IEA Bioenergy Task 37

Country Report Summaries 2017

This publication contains a compilation of summaries of country reports from members of IEA Bioenergy Task 37 (Energy from Biogas). Each country report summary includes 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 2017. Reference year for production and utilisation is as a rule 2016.

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IEA Bioenergy Task 37 - Country Reports Summary 2017

Written by members of IEA Bioenergy Task 37

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Front Cover Photo: Jordberga Biogas Plant.

Photographer: Krister Hansson
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The biogas plant in Jordberga was built in 2013 in close collaboration with the other co-owners E.ON, Skånska Biofuel Company and Nordic Sugar.

Gasum now owns and operates the biogas production plant and is responsible for the entire production chain from the purchase of raw materials to upgraded biogas. The upgraded biogas is distributed via gas pipeline to, inter alia, Skånetrafikens busses and public service stations.

The biogas raw material is dominated by locally produced greenhouse and waste and residues from agriculture and the food industry. Produced biogas is upgraded in a water scrubber, and then distributed via injection to the gas network. In addition to biogas, a high quality digestate is produced that is approved for use in organic farming. The digestate is returned to the local agriculture, thus closing the important nutrient cycle.

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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 to reduce both investment and operating costs. Publications from Task 37 provide important information intended to be used to improve both economic and environmental performance of the biogas value chain where the end product can be heat, electricity or vehicle fuel, or combinations of these products. The other product from a biogas plant, the digestate, is a very important contributor to the overall sustainability of the biogas value chain and is also addressed in various Task 37 publications.

The Task 37 working group meets twice each year to discuss the progress of the work programme. At these meetings, the national representatives also present the latest information within the field of biogas from their respective countries. These presentations are available for free download at the homepage of Task 37[1]. This current publication is the fifth 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 losses and 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://task37.ieabioenergy.com/country-reports.html

Biogas production is presented for the following plant types:

- Wastewater treatment plants
- Biowaste – co-digestion or mono-digestion 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 14.8% of Australian electricity generation during 2015-16 with bioenergy contributing an estimated 10.1% to renewable generation[2] (1.5% to total generation). The majority of bioenergy comes from the combustion of sugarcane bagasse.

2.1 Production of biogas

Data was sourced from the survey for Australian biogas[3] which was developed in 2015 to capture accurate information for biogas production. The total number of respondents at the time of this publication was 122. 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 122 respondents and is a probable figure calculated from the installed capacity of the responding biogas facilities.

The total number of AD plants is estimated at around 242. The majority are associated with municipal waste water treatment plants (WWTP) and landfill gas power units. WWTP use various technologies for the monodigestion of sewage sludge. The majority of agricultural AD plants use waste manure from piggeries (20 systems) with the remainder using manure slurry from dairies and poultry. Feedlot manure is not used for the production of biogas but stockpiled and used as a fertiliser on agricultural land. Over one half, (approximately 18) 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 2017)

Substrate/Plant type	*Estimated number of plants*	*Number of plants from survey*	*Potential production (GWh/year)**
Agriculture	*22*	*10*	*24*
Biowaste	*5*	*3*	*63*
Industrial	*34*	*14*	*44*
Landfill	*129***	*73*	*1075*
Sewage sludge (WWTP)	*52*	*22*	*381*
Total	***242***	***122***	***1587***

* Calculated from the installed capacity of the survey respondents.
** From 2006 Sustainable Power Plant Register, Australian Business Council for Sustainable Energy

Goals for 10,624 and 72,629GWh for bioelectricity were set for 2020 and 2050 respectively, to which AD using agricultural and industrial organics are key contributors (Clean Energy Council (CEC), 2008[4]). 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. The CEFC estimates a bioenergy investment opportunity of up to $5 billion by

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[2] Australian Energy Update https://www.energy.gov.au/publications/australian-energy-update-2017
3 http://biogas.nceastg.usq.edu.au
[4] http://biomassproducer.com.au/wp-content/uploads/2013/11/01AustralianBioenergyRoadmap.pdf

2020, potentially doubling the current level of installed capacity (see Australian bioenergy and energy from waste report accessed at http://www.cleanenergyfinancecorp.com.au/media/107567/the-australian-bioenergy-and-energy-from-waste-market-cefc-market-report.pdf).

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. This is due in part to uncertainty of quantity of biogas produced and associated sizing of generators.

Table 2.2 below shows how biogas is utilised across each of the categories for the 46 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 survey at end of 2017 – 122 respondents)*

Plant type	Electricity (%)	Heat (%)	CHP (%)	Flare (%)	Other
Agricultural	8.3		50	41.7	
Biowaste	40.0		20.0	20	20
Industrial	15	30	5	50	
Landfill	53.7			46.3	
Sewage sludge	33.3	26.2	21.4	19.0	

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 (see section 2.4).

2.3 Financial support systems

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 $83MWh (Nov 2017). The Emissions Reduction Fund (ERF), launched 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. 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 power purchase arrangements 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 $100 million commitment to the Australian Bioenergy Fund to provide equity in addition to debt finance for bioenergy projects.

Gas Vision 2050 is an initiative created by Australia's gas industry (Australian Gas Infrastructure Group - the Australian Pipelines and Gas Association, the Australian Petroleum Production & Exploration Association, Energy Network Australia, the Gas Appliance Manufacturers Association of Australia, and Gas Energy Australia). The vision focuses on decarbonisation of gas beyond 2030. It highlights biogas as one of the primary technologies for achieving this, with the potential for it to become mainstream and transform the sector while using already extensive existing infrastructure[4]

[4]Energy Network Australia, 2017: http://www.energynetworks.com.au/gas-vision-2050

2.4 Innovative biogas projects

Integration of biogas from sugarcane residues in sugarcane transport and milling to reduce fossil fuel usage

Australia is the third largest exporter of raw sugar in the world and the sugar industry is worth more than $2 billion per year. While utilisation of sugarcane bagasse is widespread for the production of renewable energy (steam and electricity), there are more opportunities to produce high-value products. A project being funded by the Australian Renewable Energy Agency (ARENA) aims to develop and demonstrate technologies for the conversion of sugarcane trash and bagasse into biogas and transport fuels. The project is seeking to improve the efficiency of biogas production and upgrade the biogas to compressed biomethane for use in sugarcane farming and transport. A further aspect to the project is the upgrading of digestates from biogas production through hydrothermal liquefaction (HTL) to produce biocrudes which can also be upgraded to transport fuels. Pilot scale facilities have been constructed to demonstrate all of the technologies involved in the project. Project partners include Queensland University of Technology, Griffith University, Utilitas Pty Ltd and Sunshine Sugar. This project received funding from ARENA as part of ARENA's Research and Development Program.

Figure 2.1 Sugarcane harvester loads sugarcane into a hopper

More information is available from: https://research.qut.edu.au/biorefining/projects/biogas-from-sugarcane/

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. A new energy strategy is under preparation and will be presented soon.

In the past few years prices for raw materials have increased tremendously and the plans to increase the amount of biogas plants have fallen behind schedule. Currently much effort is being invested to save existing biogas plants from bankruptcy. A new legislation is implementing a new framework. One aim is to reduce the amount energy crops like maize and grain (maximum 30% of feed), plants shall be smaller than 150 kW, energy efficiency > 67,5 % and remote controllable.

3.1 Production of biogas

Today the main production of biogas is derived from energy crops, sewage sludge and landfills (see Table 1). The annual biogas production corresponds to 1.5–2.5 TWh. Current trends are that high prices of biogas feedstock (e.g. maize) lead to severe difficulties to operate the plants economically. This has created a large interest to investigate the possibility to use alternative substrates. In total 394 approved biogas plants exist in Austria, but only 287 plants had a contract with OeMAG in 2016.

