the combustion of sugarcane bagasse. However, electricity generation from AD installations has shown highest growth over the past five years.

2.1 Production of biogas

The 2015 Country Report represents Australia's first endeavour to capture information regarding the number of operational biogas plants in Australia.

In order to provide an accurate picture of biogas activity a short survey was compiled during 2015 requesting information on type of feedstock used, biogas production data, how the biogas is utilised and digestate handling³. The total number of respondents at the time of this publication was 41. The production of biogas in GWh/year is difficult to quantify due to the variety of ways in which data are expressed. The biogas production (GWh/year) in Table 1 is derived only from the 41 respondents and is a probable figure calculated on 50-80% methane content of biogas and corrected for efficiency losses.

The total number of AD plants is estimated at around 155. The majority are associated with municipal waste water treatment plants (WWTP) and landfill gas power units (the latter were not captured in the 2015 survey data). WWTP use various technologies for the monodigestion of sewage sludge. The majority of agricultural AD plants use waste manure from piggeries (18 systems) with the remainder using manure slurry from dairies and poultry. Over one half, (approximately 17) of industrial AD plants use waste water from red meat processing and rendering plants as feedstock for biogas production. Although a number of different technologies are used, covered anaerobic lagoons (CAL) are widely employed in AD plants treating agricultural and industrial waste. There has been recent interest in the feasibility of using codigestion (e.g. using trucked organic waste, other waste streams and glycerol) at WWTP, intensive agriculture industries and red meat processing plants. Australia does not use energy crops for the production of biogas.

Table 2.1: Status of biogas production in Australia (data from 2015)

Substrate/Plant type	Estimated Number of plants	Number of plants from 2015 survey	Potential Production (GWh/year)*
Sewage sludge (WWTP)	49	19	221
Biowaste	4	2	15
Agriculture	20	9	27
Industrial	33	11	39
Landfill	49**	-	1,140**
Total	155	41	1,442

* Calculated from the estimated electricity production and an assumed efficiency of 35% with 70% methane content in biogas.

** From 2006 Sustainable Power Plant Register, Australian Business Council for Sustainable Energy

² <http://www.cleanenergycouncil.org.au/cleanenergyaustralia>

³ <http://biogas.nceastg.usq.edu.au>

Goals for 2,413 and 55,815 GWh for bioelectricity were set for 2020 and 2050 respectively, to which AD using agricultural and industrial organics are key contributors (Clean Energy Council (CEC), 2008⁴). Opportunities exist for the urban waste industry, driven by a combination of rising landfill gate fees and falling technology costs, and the intensive livestock and food processing industries, driven by readily available feedstock from process waste, higher electricity process and demand for onsite electricity, heat or steam. The Clean Energy Finance Corporation (CEFC) projected 2020 target for agricultural biogas production is 791 GWh.

2.2 Utilisation of biogas

The main use for biogas in Australia is for electricity production, heat and combined heat and power. Excess biogas is flared at WWTPs. Agricultural industries and industrial food processing flare significant amounts of biogas due in part to uncertainty of quantity of biogas produced and associated sizing of generators. This is in part indicative of systems in the early phases of adoption.

Table 2 below shows how biogas is utilised across each of the categories for the 41 survey respondents. There are insufficient data at present to obtain a reliable % value for how the biogas is utilised and the associated quantity in terms of GWh.

Table 2.2: Utilisation of biogas in Australia (data from 2015 survey – 41 respondents)

Plant type	Electricity (%)	Heat (%)	CHP (%)	Flare (%)
Biowaste	33.3	33.3	-	33.3
Sewage sludge	32.4	29.7	24.3	13.5
Industrial	20	26.7	-	53.3
Agricultural	60			40

Australia does not use biogas for vehicle fuel *per se* and there are no biogas upgrading facilities. However, the use of biogas as a vehicle fuel is currently being explored by some industries.

2.3 Financial support systems

In June 2015 the Australian Renewable Energy Target (RET), a Federal Government policy, was scaled back from the previously legislated 41,000 GWh to 33,000 GWh renewable electricity by 2020. There has been political uncertainty surrounding the RET limited investment in renewables over the past year; however, the market has recovered quite significantly.

In Australia, there are limited financial support systems in place for biogas installations. National incentives include large-scale generation certificates (LGCs) which is currently at around \$70/MWh. The Emissions Reduction Fund (ERF), released in April 2015, is a voluntary scheme that aims to provide incentives for a range of industries to adopt new practices and technologies to reduce their emissions. The ERF builds on a previous arrangement known as the Carbon Farming Initiative (CFI) and may prove an important source of revenue for biogas projects.

Direct on-site use of biogas energy provides the greatest financial benefit. Exports of electricity provide income, but with significantly lower dollar value than the savings associated with on-site energy use. This is because feed-in tariffs have been typically poor (4-8 Australian dollar cents per kWh).

The Clean Energy Finance Corporation (CEFC) (operating under the Clean Energy Finance Corporation Act 2012) provides loan support and financing instruments. In November, 2015 the CEFC announced a

⁴ <http://biomassproducer.com.au/wp-content/uploads/2013/11/01AustralianBioenergyRoadmap.pdf>

\$100 million commitment to the Australian Bioenergy Fund to provide equity in addition to debt finance for bioenergy projects.

2.4 Innovative biogas projects

Jandakot Biogas Plant, Western Australia – Commercially-viable biogas from food waste

Leading Australian garden product supplier Richgro is using ground-breaking waste-to-energy technology supplied by Biogas Renewables to meet all its power needs. Using organic waste from its onsite operations, a \$3.3 million anaerobic digestion plant with a capacity of 2 megawatts produces enough electricity for Richgro's operations at Jandakot in the south of Perth, Western Australia. That includes powering equipment and potentially Richgro's onsite vehicle fleet. And the digestate by-product from the plant can be used as a raw material in Richgro's garden products, meaning the company produces zero net waste from its operations. The plant has the capacity to process more than 35,000 tonnes a year of commercial and industrial organic waste, diverting it from landfill. Over a 20 year life the project is expected to save 142,722 tonnes of CO₂ equivalent. Low Carbon Australia, now the CEFC, provided finance for the project, which also received an Australian Government Clean Technology Investment Program grant⁵.



Figure 2.1: Jandakot Biogas Plant, Western Australia – Commercially-viable biogas from food waste

Darling Downs Fresh Eggs, Queensland – Producing biogas from chicken manure

Commissioned in 2014, Darling Downs Fresh Eggs are using the chicken manure and other organic waste from its egg production business to generate power and save more than \$250,000 a year.

⁵ More information: <http://www.cleanenergyfinancecorp.com.au/investments/case-studies/converting-waste-to-energy.aspx>

Quantum Power and RCM International are designing and installing an anaerobic digester and generators for Darling Downs Fresh Eggs. The power plant will help Darling Downs Fresh Eggs to reduce its grid electricity usage by 60 per cent in the first year and provide 100 per cent of the company's energy in non-peak periods. Heat from the biogas generator will be captured and used to warm chicken rearing sheds and heat the water for the grading floor. The facility will also reduce Darling Downs Fresh Eggs' carbon emissions by up to 1,000 tonnes a year and its methane emissions by over 6,000 tonnes of CO₂ equivalent a year⁶.



Figure 2.2: Covered anaerobic lagoon (CAL) at Darling Downs Fresh Eggs, Queensland – producing biogas from chicken manure.

⁶ More information: <https://www.cleanenergyfinancecorp.com.au/investments/case-studies/egg-producer-turns-waste-into-energy.aspx>

3. 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 million 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.

3.1 Production of biogas

Today the main production of biogas is derived from energy crops, sewage sludge and landfills (see Table 2.1). 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 3.1: Status of biogas production in Austria, contract with OeMAG (data 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

3.2 Utilisation 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 3.2: Utilisation of biogas in Austria (data from 2013)

Utilisation type	GWh
Electricity	570
Vehicle fuel	7 *
Flaring	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 Nm³/h, and have a combined capacity around six million Nm³ biomethane annually.

3.3 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
- 0.1293 EUR/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 3.1: Biogas plant in Strem nearby Güssing

3.4 Innovative biogas projects

Bio(FLEX)Net

Biomass based technologies for energy production, especially biogas as an energy carrier, are suitable for applications of demand driven energy production. Existing biogas plants are, as well as wind power and photovoltaic plants, distributed in a peripheral way. Based on that fact, biogas plants have the potential to work as a service provider for the power grid, compensating fluctuations in the energy production from other power production plants. As the change of occupancy towards the production of balancing energy can be achieved very quickly, there is the possibility to offer a rapid contribution to the power grid balancing. Therefore this leads to possibilities for additional installations of wind power and photovoltaic capacity.

The aim of the project is to evaluate the technical configuration and plant control technique which allows a market and system optimised operation of biogas plants for the demand orientated production of energy. A flexible operation of biogas plants which includes power generation as well as other components like

the biomass feeding system, was not investigated yet. On the basis of data that has to be collected, a process simulation that allows to simulate different operational states will be created. The biogas and power generation of the plant should be regulated by market signals and prediction models for the demand of balancing energy. Therefore, a control concept for the plant has been developed that allows an economic optimised operation under the given technical requirements. The project consortium is committed to ensure the transfer of the results to other biogas plants and an economic optimised output of the direct sale of the produced generated.

AD plant Brewery Göss

The utilisation of brewery residues during AD has been demonstrated several times in lab scale or in codigestion plants. In 2015 the company BDI Bioenergy built the first large-scale biogas plant which only uses residues from the brewing process like brewer spent grains and yeasts. This plant is installed at the Brewery Göss in Göss, Styria, Austria. Göss is one of the biggest breweries in Austria and belongs to the group Heineken N.V..

The biogas produced by anaerobic digestion is used in two ways. Primarily the energy should be used for the brewing process. Through the production of biogas, 100 % of the heat demand during the brewing process is covered by renewable energy. 40 % is already covered by the utilisation of waste heat from the neighboring wood processing plant, while the rest is covered by the use of biogas in a boiler. Second, a CHP unit converts the unused biogas to electricity which is fed into the grid. To close the nutrient cycle, local farmers pick up the digestate and use it as fertilizer on the fields.

4. Brazil⁷

Brazil is recognised worldwide for the high share of renewable energy in its national energy matrix. In 2015, according to the national 10-Year Plan for Energy-2024, 42.5% of the internal energy supply originates from renewable sources, which includes hydro power, firewood and charcoal, by-products of sugar cane and other renewable sources (solar energy, wind power and biomass). According to estimates, this contribution is to increase to 45.2% of the internal energy supply by the year 2024, with the increase of other renewable energy sources from 4.8% to 8.1%.