Table 3.1: Status of biogas production in Austria, contract with OeMAG (Ökostrombericht 2017)

Plant type	Number of plants with electricity generation	Energy production (GWh/year)*
Plants	**287**	**564.52**

* = Produced energy as electricity excluding efficiency losses.
Source: Ökostromberichte 2017, Energie-Control Austria

Table 3.2: Average full load hours biogas (Ökostromberichte 2017)

Average full load hours biogas in 2016		
Classification	Full load hours	Amount of plants
Best third	8,499	69
Middle third	7,753	86
Poor third	3,946	119
All plants	6,287	274

In Austria the discussion about the efficiency lead to the classification of the biogas plants in Austria. 69 biogas plants produced more than 8,499 h per year electricity.

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 10,000 natural gas vehicles (NGVs). The amount of NGVs in Austria increased from 2013 to 2014 by 12.5 % or 966 new vehicles. At the moment 172 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 (values from 2013)

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

* = installed capacity
Source: Ökostrombericht 2016; Franz Kirchmayr (Arge Kompost & Biogas)

There exist 15 biogas upgrading units. All commercial technologies are represented (amine scrubber, water scrubber, membrane and PSA). Most upgrading plants are rather small 600-800 Nm^3/h and have a combined capacity around 16.5 million Nm^3 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
0.1293EUR/kWh for higher than 750 kW_e
+ 0.02 EUR/kWh if biogas is upgraded
+ 0.02 EUR/kWh if heat is used efficiently

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

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

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

Figure 3.1: Biogas plant in Strem nearby Güssing

3.4 Innovative biogas projects

IEE project FABbiogas – Developing of a process to recover energy and materials via membranes from AD (NiMem)

Organic residues from the meat and poultry industry represent a largely untapped resource. With anaerobic digestion the inherent energy of the in-company wastes (chicken manure and slaughterhouse waste) can be recovered to a large extent. By means of anaerobic digestion of these substrates, however, the high nitrogen or sulphur concentrations in chicken manure or slaughterhouse waste lead to an inhibition of microbial flora thus to low methane yields. Monodigestion of these residues, which is not jet established, is an excellent alternative to the use of specifically grown energy crops which lately has become the subject of intensive controversial discussion. The most common solution of this problem is the co-fermentation with renewable resources substrates that contain only low concentrations of interfering substances. However, this significantly reduces the economic and environmental benefit of the biogas process.

In the NiMEM project an innovative membrane technique for integrated nitrogen removal will allow anaerobic mono-digestion of chicken manure and slaughterhouse waste in combination with a reasonable recycling of nutrients as organic fertilizer.

The removal of the inhibiting substances leads to an energy efficient production of biogas and increases the methane yield. For this purpose, sulphur is recovered by microbiological oxidation of H2S from the biogas to sulfuric acid. The highly concentrated acid is used as absorption liquid during nitrogen removal and is recycled as ammonium sulfate. Thus, a high-quality and marketable fertilizer can replace artificial fertilizers and therefore contributes to a reduced use of fossil fuels.

Chicken farms and slaughter houses are ideally suited businesses for this innovative overall concept, since the energy and waste heat generated can be used on site. Increasing involvement of biogas technology within industrial process significantly increase the efficiency of biogas as energy carrier.
An actual implementation of this project has the potential to increase the European power generation from biogas by 20%. Widely energy self-sufficient facilities can be established by an efficient utilization of the biogas thus fossil fuels are replaced.

Safe Food and Feed through an Integrated Toolbox for Mycotoxin Management (MyToolbox)

MyToolBox mobilises a multi-actor partnership with 50% industry participation (farmers, technology SME, food/feed industry), as well as academia and policy stakeholders, to develop novel interventions aimed at achieving at least a 20% reduction in crop losses due to biological (fungal) and mycotoxin contamination. Cutting edge research will result in new interventions, which will be integrated together with existing measures (such as HACCP & GAP) in a web-based Toolbox that will guide the end-user as to the most effective measure(s) to be taken to reduce crop losses taking account of individual circumstances such as geographical location, climatic conditions, land-use, crop management & storage and intended end-use. We will focus on small grain cereals, maize, peanuts and dried fruit (figs), applicable to agricultural conditions in EU and China. Crop losses using existing practices will be compared with crop losses after novel pre-harvest interventions including investigation of genetic-resistance to fungal infection, cultural control, replacement of conventional fungicides with novel bio-pesticides (organic-farming compliant), competitive biocontrol treatment and development of forecasting models to predict mycotoxin contamination at an early stage. Research into post-harvest measures including real-time monitoring during storage, innovative sorting of crops using vision-technology and novel milling technology will enable cereals with higher levels of mycotoxin contamination to be processed without breaching regulatory limits in finished products. Research into the effects of baking on mycotoxin levels will provide better understanding of process factors used in mycotoxin risk assessment.

Investigations will also extend to animal feed and novel uses of highly contaminated crops. Involvement of leading academic partners from China will aid in establishing international cooperation in mycotoxin research and, in particular, the initiation of a formal EU-China dialogue.

4. Brazil[5]

Brazil is recognised worldwide for the high share of renewable energy in its national energy matrix. In 2016, according to the national 10-Year Plan for Energy-2026, 46% of the internal energy supply originated 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 48% of the internal energy supply by the year 2026.

Over the 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 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 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. In addition, in 2017, the National Oil Agency (ANP) resolution Nr 685, dated 29.6.2017 established rules to approve quality and specification of biomethane from landfills and sewage treatment stations for mobility use, as well as for residential, industrial and commercial uses. Recently, the National Policy on Biofuels (RenovaBio) was also approved. The program stimulates biofuel production in Brazil, including biomethane, including for forecasting of environmental, economic and social sustainability, as well as compatibility with market. A bigger contribution of biofuel in the energy matrix, will facilitate reduction in carbon emissions in the transportation sector, as per the objective of the agreement signed in Paris, at COP21, whereby Brazil committed to reduce by up to 43% of greenhouse gas emissions by 2030.

In 2017, the Energy Expansion Ten Year Plan (Plano Decenal de Expansão de Energia) included, for the first time, a significant amount of biogas as an electric matrix component, indicating that this source can reach about 300 MW in 2026.

4.1 Production of biogas

According to the Biogas National Registry (*Cadastro Nacional de Biogás*), maintained by the International Center on Renewable Energies – Biogás (CIBiogas), in the year 2016 there were 165 plants in operation in Brazil, with total biogas production of around 2.2 million Nm^3/day, or 5,219 GWh/year in terms of energy. The most utilised substrates were agricultural and industry residues, with percentages of 49% and 33% of feedstock respectively. However, the highest amount of biogas was produced in sanitary landfills, with 58% of total biogas.

*Table 4.1: Current biogas production in Brazil (data from 2016)**

Plant type	Number of plants	Energy production (GWh/year)*	%
Sewage sludge	10	210	4.0%
Biowaste	9	33	0.6%
Agriculture	81	1,049	20.1%
Industrial	54	877	16.8%
Landfills	11	3,050	58.4%
Total	**165**	**5,219**	

[5] Report produced by: Leidiane Ferronato Mariani – PhD student at *Universidade Estadual de Campinas - Unicamp* and researcher at the International Center on Renewable Energies – Biogás; Marcelo Alves de Sousa – Manager of Institutional Relations of CIBiogas

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

The Energy Research Office - 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 potential for 2014 was approximately 18.5 million Nm^3/day, and 4,346 MW of installed electrical capacity (from 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 Nm^3/day and 15.25 million Nm^3/day, respectively. The estimated production of biomethane points to 5.78 million Nm^3/day in 2030 and 36 million Nm^3/day in 2050.

4.2 Utilisation of biogas

In 2016[6], 37.6% of the biogas power plants used biogas to generate thermal energy, and 56.4% to generate electric energy (Table 4.2). In the meantime, only 21,9% of all biogas generated in Brazil was used for thermal energy. Lately, the use of biogas for electric energy generation is increasing in Brazil due to the regulation changes, and especially due to the new business models, originated from the distributed generation regulations, from 2015, mainly due to the modifications in function of the ANP Resolution Nr 687/2015, which modified the ANP Resolution Nr482/2012.

The use of biogas for the generation of mechanical energy is widespread in Brazil due to the necessity for pumping the liquid slurry 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.

*Table 4.2: Utilization of biogas in Brazil (data from 2016)**

Utilisation type	No. of plants	GWh**	%
Electricity	93	4,020	77.0
Heat	62	1,143	21.9
Mechanical	6	40	0.8
Vehicle fuel	4	20	0.4
Flaring	n.a.	n.d.	-

* = Categorized according to the main type of utilisation – a few cases of multiple applications
** = Calculated from the reported or estimated raw biogas production in volume (m^3/y) and an assumption of 64 % CH_4 content.
Source: CIBiogas, 2016 (https://cibiogas.org/biogasmap)

There are 5 upgrading plants in operation in Brazil, 2 use scrubber upgrading techniques and 3 uses PSA. The biomethane produced is utilized to generate electricity and vehicle fuel. (Table 4.3)

There are three private filling stations for compressed biomethane, two in Parana and one in Rio Grande do Sul. There are 110 vehicles utilizing biomethane in Brazil, 70 in Paraná and 40 in Rio Grande do Sul. The biomethane market in the country is still incipient, with some projects in planning or installation, but there is a great prospect of growth.

[6] In the updating of the quantitative data of this report for the year 2016, only the electric power plants and biomethane production were added, with no data available on the growth of the quantity of plants with thermal use.

*Table 4.3: Biogas upgrading plants in Brazil (data from 2017)**

PLACE	SUBSTRATE	UTILISATION	CH4(%)	TECH-NOLOGY	PLANT CAPACITY (Nm3/h Raw gas)	IN OPERATION SINCE
Foz do Iguaçu, Paraná State	Organic residues	Vehicle fuels	96,5%	PSA	10	2017
Marechal Cândido Rondon, Paraná	Swine and dairy cattle wastewater	Electricity	> 96,5 %	Water scrubber	50	2009
Montenegro, Rio Grande do Sul	Codigestion - Laying hens wastewater; dairy, cellulose and citrus juices industry wastewater; and slaughterhouse wastewater	Vehicle fuel	0,97	PSA	500	2012
Santa Helena, Paraná	Codigestion - Laying hens and beef cattle wastewater	Vehicle fuel	> 96,5 %	PSA	42	2013
São Pedro da Aldeia, RJ	Landfill	Heat	97%	Water scrubber	1,200	2016

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. 687/2015 that changes the 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*).
- **Auction A-5 ANEEL on electric energy:** For the first time a large-scale biogas project won an auction on energy generation, Auction A-5 (this means 5 years to start the operation), promoted by ANEEL. The winner project is called Raízen, and trades 20.8 MW energy with the company Biogas

Bonfim, representing BRL 251 per MWh. The substrate used to produce the biogas will be sugar cane industry effluent.

- **RenovaBio**: The Ministry of Mines and Energy (MME) launched in February 2017 a public call for an incentive program to expand biofuels in Brazil. In December 2017, the program was sanctioned through Law 13.576/2017, creating the National Policy on Biofuels (RenovaBio). Biomethane is one of the fuels to be fostered by this program
- **Resolution ANP Nº 685, dated 29 June 2017:** Established rules to approve quality and specifications of biomethane from landfills, sewage treatment stations for mobility use, as well as for residential, industrial and commercial uses.

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, ABiogas 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 (*AssociaçãoBrasileira 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.
- **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".
- **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. In 2016 this project made a publication on various studies compiling technical results obtained during its execution.
- **IV Biogas Forum:** in October 2017 ABiogás organized an event with more than 300 participants registered to discuss the Brazilian biogas sector development. The event was considered the biggest one specifically on biogas in 2017.

4.4 Innovative biogas projects

Stein Ceramics

The model employs a completely mixed digester, a biomass heating system, gas drying and hydrogen sulphide removal by means of biological desulphurisation (Figure 1). Approximately 750 m³ of biogas is produced daily, which is converted into electrical energy in a generator set of 112 kVa (estimated at ca. 64 kWe). The facility has generated an avoided cost of between US$ 4350 to US$ 7250 per month and paid for itself in a 2-year period. The primary benefits were twofold: the environmental service of manure treatment and the economic benefit of revenues from biogas electricity. The size of this unit is similar to many other farms in the South of Brazil – a region, which produces 50% of the swine meat in the country.

A key aspect of biogas project success is that the suppliers of technologies are all from the same region, demonstrating that it is a model of success that has been adapted and deployed throughout a region.

Figure 4.1 Stein Ceramics

Termoverde Caieiras

Termoverde Caieiras, controlled by Solví Valorização Energética, is located at the Environmental Treatment and Valorization Center (CTVA), belonging to Essencis, in the municipality of Caieiras. It is the largest thermoelectric powered with biogas from landfill in Brazil and one of the largest in the world. With initial installed capacity of 29.5 MW, it generates clean energy from the municipal waste deposited in the landfill. The generation of energy from the methane present in the biogas is a sustainable form of valorization of the gases of the landfill, besides generating credits of carbon. It generates 250 thousand MWh energy per year, capable of serving a city of about 300 thousand inhabitants with sustainable electricity. Termoverde Caieiras was built in an area of 15,000 m² and was authorized by the National Electric Energy Agency (Aneel) to start the operation in July 2016. In addition to being an important energy boost for the region, Termoverde Caieiras's positioning has a strong commitment to social and environmental responsibility. Among the benefits of the thermoelectric plant to the environment are: the preservation of vegetation and local fauna; maintenance of existing topography; the non-generation of odors; and the exemption of pollution risks from water sources and the atmosphere.

Figure 4.2 Termoverde Caieiras

5. Denmark

The section on Denmark contains data from 2016 and 2015.

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 biogas deployment in Demark. In March 2012, the Danish Government entered a broad energy policy agreement, valid for the period 2012–2020. The agreement 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 element in the 2012 energy agreement, which is dominated by wind energy.

5.1 Production of biogas

156 biogas plants were in operation in Denmark in 2015, corresponding to 6,4 PJ of energy (see table 5.1 and Figure 5.1 below). The increase is attributed to the breakthrough resulting from the Energy Agreement of 22 March 2012.

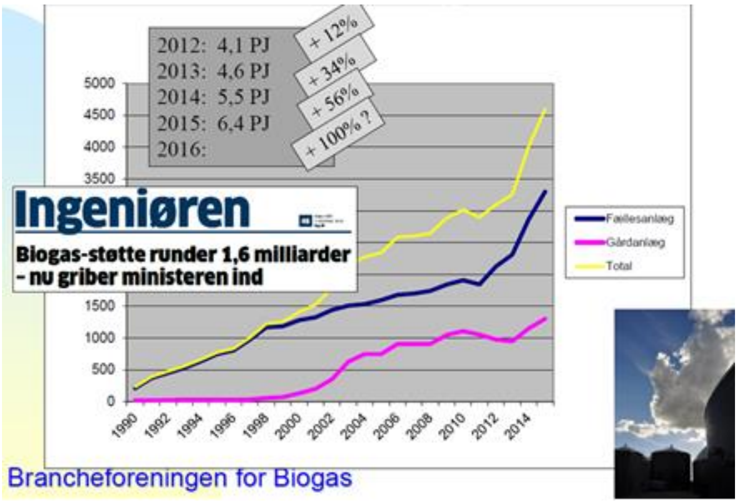

Figure 5.1: Biogas in Denmark 2015[7].