Over past years various plants for the production and utilisation of biogas have been established in the country. In fact, this sector has been growing steadily. Helping this progress of the sector is the 2015 regulation for biomethane. It establishes a standard definition (a Normative Resolution) for biomethane produced from biodegradable materials originating from agroforestry and organic waste and is the regulation applies to nationwide use of biomethane as a fuel for vehicles, commercial shipping and for residential use. The standard includes obligations regarding quality control to be met by the various economic agents who trade biomethane throughout Brazil.

4.1 Production of biogas

According to the Biogas National Registry (*Cadastro Nacional de Biogás*), maintained by the International Center on Renewable Energies – Biogás (CIBiogás), in the year 2015 there were 127 plants in operation in Brazil, with total biogas production of around 1.6 million Nm³/day, or 3,835 GW/year in terms of corresponding energy. The most utilised substrates were agriculture and industry residues, with percentages of 47% and 34%, respectively. However, the highest amount of biogas was produced in sanitary landfills, with 43% of the total.

Table 4.1: Current biogas production in Brazil (data from 2015)*

Plant type	Number of plants	Energy production (GWh/year)*	%
Sewage sludge	7	199	5.2
Biowaste	8	32	0.8
Agriculture	60	1,096	28.6
Industrial	43	860	22.4
Landfills	9	1,648	43.0
Total	127	3,835	

* = Produced energy as electricity, heat, mechanical energy and vehicle gas, excluding efficiency losses.

The Energy Research Company - EPE (*Empresa de Pesquisa Energética*), an agency related to the Ministry of Mines and Energy of Brazil, has published studies regarding the technical potential of biogas in the country. In fact, estimated biomethane production for 2014 was approximately 18.5 million Nm³/day, and 4,346 MW of installed electrical capacity (only agricultural residues and urban solids). Another study referred to a projection of their economic potential (including sanitary sewage and industrial residues). It indicated that, considering the baseline scenario, the installed capacity of the biogas fuelled combined heat and power plants will amount to 458 MW in 2030 and 2,850 MW in 2050, or, in terms of corresponding biomethane, 2.33 million Nm³/day and 15.25 million Nm³/day, respectively. The

⁷ Report produced by: Leidiane Ferronato Mariani – PhD student at *Universidade Estadual de Campinas - Unicamp* and researcher at the International Center on Renewable Energies - Biogás

estimated production of biomethane points to 5.78 million Nm³/day in 2030 and 36 million Nm³/day in 2050.

4.2 Utilisation of biogas

In 2015, 49% of the plants had heat generation as the main objective for biogas utilisation and 44% for electrical energy generation. However, only around 31% of the total biogas produced in Brazil was utilised for heat generation, whereas electrical energy generation accounted for 65%. According to the Brazilian Electricity Regulatory Agency - ANEEL, in 2015 there were 25 biogas operated thermoelectrical power plants connected to the National Interconnected System - SIN (*Sistema Interligado Nacional*), accounting for 61 MW (0.04% of the total national installed power).

The use of biogas for the generation of mechanical energy is widespread in Brazil due to the necessity for pumping the liquid sewage originated from the pig production facilities for the purpose of crop fertilisation, added to the availability of biogas from biodigesters installed in mid-2006 to provide for the Mechanism of Clean Development - a procedure contained in the Kyoto Protocol, but which was abandoned after the fall of the of carbon credit price. In 2015, besides the 6 plants that operated basically for such purpose, there were 19 other plants that applied part of their biogas production in the scheme. On the other hand, it has been estimated that there are hundreds of dispersed plants that still operate within the scope of the scheme; this creates difficulties in terms of data collection.

*Table 4.2: Utilisation of biogas in Brazil (data from 2015)**

Utilisation type	No. of plants	GWh	%
Electricity**	56	2,513	77
Heat	62	1,200	15
Mechanical	6	106	7
Vehicle fuel	3	16	< 1
Flaring	n.a.	n.d.	-

* = Categorized according to the main type of utilisation – a few cases of multiple applications

** = excluding efficiency losses

Source: CIBiogas, 2015 (<https://cibiogas.org/biogasmap>)

4.3 Financial support systems

The steady growth of biogas in Brazil results from a series of policies, research and initiatives directly or indirectly connected to this sector. They are described as follows:

Political grounds and Funding Sources

- **The National Policy on Solid Waste** points to the integrated management and the environmentally adequate management of solid wastes and ensures the adoption of initiatives related to biomass in energy production.
- **Sectoral Plan for the Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Emission Economy in Agriculture:** public policy that provides detailed descriptions of procedures for mitigation and similar activities in relation to climate change in the agricultural sector.
- **Normative Resolution n. 482/2012 by the Brazilian Electricity Regulatory Agency - ANEEL** establishes the general criteria for the access of micro and mini distributed generation to the systems of electrical energy distribution and the system of electrical energy compensation.

- **Resolution 08/2015 by the National Petroleum Agency - ANP**, which regulates the biomethane originated from organic agrisilvopastoral products and residues directed to vehicle application (CNG) and to residential and commercial facilities.
- **Program ABC - Program for Low Carbon Agriculture (*Programa Agricultura de Baixo Carbono*)**: Provides credit facilities for initiatives within the context of the Low Carbon Agriculture Plan, with resources for the treatment of animal wastes.
- **PRONAF Sustentável**: Credit facility for aspects concerning environmental sustainability for family agriculture with the application of credit resources from the National Program for Family Agriculture - PRONAF (*Programa Nacional para Agricultura Familiar*).

Actions by the private initiative, civil society and Research, Development and Innovation organizations

- **The Brazilian Association of Biogas and Biomethane – Abiogás**: (*Associação Brasileira do Biogás e Biometano*) was founded in 2013. It comprises public and private companies and institutions operating in different segments of the biogas chain. In 2015, ABiogás launched the proposal for a National Program of Biogas and Biomethane.
- **Biogas and Biomethane National Program – PNBB**: In the year 2015, the Brazilian Association for Biogas and Biomethane - ABIOGAS (*Associação Brasileira de Biogás e Biometano*) submitted the Proposal for a Biogas and Biomethane National Program - PNBB (*Programa Nacional de Biogás e Biometano*) for evaluation. The Plan aims at the creation of an institutional economic, normative and regulatory scenario that promotes the necessary favorable and stable conditions for the advancement of important projects for the sustainability of the Brazilian energy matrix.
- **The Brazilian Association of Biogas and Methane – ABBM**: (*Associação Brasileira de Biogás e Metano*) was established in 2013 and gathers together entrepreneurs, farmers, researchers and consultants. The pursuit of broader participation of biogas and biomethane in the energy matrix is one of its objectives.
- **Public Call 014/2012 - R&D by ANEEL**: Call for research and development projects on the biogas theme: "Strategic Project: Technical and Commercial Arrangements for the Insertion of Electrical Energy Generation with the use of Biogas originated from Residues and Liquid Effluents in the Brazilian Energy Matrix".
- **Rede BiogasFert** or Project "**Technologies for the production and utilisation of biogas and fertilizers with the treatment of animal manure within the scope of ABC Plan**" is a partnership undertaking involving EMBRAPA and ITAIPU. It gathers together researchers in the field of biogas and fertilizers from various universities and research institutions in the country.
- **CIBiogás-ER**, established in 2013, is an institution for research, development and innovation with the objective of transforming biogas knowledge into a product by means of the development of new business undertakings and their effective implementation in the Brazilian energy matrix.
- **Project Brazil-Germany for the Promotion of Biogas Energy Application in Brazil - PROBIOGAS**: The Brazilian Ministry of Cities (*Ministério das Cidades*) has implemented initiatives with the German Government, through GIZ (*Deutsche Gesellschaft für Internationale Zusammenarbeit*), for the application of biogas energy in Brazil.

4.4 Innovative biogas projects

Consortium Verde Brasil – Codigestion and biomethane

Consortium Verde Brasil comprises the cooperative organization *Cooperativa dos Citricultores Ecológicos do Vale do Caí - Ecocitrus* and the company *Naturovos*, with the support of Sulgás. In 2013, this consortium presented its plant for the generation of biogas and biomethane. Located in the municipality of Montenegro/RS, the enterprise makes use of Brazilian technology in production and upgrading procedures. The substrate is formed with residues from the citrus juice, dairy and cellulose industries, residues from slaughterhouses and egg-producing poultry farming. The system for biodigestion is composed of covered lagoon with heating and stirring which, in the year 2015 produced an amount of around 1,200 Nm³/day of biomethane with PSA upgrading and water washing system, to be utilised as vehicle fuel in a pilot scale project in the consortium's vehicle fleet. Large scale utilisation by vehicles and industries has been under negotiation. Surplus gas is utilised in electrical energy generation for internal consumption in the plant for the composting of wastes and biomethane production.



Figure 4.1: Consórcio Verde Brasil - www.consortioverdebrasil.com.br

Amidonaria Navegantes – Biogas for thermal energy production

Aminodaria Navegantes belongs to the rural producers cooperative C. Vale, located in the municipality of Assis Chateaubriand, Paraná State. It involves a starch industry capable of a daily production of up to 400 tons of cassava root, a typical Brazilian tuber plant. Its production encompasses modified starch, for utilisation in the paper bleaching process, and food starch for bakeries and processed meat industries (sausages and salamis). Depending on the time of the year and the kind of product under production, an amount between 570 and 1620 Nm³ of liquid effluent is produced daily in the industrial process. This material is transferred to a covered lagoon type biodigester for the anaerobic treatment phase. This project has been in operation since 2012. The daily amount of 20,000 Nm³ of biogas produced is used to generate thermal energy for industries, resulting in a reduction of up to 90% in the demand for firewood. Such an industry was one of the pioneers in the use of effluents originated in the large scale processing of cassava in Brazil. In fact, in 2015 there were 28 additional industries like this making use of biogas for the generation of thermal energy.



Figure 4.2: Source: C.Vale - <http://www.cvale.com.br/amidonarias.html> and <https://cibiogas.org/ud>

5. 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 interest in the 2012 energy agreement. In all scenarios considered to achieve fossil free status, 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.

5.1 Production of biogas

158 biogas plants are in operation in Denmark, with a yearly production of over 1.5 TWh of biogas, an increase of almost 20 % compared to 2013. The increase is attributed to the breakthrough resulting from the Energy Agreement of 22 March 2012.

Table 5.1: Current biogas production in Denmark (data from 2014) Source: Danish Energy Agency

Substrate/Plant type	Number of plants	Production (GWh/year)
Sewage sludge	53	301
Biowaste	-	-
Agriculture	65*	1,115
Industrial	6	71
Landfills	28	50
Total	152	1,537

** = At the end of 2015, the number was 71 agricultural plants*

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, highlighting that the increase could be higher if a number of biogas plant projects, which are for the moment assessed as uncertain, also will be implemented. 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.