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.

Table 5.1: Current biogas production in Denmark (data from 2015)[8].

Substrate/Plant type	Number of plants	Production (GWh/year)
Sewage sludge	52	281
Biowaste	-	-
Agriculture	71	1367
Industrial	6	67
Landfills	27	48
Total	**156**	**1763***

[7] *Source: Sander, B., Danish Biogas Business Association, 2016*

[8] *Source: Danish Energy Agency/Personal correspondence with Søren Tafdrup, 2017*

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. Co-substrates with high potential are deep litter, straw, source separated 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 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).

Phosphorus limits – more environmentally friendly consumption of phosphorus on the individual farms

It was noticed, that the current harmony rules lead to accumulation of 250 kg P / ha over 25 years. The rules were abolished from August 2017. The new rules give possibility of using a maximum of 170 kg N / ha from Livestock Manure (Nitrate Directive); Exemption for cattle farms with eco-friendly land use (230 kg N / ha from Livestock Manure). The new N-rules will worsen P-accumulation. The need to set up phosphorus limits for the supply of phosphorus by all kind of phosphorus fertilizers (commercial fertilizers, manure and other fertilizer types, such as sewage sludge) occurred. The new phosphorus limits vary between farms, depending on the type of farm, the crop rotation, the soil, the P- reserve on soils, the animal feeding practices etc. This means, that some farms will have higher limits than earlier, others will have lower. The exemption for the cattle farms means, that a specific farm can increase its harmonic demand from the normal 170 kg nitrogen per. hectare to 230 kg nitrogen per hectare, against the fact that the cattle breeder grows its fields more environmentally-friendly under certain strictly prescribed conditions. These conditions mean e.g. a crop rotation with a particularly high nitrogen uptake and a long growing season, for at least 70% of the farm's area. In addition, the farm must meet requirements of plowing down the nitrogen rich crops (leguminous) and of making laboratory tests of nitrogen and phosphorus content of the soil, every 4 years.

Table 5.2: New P-regulation from 2017[9].

	2015	2017		2020		2022		2027	
	Gældende Harmonikrav	Generelt 76 pct.	Skærpet 24 pct.	Generelt 76 pct.	Skærpet 24 pct.	Generelt x pct.	Skærpet y pct.	Generelt w pct.	Skærpet z pct.
Fjerkræ / mink	45-55 / 43	45 43	30	40	30				
Slagtesvin	33,5	40 39	30	35	30				
Søer og smågrise	34 / 37	35	30	35	30				
Kvæg/får/geder	27 (kvæg)	30	30	30	30				
Undtagelsesbrug	36	35	35	35	35				
Organisk affald	30	30	30	30	30				
Overført husdyrgødning = biogasfællesanlæg	(1,4 DE)	Vægtet gennemsnit	30	Vægtet gennemsnit	30				
Gennemsnit	32,3	[36,3]	[30,7]	[34,8]	[30,7]				
Beskyttelses niveau	**31,9**	**35,6 kg P/ha**		**34,3 kg P/ha**		**32 - 33 kg P/ha**		**30-31 kg P/ha**	

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[9] Source: Sander, B., Danish Biogas Business Association, 2016

The main aim of the new P-regulation is to achieve an average decreasing P accumulation in soil (protection level) on long term (see Table 5.2 /*Beskyttelses niveau*):

5.2 Utilisation of biogas

In 2015 biogas was mainly used for power (66%) production. 17% was upgraded, and 16 % was used for heat production in Denmark.

The use of biogas as a transport fuel is growing rapidly, as there are environmental (air quality) and economic (cheaper than imported diesel) incentives. The number of filling stations increased to 16 in 2017 (+ 1 under construction). In 2017 there are 123 city buses, 115 heavy duty vehicles and 223 light vehicles, using CNG as fuel. There is no LNG used for transport in Denmark.

Table 5.3: Utilisation of biogas in Denmark (data from 2015)

Utilisation type	GWh	%
Electricity*	1,150	66
Heat	288	16
Upgraded	308	17
Flaring	<17	< 1

* = including heat losses
Source: Danish Energy Agency/Personal correspondence with Søren Tafdrup, 2017

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.

6. Estonia

The Estonian energy market has historically been highly concentrated and oriented towards one energy source - oil shale. The significance of other sources, including renewable sources, has been low, especially before the EU accession. However, Estonia's entry into the European Union influenced its emphasis on renewable energy and the share of renewable sources has been growing steadily ever since. While Estonia is producing nearly double the target of renewables, use in the transport sector is greatly lagging behind, barely reaching 1% in 2017. The target for 2020 is 10%.

Based on the target for the transport sector, specified in the EU Renewable Energy Directive (2009/28/EC), Estonia will have to ensure that 10% of liquid fuels used in the transport sector come from renewable sources by 2020. Previous measures have not led to any considerable progress towards this target. The target can be met by using an optimal combination of various measures – the obligation to supply biofuels in the market of liquid fuels, promoting the use of biomethane in vehicles, use of biofuels with high renewable energy content in transport, etc. Estonia's transport sector is also affected by the requirement of Directive 2009/30/EC for fuel suppliers to reduce greenhouse gas emissions of supplied fuels or energy at least 6% by 31 December 2020.

Since 2017 Estonian Government launched additional support schemes to stimulate the uptake of renewable energies, especially biomethane, in transport sector.

6.1 Production of biogas

The first biogas plant in Estonia started operating in 1987 in Pärnu based at a local pig farm, however it was closed due to bankruptcy of the pig production facility. Biogas production in Estonia has been considered as an efficient manure management method that produces heat and electricity for local consumption. So far, no biogas purification plants have been built. The first one is expected to start operating in 2019 in Viljandimaa.

In 2017 there were 17 biogas plants in Estonia that can be divided into three types (see Figure 6.1):

a) Based on agricultural waste (5 plants)
b) Based on wastewater and industrial water treatment (7 plants, four and three respectively)
c) Based on landfill gas production (5 plants)

In addition, construction of a biogas plant to purify biogas to biomethane has been started in the centre of Estonia, in Viljandimaa. The expected date for the start of production is in 2019.

Currently the plants produce heat and electricity from the biogas (table 6.1).

Table 6.1. Biogas Production in Estonia in 2017, based on the production type.

	No. of plants	GWh		MW
		heat	electricity	electricity
Wastewater treatment	4		0,8	0,4
Agricultural	5		28,9	6,41
Industrial	3	60		
Landfills	5		13,18	3,75