The most 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. Co-substrates with high potential are deep litter, straw, household waste, organic industrial waste and grass cover from natural areas. As stated above, the share of energy crops and by this

their potential in the future deployment of biogas production in Denmark will be increasingly limited, due to sustainability considerations. The first priority will be to use the waste materials easily available, as pointed out by the Danish government in "Resource strategy - Denmark without waste" (2013).

A significant expansion of biogas capacity is a major challenge, as it requires finding suitable biomass feedstock, in sufficient amounts, to be co-digested with manure and slurry. This is because the available organic industrial waste is estimated to be depleted and that there are challenges with all other types of biomass, due to low potential, relatively high costs, or technological challenges to use in biogas plants. The potential of biomass to biogas is expected to be fairly stable until 2020. The amounts of manure and slurries are expected to decrease by approximately 5 %, while a slightly higher share of the total is expected to be supplied for biogas production. The available amounts of crop residues (straw, by-crops and crop silage) are also expected to increase. The most important role of biogas in the future Danish energy supply will be to balance the wind dominated electricity production. Furthermore, biogas will help convert the transport sector from fossil to "green" fuels. There are a number of factors acting as barriers or as incentives for the development of biogas in Denmark. Some have to do with project finances, others concern the interaction between developers and authorities in relation with the approval procedures, etc.

5.2 Utilisation of biogas

Today biogas is mainly used for heat and power production in Denmark. 450 GWh of electricity from biogas was produced in 2014, with an average efficiency of 38%. In 2014, some 108 GWh of biogas (7% of the total production) was injected into the natural gas network as upgraded biogas, with a small portion represented by the town gas network, in Copenhagen (not upgraded). The use of biogas as a transport fuel is only in its preliminary phase, and it is mainly operated in a virtual manner through certificates.

The general interest for using biogas as a vehicle fuel is increasing, with a total of 11 upgrading plants and 10 CNG filling stations at the end of 2015. An additional 6 upgrading projects will most likely come on line in the near future. Currently, over 80 CNG cars are in operation in Denmark, and political interest for using upgraded biogas as vehicle fuel is also increasing, especially regarding application for public transportation (city buses) and heavy duty vehicles (trucks).

Table 5.2: Utilisation of biogas in Denmark (data from 2014)

Utilisation type	GWh	%
Electricity*	1,183	77
Heat	231	15
Grid injection	108	7
Flaring	<15	< 1

* = including heat losses

Source: Danish Energy Agency 2015

5.3 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 3.5 EUR/GJ (26 DKK/GJ) and temporary support of 1.34 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 EUR/GJ in basis subsidy for combined heat and power heating (direct and indirect subsidies)
- 10.6 EUR/GJ in basis subsidy for upgrading and distribution via the natural gas grid
- 5.2 EUR/GJ in basis subsidy for industrial processes and transport

In addition:

- 3.5 EUR/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 EUR/GJ the subsidy is reduced accordingly.
- 1.34 EUR/GJ for all applications – scaled down linearly every year from 2016 to 2020 when the subsidy expires.

5.4 Innovative biogas projects

NGF Nature Energy - Holsted Biogas Plant

NGF Nature Energy Holsted was taken into operation in 2015 as the largest biogas plant in Denmark that feeds upgraded biogas in the natural gas grid.

The plant, located in the central part of Jutland Peninsula, co-digests annually some 400,000 tons of biomass, of which about 70 % is manure and slurries from cattle, pigs and mink farms, from the area around Holsted town. In order to boost the methane yield, the animal manure is co-digested with deep litter, organic waste from food and agro-industries and some energy crops.

The animal slurry/manure, from the farms in the area, is collected every day by the biogas plant operator, with its six suction road tankers. The biogas plant is connected through a piping system with a neighbouring waste separation and treatment plant, which supplies separated food waste and other organic waste from supermarkets.

The biogas plant produces annually 13 million cubic meters upgraded biogas, corresponding to the heat consumption of about 8,000 households. The upgrading plant in Holsted is Denmark's largest, with a capacity of 3,000 Nm³ of raw biogas per hour, giving about 1,800 Nm³ of biomethane per hour, which is equivalent to the average annual energy consumption of a household. The upgrading plant applies the water scrubbing technique, to remove the CO₂ from the raw biogas.



Fig. 5.1 NGF Nature Energy biogas plant in Holsted is the largest biogas plant in Denmark that feeds its produced biogas to the natural gas grid.



Fig. 5.2 Suction road tanker, for slurry transport

Organic biogas in Strellev

A new organic biogas plant was inaugurated in November 2015 at the organic dairy farm in Strellev, close to Ølgod, on Jutland. A biogas plant is a good fit in this case, because full utilisation of the farm resources is a main objective of organic farming.

The plant was supplied by AgriKomp, set up by Jørgen Hyldgaard Staldservice and it is specifically designed to handle large amounts of deep litter and other solid biomass. It converts manure/deep litter and grass clover silage into energy and climate-friendly, organic fertilizer. The plant has therefore a specially designed feeding system, wherein the dry matter is transported directly into the reactor tanks. Inside the tanks, several large paddles ensure biomass mixing so that not only the material is stirred horizontally, but also vertically, several times a day, ensuring optimum utilisation of the biomass, and a homogeneous consistency throughout the tanks. The special technique makes the plant concept very interesting for other organic farmers, as they need to utilise manure and deep litter fully, in line with the phasing out of the use of conventional manure in organic farming by 2021. The biogas plant is a benefit for the farmer, as it produces a fertilizer with contents that are easily accessible to the crops, improving utilisation of the resources of the farm. This means that feed residues, grass clippings and other “waste” vegetable materials are converted into energy and fertilizer.

The biogas is converted to electricity in a 340 kW capacity gas engine, producing 2.8 million kWh per year - equal to the total annual electricity consumption of 600 single-family households.

The 12 million DKK investment should be paid back in about 5-7 years, including a 30% government grant which is applied to promote organic biogas plants. There is a fixed feed-in tariff up to 2020 of 1.20 DKK/kWh produced electricity. By comparison, the price is only 0.15 DKK/kWh from the farm’s wind turbine.

6. Finland

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

6.1 Production of biogas

In 2014 the total energy production from biogas was 613.4 GWh from 86 different biogas production sites. Biogas production has slightly (ca 4 %) increased since 2013. Three co-digestion plants and one agricultural digester started production in 2014. Landfills continued to be the major gas producers.

Table 6.1: Status of biogas production in Finland (data from 2014)

Plant type	Number of plants	Energy production* (GWh/year)
Sewage sludge, municipal	16	149
Biowaste, codigestion	14	151
Agriculture	13	5
Industrial wastewater	3	4
Landfills	40	304
Total	86	630

* = Produced energy as electricity and heat excluding efficiency losses. ^aVehicle fuel production 17 GWh is added to total energy production. Source: Huttunen and Kuittinen, 2015, Suomen biokaasulaitosrekisteri n:o 18, 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 2015, 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.

6.2 Utilisation 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. There are nine biogas upgrading units, and upgraded biogas is used as vehicle fuel or injected into the natural gas grid. The usage of biogas as an automotive fuel has increased more than 50 % compared to 2013.

Table 6.2: Utilisation of biogas in Finland (data from 2013)

Utilisation type	GWh	%
Electricity*	159	22
Heat	455	62
Vehicle fuel	17	2
Flaring**	101	14

* = excluding efficiency losses; **not included in Table 6.1

Source: Huttunen and Kuittinen, 2015, Suomen biokaasulaitosrekisteri n:o 18, University of Eastern Finland

The ten operational upgrading plants are in most cases using water scrubbing technology, except two, one using membrane technology, and the newest one using PSA technology. There are 24 public filling stations for biomethane/CNG and three private fuelling stations in operation, 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 30 % in 2015. In total

about 1,900 gas vehicles were in operation in August 2015. Liquefied biomethane (LBG) is not used in transportation in Finland, but some LBG is exported. The first public LNG stations are under planning review in four locations in Finland. On energy basis, the price of biomethane is about half that of petrol.

6.3 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 utilised, 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 170,000 EUR has been paid for biogas production (two plants) while during the same period 84.4 million EUR has been used for wood based bioenergy and 56.5 million EUR 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 tariffs, 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.

Finally, there is no excise tax on biogas.

6.4 Innovative biogas projects

Treatment of Helsinki Region Environmental Services Authority's (HSY) biowaste is based on the part-stream dry digestion where biowaste is digested and composted. The most suitable parts of the biowaste are selected and directed to an appropriate treatment process. The capacity of treatment plant for biowaste is ca. 60,000 tonnes of biowaste a year. 44,000 of this amount can be treated in the biogas facility. At the moment about 51,000 tonnes of biowaste are treated annually of which around 35,000 tonnes are directed to the digestion process. Of this amount, the biogas facility produces on average 6 million Nm³ of biogas per year. Sulfur compounds are filtered from biogas after which the gas is directed through the gas storage to be utilised further in HSY's own gas power plant producing electricity and heat.

Digestate is pumped into the storage tank and from there further to the composting facility to be composted. A suitable mixture is formed from coarse biowaste, digestate and a stabilising medium. The mixture is composted in the composting tunnels for 2-3 weeks. Compost is then transferred to outside stacks. Compost ripened in stacks will be used as soil raw materials for greenery planting⁸.

⁸ <https://www.hsy.fi/en/experts/waste-management/ammassuo-waste-treatment-centre/Pages/Treatment-of-biowaste.aspx>



Figure 6.1: Biogas plant in Espoo (Ämmässuo Waste Treatment Centre) in operation since summer 2015.

7. 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.

7.1 Production of biogas

In France there are almost 450 biogas plants and 240 landfills. Only 113 of the 240 landfills are valorising the biogas (see Table 7.1). The number of farm AD plants is expected to double or triple by the end of 2020.

Table 7.1: Status of biogas production in France (data from 2014)

Plant type	Number of plants	Electricity production (GWh/year)	Heat production (GWh/year)	Biomethane (GWh/year)
Sewage sludge	88	41	401	
Biowaste from MSW	16	67	22	
Industrial	80	7	350	
On-farm and centralized plants	267	624	415	
Landfills with biogas valorization ¹	113	953	294	
Total	564	1,692	1,482	267²

¹ source ADEME : ITOM, les installations de traitement des ordures ménagères en France – Résultats 2010, octobre 2012 ; ² Statistics 2015 (GRDF)

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.

7.2 Utilisation 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 113 out of 240 landfills utilise biogas). Around 236 on-farms AD plants were built by the end of 2013 along with approximately 31 centralized units. In addition, 88 WWT and 80 agrofood industry AD plants are currently operating. 16 MSW AD plants were in operation in 2015.

Regarding Table 7.1, 49% of the energy recovered is transformed into electricity, 43% into heat and close to 8% into biomethane.

At the end of 2015, 20 upgrading plants were in operation, whereof 18 injecting biomethane into the gas grid, producing around 270 GWh of "green" gas. Today, all the biomethane produced is injected into the natural grid or sold in the compressed state as automotive fuel. There are more than 400 applications for injecting biomethane into the natural gas grid, which indicate a significant increase of the number of upgrading plants in the near future. The French gas operators are expecting an additional 170 new projects over the next five years, producing 4 TWh at a capacity of 46,000 Nm³/h injected into the grid. Another government goal speaks of 6 to 8 TWh of biomethane by 2023.

There are more than 13,500 vehicles, including 3,500 trucks, in use in France (265,000 Nm³/day consumption). There are 37 public filling stations and around 130 private filling stations (2012 data).

7.3 Financial support systems

In France and its overseas territories, 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 2015):

0.8652 to 0.11422 EUR/kWh_e for landfills

0.1192 to 0.227 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)

65 to 134 EUR/MWh for biomethane from WWTP sludge (depending of the volume injected and the age of the WWTP); a specific tariff has been published in June 2014);

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 via 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 7.1: 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 supplies 5 communities located close to the unit.



Figure 7.2: Biogas unit in Sourdun, France, owned by Létang Biogaz Co. The plant produces biomethane from energy crops and agricultural wastes. The biomethane is injected into the local NG grid.

8. Germany

The share of renewable energies in total energy generation is to be raised to 40-45% by 2025, to 55-60% by 2035, and to 80% 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. From 2016, direct marketing for new plants more than 100 kW_e is mandatory.

8.1 Production of biogas

The biogas production figures are roughly the same as given in the 2014 summary. It can be assumed that the current biogas production is more or less the same. However, because of the change to regulations, within the 2014 EEG, limitation of growth rate and the contribution of biogas in the energy supply will probably diminish considerably in the future. The 8,005 biogas plants in the agriculture sector make the biggest contribution to biogas production today with electricity and heat supplies of 28 TWh/year and 14.9 TWh/year, respectively (Table 8.1).

Table 8.1: Status of biogas production in Germany (data from 2015)

Substrate/Plant type	Number of plants	Energy production * (GWh/year)	
		Gross electricity**	Gross heat
Sewage sludge	1,400	1,390	1,979
Biowaste	180***	903.3	479.4
Agriculture	8,005	28,002.3	14,861.4
Industrial	80	1,204.4	639.2
Landfills	400	390	110
Total	10,065	31,890	18,069

* = Fuel not included

** = excluding efficiency losses

*** = 40 of these plants do not fulfil the German law requirement of 90 % min. input

Source: Federal Ministry for Economic Affairs and Energy (BMWi), as to 02/2016 - Development of Renewable Energy Sources in Germany based on the data of the Working Group of Renewable Energy Statistics (AGEE-Stat)

(http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/development-of-renewable-energy-sources-in-germany-2015.pdf?__blob=publicationFile&v=9)

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/year with the following proportions: biogas crops from 1.6 million ha arable land 94 TWh/year, animal manure 19 TWh/year, municipal wastes 7 TWh/year and industrial wastes 3 TWh/year. 81 TWh/year (66%) of this potential was used in 2014.

8.2 Utilisation of biogas

According to information from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, in 2015 most of the biogas was used for electricity and heat production, while biomethane utilisation as a vehicle fuel is rare (Table 8.2). The share of energy consumption in Germany for electricity, heat and fuel amounted to 5.0%, 1.4% and 0.1%, respectively.

Table 8.2: Utilisation of biogas in Germany (data from 2015)

Utilisation type	GWh/year	%
Electricity*	31,890	58.1
Heat	18,069	32.9
Vehicle fuel	580	1.1
Flaring**	4,379	8.0

* = excluding efficiency losses

** = estimation, 5 % flaring losses for all types of production but landfill (10 %)

Source: Federal Ministry for Economic Affairs and Energy (BMWi), as to 02/2016

In 2015 a total number of 188 biogas upgrading plants were in operation with a feed-in capacity to the gas grid of 110,310 Nm³/h biomethane (DBFZ, 2016), an increase in capacity compared to the previous year of 21%, delivered by 6 new plants. It is evident that the negative trend suggested by the 2014 EEG reform is starting to manifest itself.

Based on data from Erdgas Mobil GmbH, in 2014 about 170 filling stations with 100% biomethane sold 580 GWh biomethane. This corresponds to more than 20% of natural gas consumption by the 95,000 registered gas fuelled vehicles in Germany.

8.3 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 interval, 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 tariffs are set out (Table 8.4).

Table 8.4: 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

8.4 Innovative biogas projects

Demand driven electricity production on the Bavarian State Research Centre for Agriculture

For an alternative energy supply and the phased shut-down of nuclear power plants the Bavarian State Research Centre for Agriculture started the operation of a slurry based biogas plant in September 2014. The electrical performance of the biogas plant is 75 KW. Goals of the project are

- regional consumption of electricity and heat,
- common treatment of manure from nearby farms and storage of biogas,
- generation of electricity at intervals of four hours each morning and evening for demand driven energy production,
- supply of the Almesbacher buildings with excess thermal energy by means of feed into the existing heat network of wood chip heating system and
- collection of legal and organizational experience.



Figure 8.1: Digester and digestate storage tank (left) and 75 KW el. CHP (right) for demand driven energy supply at the Bavarian State Research Center for Agriculture

source: www.lfl.bayern.de/lvfz/almesbach/060368/index.php



Fig. 8.2: Biogas plant of agt bio energy GmbH (Trebbin, State Brandenburg), Substrate (cow slurry, maize silage, grass silage), digester for hydrolysis and biogas production, airtight digestate storage, CHP 1 MWel., feed-in capacity 350 Nm³/h biomethane

http://www.agt-eg.de/bioenergy_start.php?lang=en

9. 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 (www.energi21.no):

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.

According to the Report to the Storting No 39 (2008–2009), 30% (4–5 million tonne/year) of manure is to be used for biogas production together with 600,000 tonne 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 tonnes of CO₂ 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

9.1 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) were produced.

Theoretical potentials: Sewage sludge (350 GWh), Food waste (635 GWh), Agriculture (2180 GWh based on manure), Industrial (no estimates, important industries are pulp and paper, fish farming and food industry). Fish farming is probably several thousand GWh; the first small plant was established in 2015. Landfilling of organic material is banned and thus the potential will be reduced.

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)

Table 9.1: Status of biogas production in Norway (data from 2010)

Substrate/Plant type	Number of plants	Production (GWh/year)*
Sewage sludge	26	222
Biowaste (food waste)	13	63
Agriculture	6 (1 larger)	43
Industrial	2	n.d.
Landfills	85	270
Total	132	min. 630

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

9.2 Utilisation of biogas

In Norway electricity prices are quite low and thus on economic grounds there is no incentive to generate electricity from biogas. Gas from landfills and smaller plants is usually used for heat production, and in only a few cases for the production of electricity. During recent years, in line with the Norwegian biogas strategy, almost all new plants upgrade the biogas to vehicle fuel quality. Statistical data on the utilisation is not complete, see table 9.2

Table 9.2: Utilisation of biogas in Norway (data from 2014)

Utilisation type	GWh	% (ca)
Electricity	42*	10
Heat	174*	30
Vehicle fuel	250	40
Flaring	?	

* = excluding utilisation in industry

In Norway there are 25 filling stations for compressed biomethane, 6 in the Stavanger region and 19 in the Oslo region. Some of these are combinations of CNG/biomethane. There are also plans to establish filling stations for biomethane in Trondheim and Bergen. Today, several buses use CNG in Trondheim and Bergen.

The market for biomethane use as vehicle fuel is expected to grow. Most of the increased biogas produced will be used as vehicle fuel.

Today almost 1,000 vehicles, including approximately 400 buses run on methane (NGVA Europe statistics 2013).

There are 8 upgrading plants in operation in Norway. Seven use scrubber upgrading techniques, one uses membrane (Dutch membrane producer). There is one that produce LBG. There could have been a more developed market for LNG powered heavy transport if the methane diesel technology (dual fuel) would have been commercially available.

Table 9.3: Norwegian upgrading plants

Plant	GWh delivered	Tech-nology	Year started	Substrate	Raw biogas treatment capacity
1	-	Amine	2010	Sludge	600
2	45 (planned)	Water (LBG)	2013	Food waste	1,100
3	20	Amine	2001 2008 2013	Sludge/ Food Waste	600
4	18	Membrane	2014	Food Waste	330
5	70 (planned)	Water	2015	Manure/ biowaste Food waste	1,200
6	25	Water	2015	Food waste	
7	17	Amine	2015	Sludge/ biowaste Food waste	700
8	60	Amine	2016	Sludge/ food waste	1,200

9.3 Financial support systems

The two most important incentives for increasing the supply of substrates are the landfill guidelines that banned landfilling of biodegradables from 2009, and that for each tonne wet weight of manure treated in a biogas plant a payment of NOK 60 (6.50 EUR) is made. The latter is an action taken to fulfil the Norwegian strategy (Storting No 39 2008 – 2009), with the goal to have 30% of Norway's manure treated by 2020.

To stimulate production of biogas, different schemes for investment aid are available, depending on plant size. Generally investment grants of about 30% are given, the limit accepted by EEA – The European Economic Area Agreement, but up to 50% is allowed in special pilot plant/research projects.

End-use of biogas as electricity is eligible for green certificate system, but the benefit is small and fluctuates since it is market-based, so together with the low electricity price this is not a real option for biogas producers. More interesting is upgrading the biogas and taking benefit of the tax exemption when used as automotive fuel. Natural gas use as vehicle fuel on the other hand will from 2016 no longer be exempt from tax.

9.4 Innovative biogas projects

Increased biogas yields through hyperthermophile hygienisation (The HTE-process)

Hyperthermics Energy AS⁹, will during 2016 install a first full scale biomass pretreatment unit at the biogas plant at Lindum in Drammen. The unit operates at 80 °C and is incubated with H₂ producing hyperthermofilic organisms, for example strains of the *Thermotoga Maritima* family. Uses of hydrogen from the HTE pre-treatment process are numerous.

⁹ <http://www.hyperthermics.com/>

Laboratory tests have shown significant increase in the energy yield obtained from organic waste and other biomass by introducing hyperthermophilic (HT) fermentation as pretreatment (hygienisation step) to a biogas process. In addition to H₂, the fermentation process produces organic acids and alcohols, all good substrates for the following biogas process.