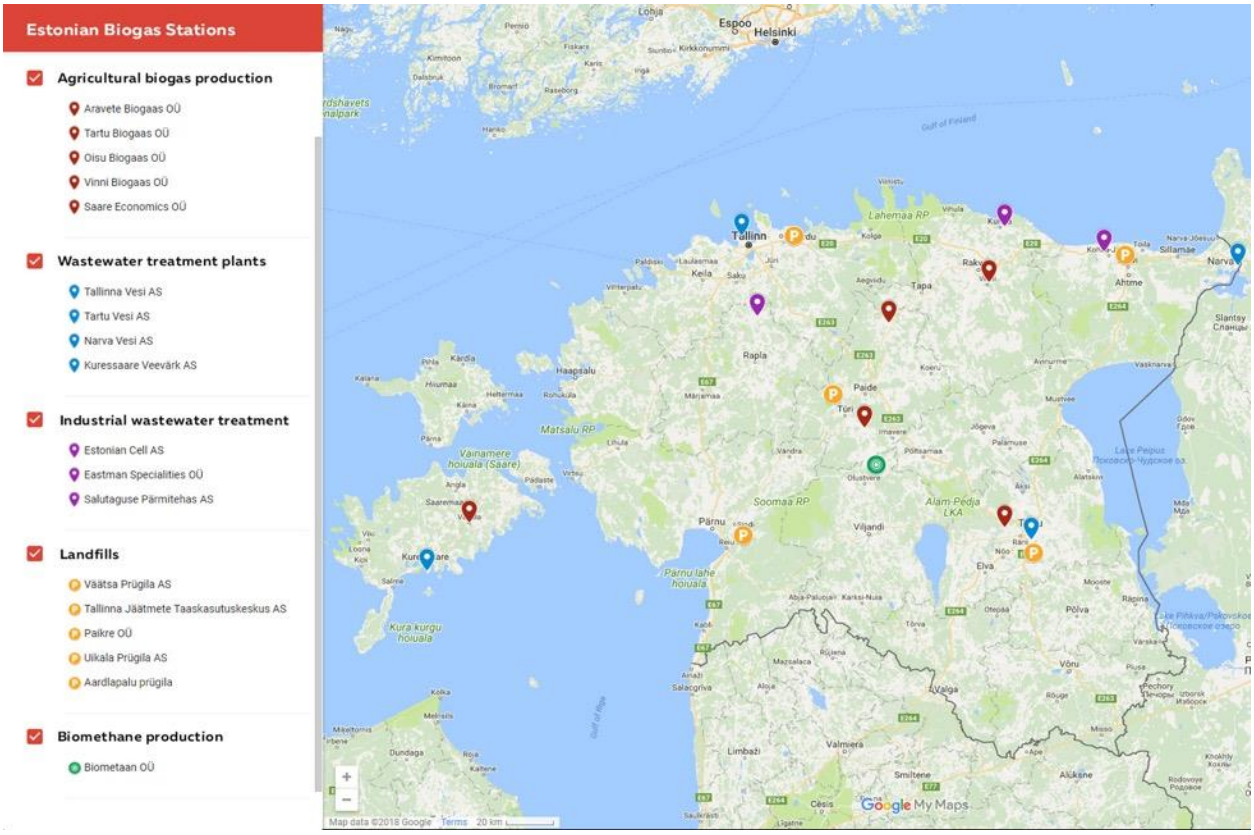

Figure 6.1: Estonian biogas plants in 2017

The biogas potential in Estonia was calculated with the preparation of the National Development Plan of the Energy Sector until 2030 and the accompanying action plans. The biogas potential for Estonia is estimated to be 633 million Nm^3, of which 21 million Nm^3 would be from landfills. This would enable us to produce 380 million Nm^3 of biomethane. The study concluded that biogas has large unused energy potential. In addition to operational heating installations and power plants that produce heat and electricity from biogas, biomethane produced from biogas can be an important resource for increasing the use of renewable energy in the transport sector. Additional utilisation of the biogas resources is currently not required to meet Estonia's overall target for renewable energy by 2020, but there is a need to identify cost-effective options for meeting the renewable energy target of the transport sector. Based on the experiences of neighbouring countries, the Renewable Energy Action Plan until 2020 includes measures for placing biomethane on the market and those measures are listed among the actions for the implementation of the NDPES 2030 measures.

6.2 Utilisation of biogas

Currently, the produced biogas is used on site for heat and electricity production. However, measures have been taken in the past years to increase the use of biomethane in the transport sector.

Estonian private car stock is one of the least energy efficient in the European Union. Motorisation rate in Estonia is ca 500 cars per 1 000 inhabitants and it is steadily growing. Road transport and fuel consumption in transport have increased at the same rate as the economy, which is why Estonia has one of the most transport intensive and fuel intensive economies in Europe – for instance, Estonia uses twice as much transport fuel per unit of GDP than the EU average. This can partly be explained by low population density. The regional final energy consumption of transport sector was 8850 GWh in 2016.

The public transport of larger cities of Tartu and Pärnu is moving towards gas-buses that would use biomethane as a fuel in the future. In addition, the network of natural gas fuel stations is being developed all over Estonia that would be able to also distribute biomethane when the necessary production levels are reached in the upcoming years.

6.3 Financial support systems

Estonia has no feed-in tariffs, but other support systems are used, mainly focused on increasing the use of biomethane as automotive fuel. There are currently two types of support systems:

1. Investment subsidies
   a. Biogas plant construction – The support measure is organised by the Estonian Agricultural Information Board and they support 15-40% of the plant's costs, depending on the specific details. The yearly budget for the measure is 22,5 million euros.
   b. Biomethane production unit development – the measure is managed by Environmental Investment Centre and its yearly budget is 28 million euros. They cover up to 35% of the costs.
   c. Biomethane bus purchase for local governments – the measure is managed by Environmental Investment Centre and its yearly budget is 28 million euros. They cover up to 30% of the costs.
   d. Biomethane station construction – the measure is managed by Environmental Investment Centre and its yearly budget is 2,23 million euros. They cover up to 35% of the costs.

2. Business promotion for selling biomethane
   a. Electricity produced from renewable sources, including biogas. It is managed by the Estonian grid operator Elering AS and was 53€/MWh in 2017.
   b. Sale of biomethane to the transport sector is managed by the Estonian grid operator Elering AS and is calculated as 100€/MWh less last month's natural gas average market price.

7. Finland

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

7.1 Production of biogas

In 2016 the total recovered energy production from biogas was 623 GWh from 86 different biogas production sites. Biogas production has slightly (ca 2 %) increased since 2015. Landfills continued to be the major gas producers, although the amount of collected landfill gas as well as the utilization of landfill gas decreased by 6% compared to 2015.

Table 7.1: Status of biogas production in Finland (data from 2015)

Plant type	Number of plants	Energy production* (GWh/year)
Sewage sludge, municipal	16	152
Biowaste,codigestion	16	219
Agriculture	13	7
Industrial wastewater	3	5
Landfills	40	240
Total	**88**	**623**

* = Produced energy as electricity and heat excluding efficiency losses. [a]Vehicle fuel production 98 GWh should be added to total energy production. Source: Huttunen and Kuittinen, 2017, Suomen biokaasulaitosrekisteri n:o 20, 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 2016, about 24 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.

7.2 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 11 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 decreased 6 % compared to 2015 for the first time since vehicle use started in 2002. On the other hand, vehicle fuel use has increased outside the natural gas grid.

Table 7.2: Utilisation of biogas in Finland (data from 2015)

Utilisation type	GWh	%
Electricity*	143	19
Heat	480	65
Vehicle fuel**	200	
Flaring**	114	16

* = excluding efficiency losses; **capacity, biomethane consumption as transport fuel 21.4GWh, not included in Table 7.1
Source: Huttunen and Kuittinen, 2016, Suomen biokaasulaitosrekisteri n:o 19, University of Eastern Finland

The operational upgrading plants are in most cases using water scrubbing technology, except one using membrane technology, and two 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 50% in 2016. 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 2 public LNG stations were opened in Finland. On energy basis, the price of biomethane is about half that of petrol.

7.3 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.

7.4 Innovative biogas projects

Kalmari biogas plant has been in continuously running since 1998. The plant has been updated during the years and the capacity has been increased. Since 2015 main energy has come from dry fermentation plant (batch process) which uses grass, silage, straw, horse manure and wood chips as biogas raw-material (Figure 7.1).

Figure 7.1. Dry fermentation process at Kalmari farm.

8. France

The vision of the French Environment and Energy Management Agency is to produce 70 TWh biogas annually by 2035 and that approximately 400 biogas plants are to be built every year. 60% of the biogas produced shall be injected into the grid, 40% shall be used to generate electricity and heat within CHP plants. In 2050, the aim is to produce 100 TWh/y.