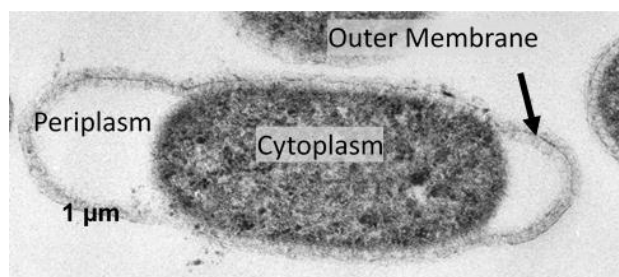


Figure 9.1: *Thermotoga Maritima*

The full scale plant has an annual design capacity of 10,000 tons of food waste and will be operational during the second half of 2016. In addition to regular production, the installation will be used as a full scale research infrastructure to test different substrates as well as biohydrogen production.

Biokraft Skogn (<http://www.biokraft.no/>)

This new industrial biogas plant will use bi-products from Norwegian marine industries combined with waste from the pulp and paper industry at Skogn, as well as other industrial wastes and bi-products.

Groundwork commenced on Biokraft Skogn biogas plant in the autumn of 2015. The plant will initially produce 12.5 million Nm³ of LBG. However, the plant will be prepared for a doubling of capacity up to 25 million Nm³. The plant's location at Skogn gives logistical advantages, being reachable directly by road, rail and boat.



Figure 9.2: *Biokraft Skogn, new biogas plant with LBG production*

Biokraft AS has a significant R&D initiative supported by the Norwegian Research Council that aims to develop innovative solutions for recycling of nutrients from biogas production and complete exploitation of resources and biological CO₂ capture and reutilisation. The primary shareholders in Biokraft AS are Scandinavian Biogas Fuels AB and TrønderEnergi.

10. 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 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 be based north of the border.

A Government Bioenergy Strategy is due to be released. 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.

10.1 Production of biogas

The exact number of biogas plants in the Republic of Ireland is hard to access in detail. Many wastewater 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 those for wastewater sludge treatment. The Irish Bioenergy Association (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 10.1.

Table 10.1: Biogas production in the Republic of Ireland (data from 2015)

Plant type	Number of plants	Installed capacity
Sewage sludge	14	n.d.
Biowaste		
Agriculture	9	3.9 MW _e
Industrial		
Landfills	8	29 MW _e
Total	31	

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. The biofuel obligation certificate (BOC) system operated by the National Oil Reserve Agency (NORA) allows for payment of three certificates to producers of gaseous biofuel with an energy value in excess of 35 MJ/Nm³ if produced from residues or from second or third generation substrates and used for transport fuel. The certificates trade at a price that reflects the difference between 1L of diesel and 1L of biodiesel. It is very likely that the return on biogas as a transport fuel is superior to the return on electricity from biogas. Gas Networks Ireland (GNI) in a 2015 publication "Network Development Plan: assessing future demand and supply position" (<http://www.gasnetworks.ie/>) proposes a target of 5% substitution of natural gas with green gas by 2020, rising to 20% by 2030.

A Bord Gais report¹⁰ 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

¹⁰

<http://www.gasnetworks.ie/Global/About%20Us/About%20Us%20documents/The%20Future%20of%20Renewable%20Gas%20in%20Ireland.pdf>

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. 1,400 million EUR. 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 complete with a gas grid injection point.

In the last three 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.

10.2 Financial support systems

Support to biogas in the Republic of Ireland includes:

- A landfill levy of 75 EUR/tonne 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 7.2 Euro cent/kWh_e in 2007 and was raised to 12 Euro cent/kWh_e 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 Euro cent /kWh_e
- AD CHP greater than 500 kW: 13 Euro cent/kWh_e
- AD (non CHP) equal to or less than 500 kW: 11 Euro cent/kWh_e
- AD (non CHP) greater than 500 kW: 10 Euro cent/kWh_e



Figure 10.1: 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 kW_e. (Source: SEAI (Sustainable Energy Authority of Ireland) Anaerobic Digestion: A case study – McDonnell Farms Biogas Limited, Shanagolden, Co. Limerick))

10.3 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 Institute (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.

11. Republic of Korea

Total energy production has been steadily increased over recent years; renewable energy accounted for 3.5% (9.9 MTOE, million tonnes of oil equivalent = 115 TWh) in 2012 of which 1.6 MTOE was bioenergy (8.9% from biogas plants and 6.2% 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.

11.1 Production of biogas

A total of 92 biogas plants are now in operation and produce almost 2,603 GWh per year. Landfill gas (LFG) contributes 43.3% (1,128 GWh/yr), biogas from sewage sludge 40.2%, biowaste 16.4% etc. Biowaste mainly consists of food waste, food waste leachate, and digestible co-substrates. Table 11.1 shows Korean biogas production from different types of plants.

Table 11.1: Status of biogas production in Korea (data from 2014)

Substrate/Plant type	Number of plants	Production* (GWh/year)
Sewage sludge	45	1,045
Biowaste (co-digestion)	20	427
Agriculture	6	3
Industrial	-	-
Landfills**	21	1,128
Total	92	2,603

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

** based on 2013 data.

Electricity generation from biogas plants amounted to only 39 GWh in 2012. There are 15 new biogas plants under construction to treat 4,764 tonnes of food waste and food waste leachate daily to produce 454 GWh biogas by 2017. The electricity generated from LFG reached 293 GWh in 2013. The electricity production is expected to increase to 1,937 GWh by 2020.

11.2 Utilisation of biogas

About 51% (1,320 GWh) of the biogas is utilised for electricity production. The main part (25.5%, 664 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 and increased compared to the previous year (16.6%). The utilisation of biogas as vehicle fuel was only 1% of the total biogas production. The utilisation of biogas in Korea is summarized in Table 11.2.

Table 11.2: Utilisation of biogas in Korea (data from 2013)

Utilisation type	GWh	%
Electricity*	1,320	50.7
Heat	664	25.5
Vehicle fuel	26	1.0
Flaring	431	16.6
Biogas sale	162	6.2
Total	2,603	100

* = including efficiency losses.

The number of buses using CNG as a vehicle fuel reached 31,101 and the number of gas filling stations reached 197, including 6 biomethane filling stations. However, these biomethane filling stations only supply 0.2% of the total number of buses.

Biogas upgrading is carried out by water scrubbing or PSA at 3 wastewater treatment plants and 3 food waste leachate plants. Two other food waste AD plants for biogas upgrading 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.

11.3 Financial support systems

There are no tariffs or subsidies for biogas. However, 10% VAT (Value Added Tax) and a 2% tariff will be charged when the mixture of CNG and biomethane is sold. A feed-in tariff system was implemented until 2011.

However the RPS (Renewable Portfolio Standard) system has been enforced since 2012, requiring all power plants generating over 500 MW electricity to supply also a certain share of renewable energy. As “Mandatory Supply Quantity (MSQ)”, 2% of the total power generation should be supplied using an appropriate kind of renewable energy. There is a governmental target to increase MSQ up to 10% of the total power generation in 2022. The average REC price (non-solar energy) has been around KRW 98,800/MWh (77 EUR/MWh) in December 2015.



Figure 11: Asan Biogas Power Plant that is producing 7.33GWh electricity (3,014,550 Nm³ biogas) annually (source : Bioenergy Farm Asan Co. Ltd., Chungnam, Korea)

11.4 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 US Dollars (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 m³. Research on biogas upgrading, system development for odour control, O/M manual development for the AD plant and application of digestate.

12. Sweden

In Sweden there is a governmental aim to produce 50% 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 of a Swedish Government Official Report on the subject were published in 2013. The Swedish Energy Agency have recently been given the task to suggest a strategy to implement them, but with no set deadline and with no additional resources. The gas business in Sweden has in 2015 launched their own vision and strategy work, envisioning that 15 TWh of biogas could be produced by 2030, thereof 12TWh to be used as vehicle fuel. Biomethane from gasification of forestry residues constitutes a major share of the envisioned potential.

12.1 Production of biogas

In Sweden the production of biogas has been stagnant or slowly climbing 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 12.1 shows the Swedish biogas production from different types of plants.

Table 12.1: Biogas production in Sweden from different plants (data from 2014)

Plant type	Number of plants	Biogas production* (GWh/year)
Sewage sludge	139	679
Biowaste	35	717
Agriculture	39	44
Industrial	5	123
Landfills	60	219
Gasification	1	1
Sum	277	1,783

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

Source = Produktion och användning av biogas år 2014, Statens Energimyndighet 2015

The potential to produce biogas from anaerobic digestion and gasification up to 2030 has been evaluated (Dahlgren S (2013) “*Realiserbar biogaspotential 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, almost 60% of the biogas produced is upgraded to biomethane and this proportion is expected to increase even more in the period to 2030.

12.2 Utilisation of biogas

In Sweden, almost 60% of the biogas is used as vehicle gas. This part has been increasing every year to meet the growing demand of the gas powered automotive market. The main part of the remaining biogas is used for heat production. The entire utilisation of biogas in Sweden is summarized in Table 12.2 below.

Table 12.2: Utilisation of biogas in Sweden (data from 2013)

Utilisation type	GWh	%
Electricity*	58	3
Heat**	434	24
Vehicle fuel	1,017	57
Industrial	75	4
Flaring	191	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 2014, Statens Energimyndighet 2015

In Sweden, the bulk of the upgraded biogas is used as automotive fuel and designated “fordonsgas” (vehicle gas). The biomethane is produced in 59 biogas upgrading plants with various technologies (~70% water scrubbers, ~10% PSA, ~15% amine scrubbers, and one membrane based). In one plant, with a capacity of 60 GWh, the biomethane is liquefied and sold as LBG (Liquefied BioGas). Of the methane used as an automotive fuel, the biomethane share was 70% on energy basis in 2015. It is used by 50,000 gas vehicles, including 2,300 buses and 800 heavy duty vehicles. More than 225 filling stations dispense vehicle gas, out of which 163 are public. Six of these offer liquefied vehicle gas (LNG/LBG).

12.3 Financial support systems

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

- No carbon dioxide or energy tax on biogas until the end of 2020 (recently approved by the European Commission). Corresponding to around 70 EUR/MWh compared to petrol and 56 €/MWh compared to diesel, and of which 24 EUR/MWh is from the carbon dioxide relief and the remaining part is from the energy tax relief.
- 40% reduction of the fringe benefit tax for use of company NGVs until the end of 2016, up to a limit of 16,000 SEK (1,700 EUR). Will probably be extended for another 3 years, but then up to a limit of 10,000 SEK (1,070 EUR).
- Investment grants for marketing of new technologies and new solutions for biogas during the period 2010-2016. Maximum 45% or 25 MSEK (~3 M EUR) of investment cost, 90 MSEK per year.
- “Klimatklivet” – the climate leap, is the continuation of the former climate investments programmes benefitting the municipal sector. From 2015 to 2018 a total of 1,925 MSEK is available for applications on all measures which improves the fulfilment of Sweden’s climate goals. Already in the first round of applications, biogas and NGV’s have been greatly awarded.
- A joint electricity certificate marketed between Norway and Sweden. The producer receives 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 2014-2015 ranged between 140-192 SEK/MWh (15-20 EUR/MWh), with a declining trend.
- Maximum of 40 SEK/MWh (~EUR 4.3/MWh) for manure based biogas production to reduce methane emissions from manure. The total budget 10 year budget of 240 MSEK (2014-2023) has been increased for the period 2016-2019 by 120 MSEK.

12.4 Innovative biogas projects

GoBiGas thermal gasification and methanation produced 30 GWh during 2015

<http://gobigas.goteborgenergi.se/>

As can be seen in the statistics part, the GoBiGas 1 (Gothenburg Biomass Gasification Project) plant started producing and injecting biomethane into the natural gas grid in late 2014, after more than one year of tests after the official start in 2013. During 2015 this pre-commercial 20MW test facility has run more or less continuously, producing roughly 30 GWh of biomethane which has been injected to the natural gas grid. It has to be emphasized that it is a pre-commercial plant, still being used for research and technology development and operational testing. It has been planned to make a commercial plant at a later second phase. The target is to run the current 20 MW plant for 8,000 hours a year, with a cold gas efficiency of 65% (biomass to biomethane) and a total energy efficiency of 90% (biomass to useful energy, biomethane + district heating). The substrate up to now has been wood pellets, but from 2016 tests will be conducted with the target fuel, wood chips. Right now the wood chips are manufactured from carefully controlled wood biomass, in order to be able to compare different test runs. Eventually all types of forest residues will be accepted, also slash – branches and tops. Doing that, the current setup could conceivably balance income with costs, despite the current low prices of energy and transport fuels.

The start-up road has been adventurous and sometimes rocky, but with steady progress and generating new operational technologies and know-how, together with a number of scientific papers. However, lately there has been a change of hearts among the local decision makers in Gothenburg, and in order to cut costs there was even a discussion to end the GoBiGas trial prematurely. Luckily this was not the final outcome of the debate. However, the chances seem slim to ever see the launch of a phase two 100MW plant, the politicians sending a strong signal to not consider working on it. They have also called upon Göteborg Energi to stop investing in new biogas production, inclusive of AD based ones, and show economic viability for all the ongoing biogas business ventures.



Figure 12.1: The GoBiGas plant in Gothenburg is the first of its kind in the world, injecting biomethane from thermal gasification and methanation to the natural gas grid of Gothenburg. At full production, the 20 MW_{methane} plant will deliver 160 GWh/yr. Photo: Rob Vanstone

Contact: Ingemar Gunnarsson, Göteborg Energi, Gothenburg. ingemar.gunnarsson@goteborgenergi.se

13. 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

13.1 Production of biogas

In Switzerland there are around 611 biogas plants and six landfills, see Table 13.1. The total gross biogas production was 1,114 GWh in 2014.

Table 13.1: Status of biogas production in Switzerland (data from 2014)

Plant type	Number of plants	Biogas production* (GWh/year)
Sewage sludge	~ 465	573
Biowaste (co-digestion)	25	195
Agriculture	98	258
Industrial waste water	23	77
Landfills	6	11
Total	617	1,114

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



Figure 13.1: Biogas plant in Kägiswil, producing annually 1.5 GWh electricity and 1.7 GWh heat.

13.2 Utilisation of biogas

The biogas is mainly used to produce electricity and heat in CHP plants, but the biomethane production is growing rapidly, see Table 13.2.

Table 13.2: Utilisation of biogas in Switzerland (data from 2014)

Utilisation type	GWh
Electricity*	289
Biomethane	192
Flaring	n.d.

* = excluding efficiency losses

There are 24 upgrading plants (mainly PSA units, amine scrubbers and organic physical scrubbers), two on agricultural sites, ten on wastewater treatment plants and nine at biowaste AD sites, with total biomethane production of approximately 192 GWh. The target is to inject 300 GWh into the natural gas 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>).

13.3 Financial support systems

In Switzerland there are feed-in tariffs for electricity according to Table 13.3 below.

Table 13.3: Feed-in tariff for electricity in Switzerland in Swiss currency (CHF). 1 EUR \approx 1.2 CHF

Power class	$\leq 50 \text{ kW}_e$	$\leq 100 \text{ kW}_e$	$\leq 500 \text{ kW}_e$	$\leq 5 \text{ MW}_e$	$> 5 \text{ MW}_e$
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.

13.4 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 13.2: Thermophilic biowaste reactor of Biogas Zürich (© Biogas Zürich)

14. 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% achieved 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.

14.1 Production of biogas

In the Netherlands there are 252 biogas plants producing around 4 TWh of biogas (data from 2013). Installed capacity is given for production of heat, electricity and upgraded biogas in Table 14.1 to give an indication how the production is distributed. For electricity and heat production are available, see Table 14.2. Biogas upgrading to biomethane with subsequent gas grid injection is included in the figures, corresponding to approx. 900 GWh.

Table 14.1: Status of biogas production in The Netherlands (data from 2013)

Plant type	Number of plants	Installed Heat capacity (MW)*	Installed electricity capacity (MWe)	Upgrading capacity (Nm ³ 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/>

Table 14.2: Status of biogas production in The Netherlands (data from 2014)

Plant type	E-production (GWh/year)	Heat production (GWh/year)
Sewage sludge	201	1,288
Biowaste + industrial	298	784
Agriculture	525	2,161
Landfills	56	72
Total	1,080	1,814

The development of biogas in the Netherlands has not been very strong during recent years, mainly due to the increasing costs of feedstocks. The development has been focused on energy utilisation of industrial and municipal biowaste while the development in the agricultural sector has been very slow. Due to changes in the feed-in tariff system (more money available) it is expected that new projects will develop 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 Nm³ of biogas (63% CH₄ content), which corresponds to around 7 TWh. In 2030, this could potentially increase to 4,600 million Nm³ biogas, which corresponds to almost 30 TWh.

14.2 Utilisation of biogas

In the Netherlands, 80 % of the produced biogas is utilised, corresponding to around 3.2 TWh delivered, as either heat, electricity or vehicle fuel, as seen in Table 14.3.

Table 14.3: Utilisation of biogas in the Netherlands (data from 2014)

Utilisation type	GWh	%
Electricity*	1,080	33%
Heat*	1,814	56%
Vehicle fuel	approx. 270	8%
Flaring	71**	2%

* = excluding efficiency losses. ** = data from 2013

The gas grid requirement of 88% methane may seem to make the biogas upgrading cheaper and suitable for technologies and designs adapted for producing lower biomethane qualities, but due to wobbe index limitations this is not always the case. It may be necessary to upgrade further, and then dilute with nitrogen to also meet the calorific requirement. In 2012, the first biogas upgrading unit using cryogenic separation was taken into operation in the Netherlands. Data from May 2014 show that 7,500 vehicles were running on methane with 186 filling stations available (<http://www.ngvaeurope.eu/european-ngv-statistics>).

14.3 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 14.3) 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 14.3 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 14.3: 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

14.4 Innovative biogas projects

Attero plant in Wijster

Attero is a waste treatment company with several production locations in the Netherlands. Attero refines biogas in its own green gas hub at the location of the plant in Wijster. At Wijster, Attero has gained over 25 years of experience in green gas production, thanks to the local landfill where the first biogas upgrading and gas grid injection operation started.

Two additional digesters: At Wijster, Attero has a digester for the organic liquid fraction (OLF). This is organic household refuse that has ended up in grey wheelie bins and as a result may not be used in compost. Mr Huigen notes that "Organic household refuse is separated from the 'grey' waste stream and is digested separately, in this way, it's still sustainable. In addition to that, we have a digester for green organic household refuse, which is separated at source. We use the component that is easily degradable and convert it to biogas. What's left of the digested materials is mixed in with bulky organic household refuse and turned into compost".

Key function: One of the most important success factors in the development of biogas projects is the availability of affordable biomass and the corresponding logistical structure required to deliver it and to transport the products away. The Wijster plant has years of experience in this area, and is in a good position to develop biogas production still further. Mr. Huigen notes that, "We have been working on an energy infrastructure that facilitates biogas production from a regional centre: the green gas hub".

Refining to natural gas quality: The most valuable part of the process is refining biogas to natural gas quality. Any CO₂, contaminants, and moisture that are present have to be removed. For this reason there are three installations at Wijster, each of which works in a different way. The first one to become operational pressurises the gas to remove CO₂ and any contaminants (PSA). The other one is a water scrubber that uses water to refine biogas to green gas. Since 2014, the site has been operating a membrane installation that, in addition to green gas, produces pure liquid CO₂ for use in the horticultural sector. All residual products are thus put to good use.

Table 14.4: ATTERO's gas refining installations at Wijster

Technique	Capacity (Nm ³ biogas/h)	Green gas prod. (Nm ³ /h)	In operation since
PSA	1,200	840	1989
Water Scrubbing	1,000	700	2012
Membranes	800	560*	2014

* = As well as the production of pure liquid CO₂

Pilot for LNG: The Wijster site also boasts a fourth installation, which is used to refine biogas to bio-LNG. The bio-LNG installation is a pilot project run by the Iveco Schouten car dealership. Wijster supplies the biogas on which their cryogenic installation runs, and which is used to produce green gas to fuel heavy duty trucks.

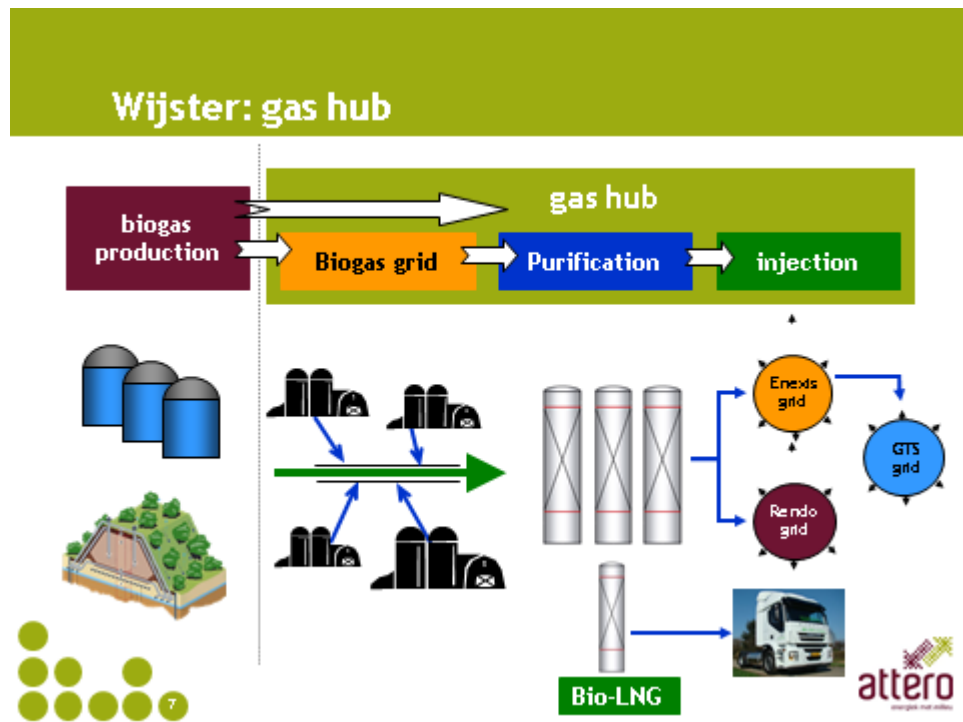


Figure 14.1: Overview of the Attero biogas plant in Wijster

15. United Kingdom

The UK government is still supporting the rollout 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 subsidies (4 ROCs each worth approximately £43/MWe) for AD has seen an increase of farm fed (grass) facilities.