8.1 Production of biogas

In France, at the end of 2017, there are almost 574 AD plants and 113 landfills, which are producing biogas (see Table 8.1).

Table 8.1: Status of biogas production in France (data from 2017)

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	390	765	627	
Landfills with biogas valorization*	113	953	294	
Total	**687**	**1,833**	**1,694**	**406****

* source ADEME : ITOM, les installations de traitement des ordures ménagères en France – Résultats 2010, octobre 2012; ** Renewable gas French panorama 2017 (*in French*), SER 2018.

8.2 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 utilize biogas). Around 390 on-farms AD plants were built by the end of 2017.

In addition, 88 WWT and 80 agri-food industry AD plants are currently operating. 16 MSW AD plants were always in operation in 2017.

Regarding Table 8.1, 47% of the energy recovered has been transformed into electricity, 43% into heat and close to 10% into biomethane.

At the end of 2017, 47 upgrading plants were in operation, of which 44 inject biomethane into the natural gas grid, producing 406 GWh of green gas. Today, all the biomethane produced is injected into the natural gas grid or sold in the compressed state as automotive fuel. There are 360 applications for injecting biomethane into the natural gas grid, which indicate an increase of the number of upgrading plants in the near future. The governmental plurennial energy programming (PPE) speaks of 8 TWh of biomethane injected into the natural gas grid by 2023.

8.3 Financial support systems

In France and its overseas territories, there is a feed-in-tariff system for electricity and biomethane. New tariffs for electricity have been published at the end of 2016 with some major changes and range from 150 to 225 EUR/MWh:

- Limit to 500 kWel of maximum power to benefit from the purchase price;
- The purchase electricity contract goes from 15 to 20 years;
- The need to study the option of biomethane injection over 300 kW of electric power;

- There is no more energy efficiency bonus;
- The rate is degressive from 2018 (0.5 % per trimester);
- The bonus for manure is increasing by 10 EUR/MWh.

Biomethane feed-in tariffs are following (values of 2018):

- landfills (depending of volume): 47.7 to 100.7 EUR/MWh
- WWTP sludge (depending of the volume injected and the age of the plant): 55.1 to 142 EUR/MWh
- AD plants (depending of volume and the nature of the feedstock): 73.1 to 132.5 EUR/MWh

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 8.1: Collective unit in Mortagne sur Sèvre, west of France, owned by Agribiométhane Ltd. (picture: GRDF). The plant produces biomethane from manure and agri-food wastes. This is first French plant that uses a PSA system to clean the biogas.

Figure 8.2: Collective unit in Vinzier, French Geneva Lake area, owned by Terragr'Eau Co (picture: GRDF). The plant uses various products from agro food biowaste and manure. This is first French plant that uses an amine scrubber to clean the biogas.

9. Germany

In 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) plays a key role in the success of the German energy transition. 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 150 MW_e compared to 2,500 MW_e for onshore wind and solar power. In order to ensure more competition, an auction model was introduced within the EEG 2017.

Furthermore, the clean air guideline (TA LUFT) is about to get amended. Here regulations for open digestate storage and thresholds for methane and formaldehyde emissions from CHP units are the most important changes for biogas plants, which are discussed.

Strategy papers released at the end of 2016 from the Federal Ministry for Economic Affairs and Energy as well as the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety state a clear shift for the biogas sector in regards of substrates and energy utilization beyond the period of the EEG (in particular beyond 2030). Substrates shall be mainly waste materials and by-products; the energy should be used increasingly in the transportation sector. However, until 2030 energy provision from CHP shall even increase slightly. Details for the management of the necessary transition are not given.

9.1 Production of biogas

The biogas production figures are roughly the same as given in the 2015 summary. However, due to the change of the latest EEG regulations (2014 and 2016) as well as the introduced auction model, limitation of growth rate and the contribution of biogas in the energy supply will diminish. The 8,200 biogas (production) plants in the agricultural sector made the biggest contribution to biogas production in 2016 with electricity and heat supplies of 30.5 TWh/year and 14.3 TWh/year, respectively (Table 9.1).

In 2016, a total number of 196 biogas upgrading plants were in operation with a feed-in capacity to the gas grid of 115,400 m^3_{STP}/h biomethane (DBFZ, 2018) with a marginal increase in capacity of 3 % compared to the previous year, delivered by 9 new plants.

Table 9.1: Status of biogas production in Germany (data from 2017, year of reference 2016)

Substrate/Plant type	No. of plants	Energy production [10]* (GWh/year)	
		Gross electricity**	Gross heat[11]
Sewage sludge	1,258[12]	1,440	2,077
Biowaste	335 (135 + 200)[13]	1,248	562
Agriculture	8,200	30,552	14,312
Biomethane	196	2,354	2,648[14]
Landfills	442[15]	358	120
Total	**10,431**	**35,951**	**19,157**

* = Fuel not included; ** = excluding efficiency losses

The calculated total technical biogas potential available for energy provision varies between 155 and 265 $TWh_{Hs}\,a^{-1}$ in line with possible restrictions on usage of cultivated biomass for energy purposes in 2015. Around 30 % of the calculated potential is currently used for biogas generation in Germany. Table 9.2 provides an overview of the total technical potential with respect to the substrates used for biogas production[16].

Table 9.2: Calculated total technical biogas potential in Germany in 2015 (data according to Daniel-Gromke et al. 2017[17])

Substrate	Biogas potential, [$TWh_{Hs}\,a^{-1}$]
energy crops (incl. legumes)	106.9
grassland	69.9
animal excrements	39.7
straw	31.1
municipal residues	13.0
industrial residues	33.0

[10] Federal Ministry for Economic Affairs and Energy (BMWi): Development of Renewable Energy Sources in Germany based on the data of the Working Group of Renewable Energy Statistics (AGEE-Stat), December 2016. (http://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/zeitreihen-zur-entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2015.pdf?__blob=publicationFile&v=11, accessed on 21.01.2017)

[11] Heat utilization (external heat purposes excluding heat demand for biogas production); heat production from biogas and biomethane (without sewage sludge and landfills) in 2016 16.9 TWh_{th} in total (AGEE-Stat 2017); from biomethane-based CHP according to the Federal Network Agency (BNetzA); heat from biogas according to ratio of waste/agricultural plants

[12] Federal Statistical Office (destatis): https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2017/08/PD17_274_433pdf.pdf?__blob=publicationFile , accessed on 13.02.2018)

[13] Substrate input of 135 plants ≥ 90% of biowaste of the whole input amount per year (according to §27a EEG 2012, §45 EEG 2014); biowaste is defined as separate collected municipal waste (e.g. kitchen waste, green waste); about 200 co-fermentation plants with substrate input < 90% of biowaste including plants using agro-industrial residues.

[14] Heat production resp. heat utilization from biomethane-based CHP; electricity production from biomethane according to the Federal Network Agency (BNetzA); estimation of the heat production: electrical efficiency rate of 40%, thermal efficiency rate of 45%.

[15] Data for 2014 according to the Federal Statistical Office (destatis): (https://www.destatis.de/DE/Publikationen/Thematisch/UmweltstatistischeErhebungen/Abfallwirtschaft/Abfallentsorgung2190100157004.pdf?__blob=publicationFile, accessed on 14.02.2018)

[16] Daniel-Gromke, J.; Rensberg, N.; Denysenko, V.; Erdmann, G.; Schmalfuß, T.; Hüttenrauch, J.; Schuhmann, E.; Erler, R.; Beil, M. (2017). Efficient small scale biogas upgrading plants: potential analysis & economic assessment. In: Ek, L.; Ehrnrooth, H.; Scarlat, N.; Grassi, A.; Helm, P. (Hrsg.) *Papers of the 25th European Biomass Conference*: *Setting the course for a bio-based economy*. *Extracted from the Proceedings of the International Conference held in Stockholm, Sweden*. Florence (Italy): ETA-Florence Renewable Energies. ISBN: 978-88-89407-17-2. pp. 1105–1109.