15.1 Production of biogas

Overall electrical capacity from biogas (sewage sludge, landfill gas and AD) equated to 1,641 MW in 2015.

There are today 95 AD plants treating food waste (35 MW_e) and 163 farm plants (216 MW_e). 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 17% during the period 2013-15. These statistics have been compiled from various sources. No complete set of biogas production is collected by any organisation.

Table 15.1: Status of biogas production in the UK (data 2015 - Renewable electricity generation)

Substrate/Plant type	Number of plants	Electricity generation (GWh/year)	Capacity (MW _e)
Sewage sludge ¹	186	846	208
Biowaste	95 ²	707 ¹	135 ²
Agriculture	163 ²	1,009 ¹	216 ¹
Industrial	27 ^{1,2}	n.d.	31 ^{1,3}
Landfills	442 ^{1,3}	5,045 ¹	1,051 ¹
Total	913	7,607	1,641

Sources: ¹DUKES (2015)¹¹; ²National Biogas Portal, National Non Food Crops Foundation (NNFCC); ³Anaerobic Digestion and Bioresources Association (ADBA) From 2006 Sustainable Power Plant Register, Australian Business Council for Sustainable Energy

15.2 Utilisation of biogas

The main use for biogas in the UK today is for electricity production with 7,607GWh produced in 2015 from landfill, sewage sludge and Anaerobic Digestion 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. However, those 4 plants generated 729 MWh of heat between November 2011 and August 2014. Biomethane production is starting to grow within the UK. Between November 2011 and August 2014, approximately 65GWh of equivalent heat was generated by the gas produced by 3 sites. Progress into 2015 was very encouraging

¹¹ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/450298/DUKES_2015_Chapter_6.pdf

with the likes of the Minworth gas to grid facility opening. This plant, which is the biggest of its kind in the UK, will be able to convert 1,200 Nm³/h biogas into 750 Nm³/h biomethane which will be injected into the National 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. These operations are not included in the statistics of this report. See figure 15.2 for details.

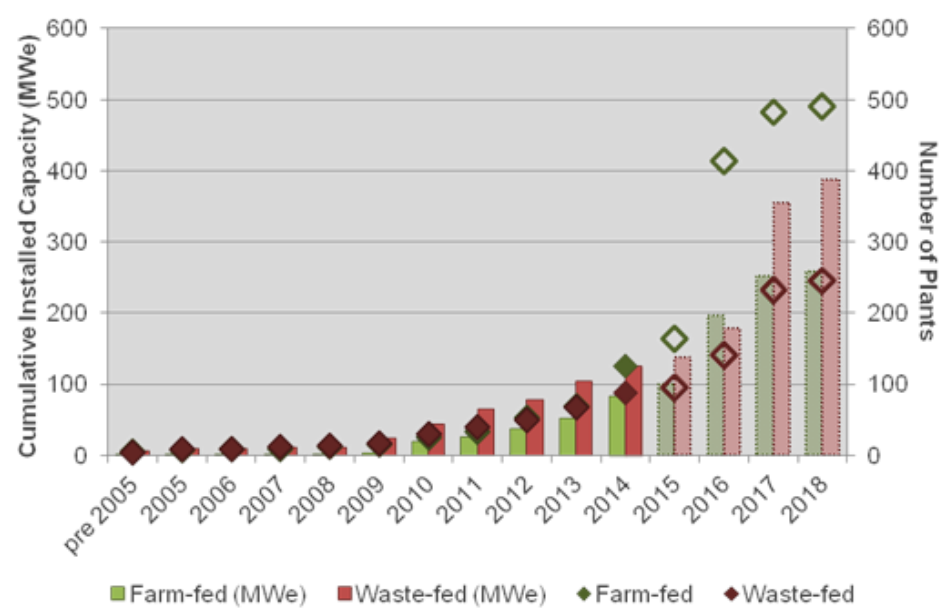


Figure 15.1: Growth of the UK's AD sector, both farm and waste fed (Source: Reproduced by courtesy of NNFFCC (2014) © AD biogas in 2030 could be around 23 to 37 TWh (Analysis of Characteristics and Growth Assumptions Regarding AD Biogas. see link¹²)

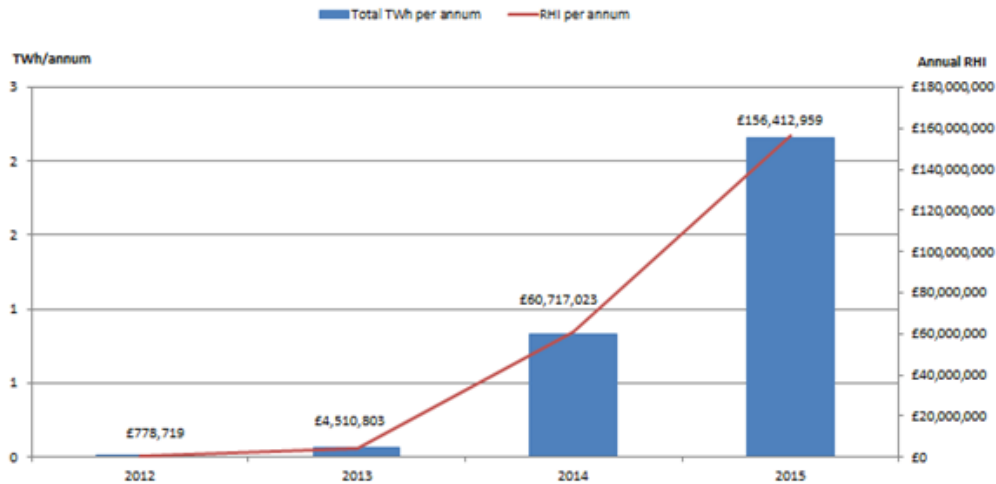


Figure 15.2: Annual Biomethane to Grid and RHI (Renewable Heat Incentive)

In terms of fuel, around 2 million litres were produced for vehicles by the biogas industry during the period Jan 2014 – May 2014. No more recent statistics are available. The Gasrec Albury site has closed down, so now there is no longer any production of liquefied biomethane in the UK (previously approximately 4,000 tonnes production per year).

¹² https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48166/2711-SKM-enviros-report-rhi.pdf

15.3 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 15.2: The Feed in Tariff (pence/kWh) 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
	1 April 2015 to 30 September 2015	10.13
	1 October 2015 to 21 March 2016	9.12
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
	1 April 2015 to 30th September 2015	10.13
	1 October 2015 to 31st March 2016	9.12
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
	1 April 2015 to 30th September 2015	8.68
	1 October 2015 to 31st March 2016	8.68

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 value of ROCs varies as follows: the upper limit is set by the buy-out price, which is the penalty suppliers need to pay for each missing ROC. During the 2015-16 obligation period the buy-out price is £44.33 per ROC.

The Renewable Heat Incentive (RHI) provides a fixed income (per kWh) to generators of renewable heat, and producers of renewable biogas and biomethane. From 1st July 2015 the RHI payment which was instrumental in the growth of biomethane production has been cut severely as shown in the Table below

Table 15.3: Renewable heat incentive (pence/kWh) for various sources. Increases due to inflation linkage

Tariff name	Eligible technology	Eligible sizes	Tariffs (p/kWh)
Biomethane injection	Biomethane until July 2015	biomethane all capacities	7.5
	Post July 2015	1 st 40 GWh 2 nd 40 GWh > 80 GWh	6.52 3.83 2.95
Small biogas combustion	Biogas combustion	Less than 200 kWth Post 1 July 2015	7.5 7.62
Medium biogas combustion (commissioned on or after 4 December 2013)		200 kWth and above & less than 600 kWth Post 1 July 2015	5.9 5.99
Large biogas combustion (commissioned on or after 4 December 2013)		600 kWth and above Post 1 July 2015	2.2 2.24

Renewable Transport Fuel Obligation (RTFO) is a requirement on transport fuel suppliers to ensure that 5% 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 (~ € 12.5).

15.4 Innovative biogas projects

Wyke Farms Ltd

This 480 ha family-owned farm operates its business in such a way as to minimise its impact on the local environment and to create a truly agrobiotic relationship with the environment. It is a long established cheese making business, drawing its milk supply from its own two herds (2,500 cows) and 110 surrounding farms, processing 300 million litres of milk into 14,000 tonnes of organic Cheddar Cheese. The existing capacity of 15,000 tonnes can be scaled up to 40,000 tonnes per year. The aim is to create a wholly sustainable working farm for which the AD plant is key in the potential scaling up of the capacity (15,000 tonnes per year to 40,000). The purpose of the plant is to source all its electricity and gas needs from the biogas plant and subsequently also to include biomethane to fuel the fleet of milk tankers and other vehicles on the farm. Phase 1 involved the construction of 2 x 5,000 m³ digesters and 2 x 500 kW_e CHPs where one CHP sold the electricity to the grid distribution network and the other to the cheese processing plant. It has a throughput of 300 tonnes per day. This consist of a mix of pig and cow slurry, whey permeate and other milk products, bakery residues and any surplus grass and maize silage as well as rape seed straw. In phase 2, which is the situation as in 2015, 50% of the biogas used for electricity was diverted for upgrading to biomethane for injection into the gas grid. Phase 3 is scheduled to use the biomethane to fuel the farm's milk transport fleet and other vehicles.



Figure 15.3: Wyke Farm.

Cullompton Farm (David Parrish)

The digester is 3 years old and has a capacity of 700m³ and the CHP 80kW_e. Unlike many digesters in the UK, the plant has a covered digestate store, illustrating best practice. Digestate is separated into a liquid and fibre fraction using a Murcott elevator belt press separator, which has also supplied the plant with their auto-degritting technology. The plant is fed on slurry from approximately 130 cows, plus chicken manure from their free range broiler house. The surplus heat is supposed to be used in their broiler houses.