[17] ibid.

9.2 Utilisation of biogas

According to information from the Federal Ministry for Economic Affairs and Energy (BMWi), in 2016 most of the biogas was used for electricity and heat production, while biomethane utilisation as a vehicle fuel dropped by 2% in comparison to 2015 (Table 9.2). The share of energy consumption in Germany for electricity, heat and fuel amounted to 5.6%, 1.6% and 0.1%, respectively.

Table 9.3: Utilisation of biogas in Germany (data from 2017, year of reference 2016)

Utilisation type	GWh/year	%
Electricity*	35,951	60
Heat	19,157	32
Vehicle fuel**	379	1
Flaring***	4,379	7

* = excluding efficiency losses
** = according to the Federal Ministry for Economic Affairs and Energy (BMWi), as to 12/2017
*** = estimation, 5 % flaring losses for all types of production but landfill (10 %)

According to the 4th progress report of the Initiative for natural gas-based mobility[18], the number of filling stations offering biomethane (partly or up to 100%) declined from 293 to 251 in 2015 (data from 05/2016). The amount of biomethane is accounted for 0,46 TWh which corresponds to 20 % of the whole amount of natural gas sold in 2015 as a vehicle fuel.

9.3 Financial support systems

The amendment of the Renewable Energy Sources Act (EEG) 2017, which entered into the force on 1.1.2017, stands for the switch from feed-in tariffs models as applied in the previous EEG versions 2000 – 2014 to the auction models for renewable energies. Beside on- and off-shore wind and PV facilities the newly built biogas plants with an installed electrical capacity of more than 150 kW_e as well as already existing biogas facilities can participate in auctions. In order to be able to participate, the biogas plants to be built should already have the building permission and be registered with the Federal Network Agency (BNetzA). The existing biogas plants can bid in order to receive the follow-up 10-years funding only by compliance with the flexible operation and only in case if they entitled to a maximum of 8 years of further regular tariff payment. To further incentivize a demand-oriented generation of the electricity from biogas, not more than a half of the maximum possible rated power will be remunerated for biogas and biomethane plants. Thus, it is necessary to install at least a twofold CHP overcapacity in relation to the average rated power output. The development corridor initially introduced within the EEG 2014 was further specified and is defined as following for two periods:

- from 2017 till 2019 – 150 MW_{el} of the installed biomass capacities and
- from 2020 till 2022 – 200 MW_{el} of the installed biomass capacities can be auctioned each year.

The first auction for biogas plants took place on 1 September 2017. For biomass there were 122,446 kW_e of the installed electrical capacity tendered. The number of submitted bids accounted for 33 but only 24 with the installed capacity of 27,551 kW_e were accepted (with 2 of them being wood-based CHP-units). Nine submitted bids were excluded from the auction due to formal errors. Thus, in total the bids from 21 biogas plants (most of them being already in operation with substrate input based on the energy crops) and one biomethane-driven CHP-unit were accepted. Biogas plants already in operation received the

[18] German Energy Agency (dena): Sustainable mobility based on natural gas and biomethane. Market development 2015/2016. Fourth progress report, 2016. (http://www.erdgasmobilitaet.info/service-und-aktuelles/downloads.html, accessed on 22.12.2016)

highest bid amount of 16.9 c/kWh, whereas the bid prices for biogas plants to be newly built amounted to 14.83 c/kWh.

For the auction in 2018 the bid prices shall be reduced by 1% compared to 2017. According to § 28 (3a) EEG 2017 the installed capacity of 150 MW_e shall be extended by additional 94 MW_e remaining from 2017. At the same time, the volume to be auctioned shall be further reduced by the amount of the installed electrical capacity, which will be taken into operation in 2018.

The cap for maize input in biogas plants to be built is further specified within the EEG 2017. The utilisation of maize silage and corn (including whole crop silage, corn-cob-mix, grain maize and ground ear maize) is limited to maximum of 50 % for the mass-based substrate input. The maize cap will be lowered in the future and thus will decrease to 47 % in 2019-2020 and to 44 % in 2021-2022[19].

9.4 Innovative biogas projects

For reaching climate protection targets, it is essential to quantify the emissions from greenhouse gas emitting sources. The results enable to determine the environmental impact of a technology and to gain knowledge of the value of emission mitigation strategies. Biogas plants emit methane. Known major sources are leakages, pressure relief vents, gas utilisation devices and open storage tanks. To date, no common European standard is established to measure the overall emission rates of methane from biogas plants. The objective of the project "European harmonisation of methods to quantify methane emissions from biogas plants (MetHarmo)" is to harmonise some first national approaches to quantify the emissions to a common procedure. The project started with a European workshop on methane emissions from biogas plants targeting at an overview on the state of the art. The second step is to perform two common measurement campaigns on a biogas plant with teams from all participating European countries. The evaluation of the results aims the evaluation of differences between the various techniques and further a harmonisation of similar methods or transferability of results between different methods. This shall result in a practical guideline recommending methods and giving assistance for the comparability and weighting of results gained with different techniques.

To efficiently convert biomass and agricultural, industrial and municipal waste into fermentable sugars or chemical building blocks enzymes play an indispensable role. Additional to enzymes out of the microbiological process of anaerobic digestion it requires the availability of enzymes that have proven to be effective in practice and can be produced at an industrial scale. The project DEMETER 'Demonstrating more efficient enzyme production to increase biogas yields' (http://www.demeter-eu-project.eu/) will increase the yield of enzyme product in the fermentation process at the industrial scale as well as the down-stream processing. The entire enzyme production process, including downstream processing, shall be improved in order to increase the yield of industrial-scale production and to demonstrate the economic viability of a *Myceliophthora thermophila C1* based enzyme product. Further, DEMETER aims to reduce the cost of the end product making the enzymes available for wide-spread application in biogas production. Laboratory and practical tests shall improve the enzyme production (the C1 biogas enzyme should increase the degradable fraction of organic material and the degradation rate and reduce the viscosity during anaerobic digestion). Another objective of the project is to quantify the effect of the enzyme on the biogas production in anaerobic digestion processes.

The project "GAZELLE – Integrated Control of Biogas Plants for Flexibilization and Energetic Optimization" carried out by DBFZ aims to combine substrate management, substrate pre-treatment, heat

[19] Federal Ministry for Economic Affairs and Energy (BMWi): Renewable Energy Sources Act EEG 2017 (https://www.bmwi.de/Redaktion/DE/Gesetze/Energie/EEG.html, accessed on 14.02.2018)

and gas management, process monitoring and model predictive control in order to reach a high level of process flexibility and economic efficiency of biogas plants.

To enable demand-oriented provision of energy from biogas plants it is necessary to evaluate and possibly extend the already existing plant equipment. In particular, the reliable prediction of the gas storage filling level plays a crucial role in the gas management for flexible plant operation, as it determines the switching points for conversion units and gas flares. In practice, significant deviations between the displayed value and the actual filling level can be observed. Effects of imprecise measurements can entail overestimations of the actual available storage volume, which then will induce the unintended release of biogas through overpressure valves in case of exceeding the maximum filling level. Against this background, the project ManBio 'Development of technical measures for improving gas management on biogas plants' funded by the Federal Ministry for Economic Affairs and Energy and coordinated by DBFZ is based on a technical analysis of the most common systems and the most important influencing factors for gas storage operation. Based thereon, a measurement system will be modified, the influencing factors will be depicted in a model and a model-based determination of the gas storage level will be conducted. The technical implementation and testing during continuous operation will be realized on the research biogas plant of the DBFZ and further operating biogas plant. In conclusion, recommendations for practical plant operation including ecological and economical assessment will be given. Here, possible emission reduction potentials for existing biogas plants in Germany will be pointed out.