16. 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 16.1).

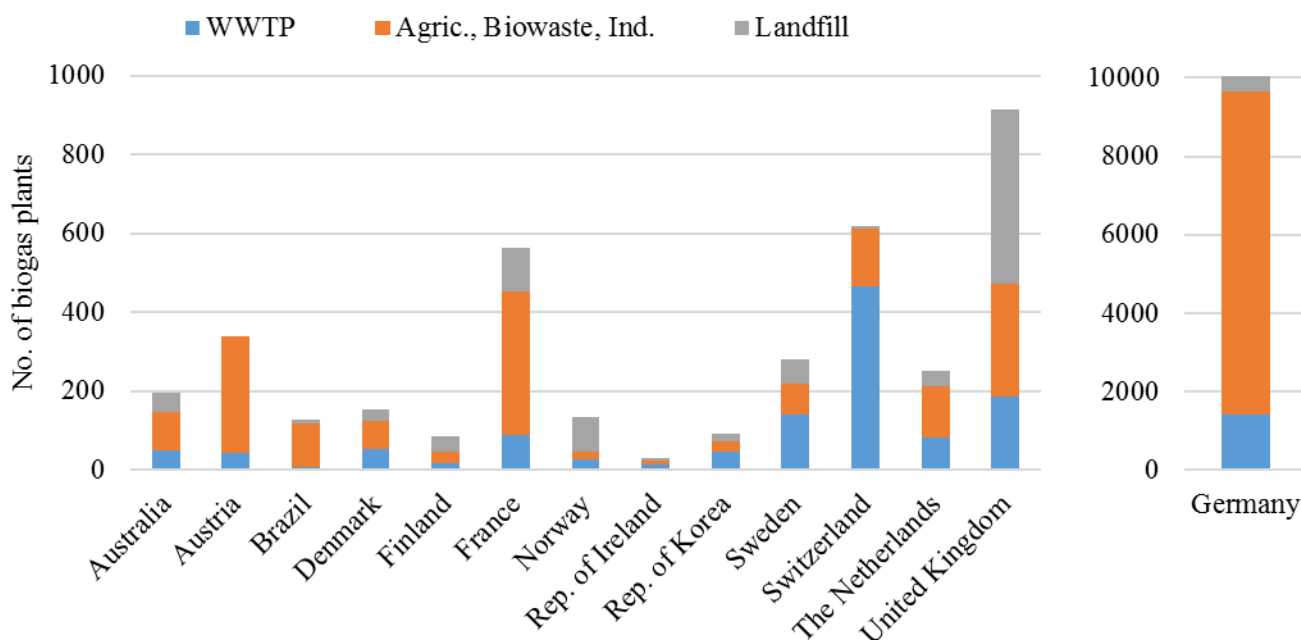
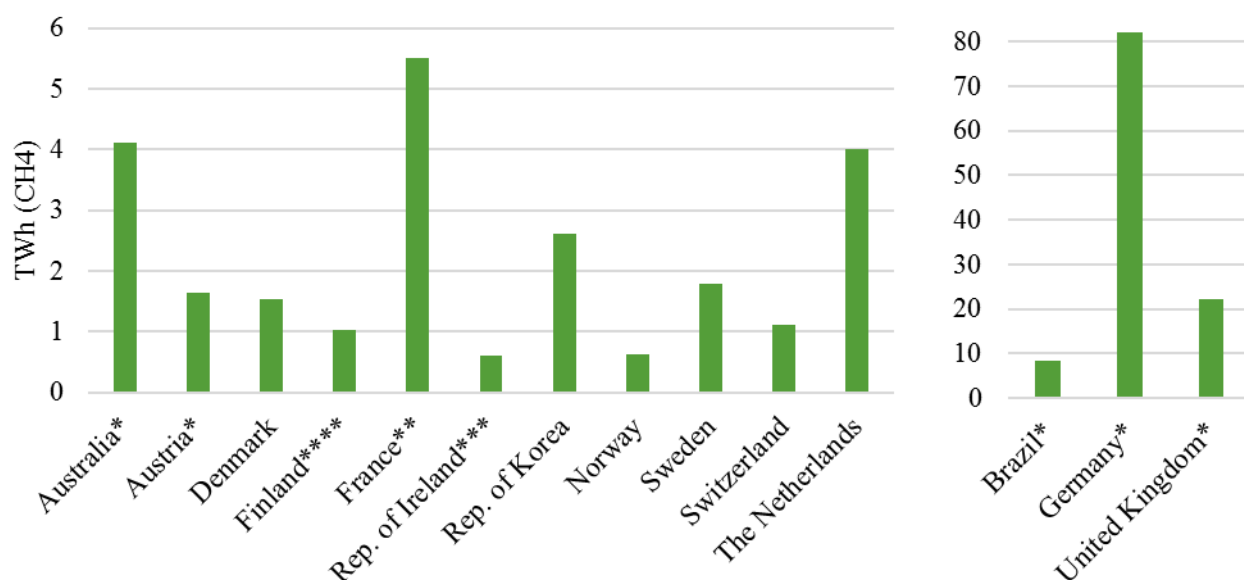


Figure 16.1: Number of biogas plants in operation in the IEA Bioenergy Task 37 member countries (2014-15).

The annual biogas production is around 80 TWh in Germany, 22 TWh in the UK¹³, 8.5 TWh in Brazil, 5.5 in France and 4 TWh in the Netherlands. Remaining countries show production rates in the range of 0.5-2 TWh (see Figure 16.2). 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, indicating the degree of landfilling of organic waste material. The actual biogas production is not reported in all countries, so in this report it has been calculated, based mostly on the electricity production with an assumed efficiency of 35%.

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. Germany is not far behind in absolute numbers (530 GWh). Many other countries, such as France, Denmark and South Korea, have emerging markets for biomethane as an automotive fuel.

¹³ Only biogas for electricity generation, excluding biomethane plants (estimation production potential 2 TWh end 2015) and renewable heat (RHI, negligible amounts)



* = 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%

**** = Calculated from the reported electricity production and an assumed efficiency of 35%, and from the sum of the other utilisation types

Figure 16.2: Annual biogas production in the IEA Bioenergy Task 37 member countries (2014-15).

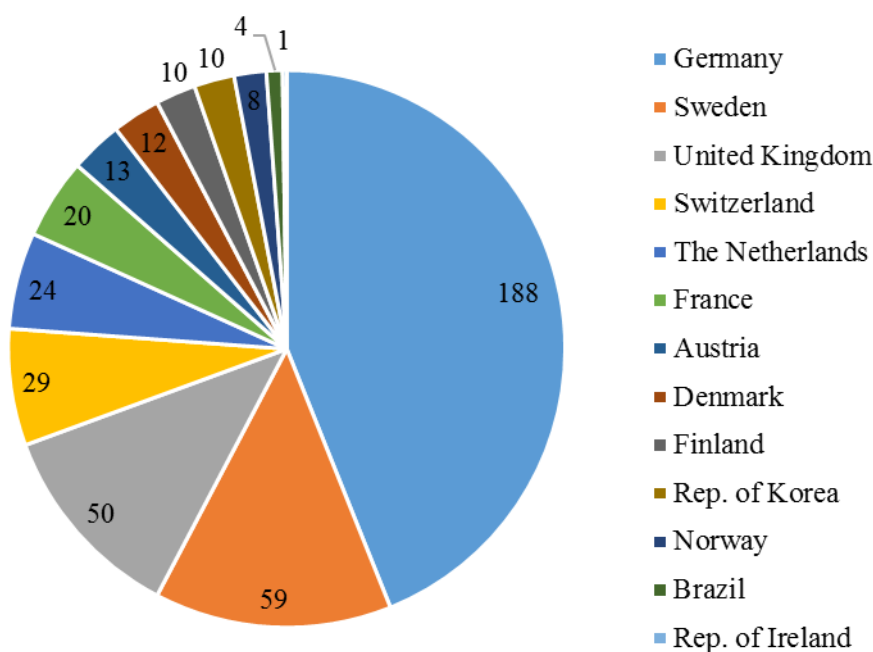


Figure 16.3a: The distribution of the reported operational biogas upgrading units in the IEA Bioenergy Task 37 member countries. The labels are in the order from the largest to the smallest.

The amount of biomethane produced and the number of biogas upgrading plants is increasing. In Figure 16.3 the distribution of 428 biogas upgrading plants among the IEA Bioenergy Task 37 member countries are shown and among the technologies in use, respectively.

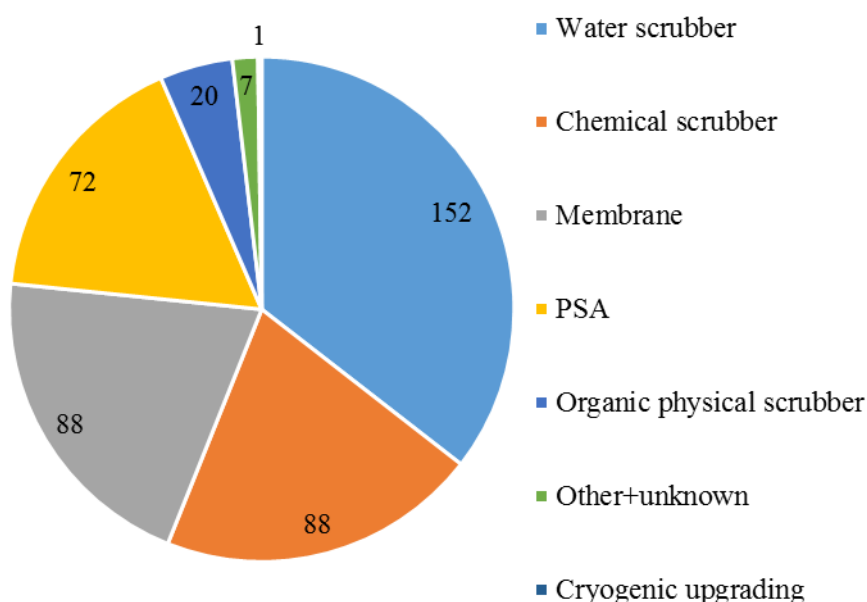


Figure 16.3b: The distribution of upgrading technologies for the reported operational biogas upgrading units in the IEA Bioenergy Task 37 member countries. The labels are in the order from the largest to the smallest.

The two dominating countries, Germany and Sweden, have increased slightly in relative terms and keep their positions. Compared to last year, the UK has almost doubled its number of upgrading plants, and is now in third place. France and Denmark also show great percentage growth, doubling since last year. It is likely that these three countries will continue to grow. In the UK growth might soon stop because of major changes in the supporting policies.

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 the 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 an automotive fuel. With benefits offered, gas grid injection, is also growing, such as in France, Denmark and the UK.

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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