10. Norway

The net consumption of energy in Norway was 213 TWh in 2017. The net use of hydropower was 113.7 TWh, biofuels (mainly wood) was 14,9 TWh and heating from central heating plant was 6.0 TWh. The use of oil and oil products was 64.3 TWh, natural gas was 5.2 TWh while the use of coal was 7.9 TWh.[20] Almost 65 % of the energy consumption in Norway in 2017 was then based on renewable sources, mainly hydropower and wood. The goal set for 2020 is 67.5 %, the highest in Europe.[21]

According to the Parliamentary White Paper No 39 (2008–2009), Climate Challenges –Agriculture part of the Solution, 30% (4–5 million tons/year) of manure is to be used for biogas production together with 600,000 tons of food waste (i.e. approximately 60% of available food waste) by 2020. The main incentive for this goal is to reduce emissions of GHG from agriculture by 500,000 tons of CO_2 equivalent. The Norwegian government presented a national sector-spanning biogas strategy in October 2014. The strategy claims that biogas is an instrument that will contribute to a national reduction of emissions by 2020 and to the objective that Norway shall be a low-emission society by 2050. A considerable technical potential for production and uses 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

The production of biogas is also mentioned as a tool for the reduction of GHG emission in the Norwegian National Strategy for Bioeconomy (2016), the Report to the Parliament No 41 (2016 – 2017) "The Norwegian Strategy for Climate 2030 – Norwegian readjustment in European Cooperation (2017)", the Report to the Parliament about Agriculture No 11 (2016–2017) and the Report to the Parliament No 45 (2016 – 2017) "Waste as resource – waste politics and circular economy".

10.1 Production of biogas

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% from

Figure 10.1
The Norwegian king opens a new biogas plant at Saugbrugs pulp and paper plant at Monday (3. April 2017). The biogas plant will produce about 2.5 mill Nm3 biomethane per year. The biomethane is upgraded and used for transport. The investment cost was about 16 mill EUR.

[20] SSB 20. June 2018: Statistics Norway is the national statistical institute of Norway and the main producer of official statistics.
[21] Bergh, M., Bleskestad, B and Bøeng, A.C. (2014). Høye mål for fornybar energi. Samfunnspeilet 3, 2014, SSB.

landfills, 7% straw, 6% waste water sludge[22]. In addition, there is a potential of several thousand GWh from the fish farming industry, mainly based on sludge from the production.

Table 10.1 shows the biogas production capacity in Norway. Many smaller biogas plants were established 10 – 30 years ago at wastewater treatment plants, mainly to stabilize the produced sludge. The produced biogas was mainly used for heating at the plant, in some cases also for electricity and sometimes just flared off to avoid methane emission. During the last years, the larger sewage treatment plants upgrade the biogas to fuel quality, mainly used for local bus transport.

During the last ten years, food waste from the larger cities is used for biogas production instead of being incinerated or composted (or earlier deposited at landfills). Preferably, the sludge and the food waste are handled separately to obtain better quality of the digestate when it is used as fertilizer. However, for economic reasons, these two waste streams are mixed at some plants.

In Norway, most farms are quite small, and we do have only very few farm biogas plants, actually only 4 in 2017. Some of these are coupled to agricultural schools where the small biogas plants are used for education. One large biogas plant assembles manure from many farms, mix the manure with food waste and upgrade the gas to fuel quality. This plant is described as an innovative project later on in this chapter.

Figure 10.2. TINE SA wants to use biomethane as fuel ("KUKRAFT" – the Norwegian word for "COW POWER"). Tine SA is Norway's largest producer, distributor and exporter of dairy products with 11,400 members (owners) and 9,000 cooperative farms.

Landfilling of organic material was banned in 2009 and thus the biogas from landfills is reduced. The landfill gas is most often flared off, used for production of electricity or heat at nearby biogas plants. There is not any updated statistics available since 2013 and these numbers are omitted from table 10.1.

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[22] The Norwegian Environment Agency, 2013. Report TA3020.

Table 10.1: Status of biogas production in Norway (data from 2013 - 2017)[23]

Substrate/Plant type	Number of plants	Production capasity (GWh/year)
Sewage sludge	24	223
Biowaste (food waste)	5	169
Biowaste and sewage sludge	4	112
Agriculture	5 (1 larger)	67
Industrial	3	167
Total	**39**	**738**

10.2 Utilisation of biogas

In Norway electricity prices are quite low and there is no economic reason 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 larger plants upgrade the biogas to vehicle fuel quality. Statistical data on the utilisation is not complete, see table 10.2

Table 10.2: Utilisation of biogas in Norway (data from 2014 - 2018)*

Utilisation type	GWh	% (ca)
Electricity (and heat)	74	10
Heat	241	33
Vehicle fuel	423	57

* Flaring is excluded from the table

In Norway there are about 35 filling stations for biomethane, most of them in the Stavanger and Oslo region and at both side of Oslofjorden. Some few of these are combinations of CNG/biomethane. There are not any filling stations for biomethane in the northern part of Norway. The market for biomethane use as vehicle fuel is expected to grow, but not so much as expected earlier due to more and more cars using electricity. Today almost 1,700 vehicles, including approximately 800 buses, 740 lorries and delivery and trailer trucks run on gas (SSB, 2018[24]) mainly biomethane in Norway. There are 14 upgrading plants in operation in Norway. Twelve use scrubber upgrading techniques, two uses membrane. Two of these produce LBG while the rest produce CBG.

[23] Numbers are from The Norwegian Environment Agency, 2013. Report TA3020, and updated data as direct information from larger plants (2018).
[24] https://www.ssb.no/statbank/table/11823

10.3 Financial support systems

The two most important incentives for increasing the supply of substrates are the landfill regulation 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.

10.4 Innovative biogas projects

Biokraft Skogn

This new industrial biogas plant uses 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 and was built in 2016 and was ready for production late in 2017/2018. The plant will initially produce 12.5 million Nm^3 of LBG. However, the plant will be prepared for a doubling of capacity up to 25 million Nm^3. The plant's location at Skogn gives logistical advantages, being reachable directly by road, rail and boat. Biokraft AS has a significant R&D initiative supported by the Norwegian Research Council.

Figure 10.3: Biokraft Skogn, new biogas plant with LBG production

The Magic Factory – Greve Biogass

The Magic Factory - close to Tønsberg in the south-east part of Norway recycles food waste and manure into biogas, green CO_2 and valuable biofertilizer for food production. The food waste comes from households and the manure comes from farms in Vestfold County. Currently some 110,000 tonnes of food waste and manure are recycled annually at the plant. The produced biogas is upgraded and fed into a gas grid and primarily used as vehicle fuel replacing about 5 million litres of diesel. The close collaboration with agriculture has contributed to the plant receiving status as a National Pilot Plant. Agriculture in Vestfold County (2157 km^2 and about 250 000 inhabitants) reached the government's goal of 30% of all manure being digested to produce biogas before 2020 already by 2016. Carbon capture takes place through renewable and green CO_2 from the factory being used inside industrially-adapted greenhouses for food production, together with bio-fertiliser from the factory. A Magic Pilot Greenhouse is under construction, with a plan for rolling out industrial greenhouses for local food production. Work is also under way on a knowledge and visitor centre next to The Magic Factory.

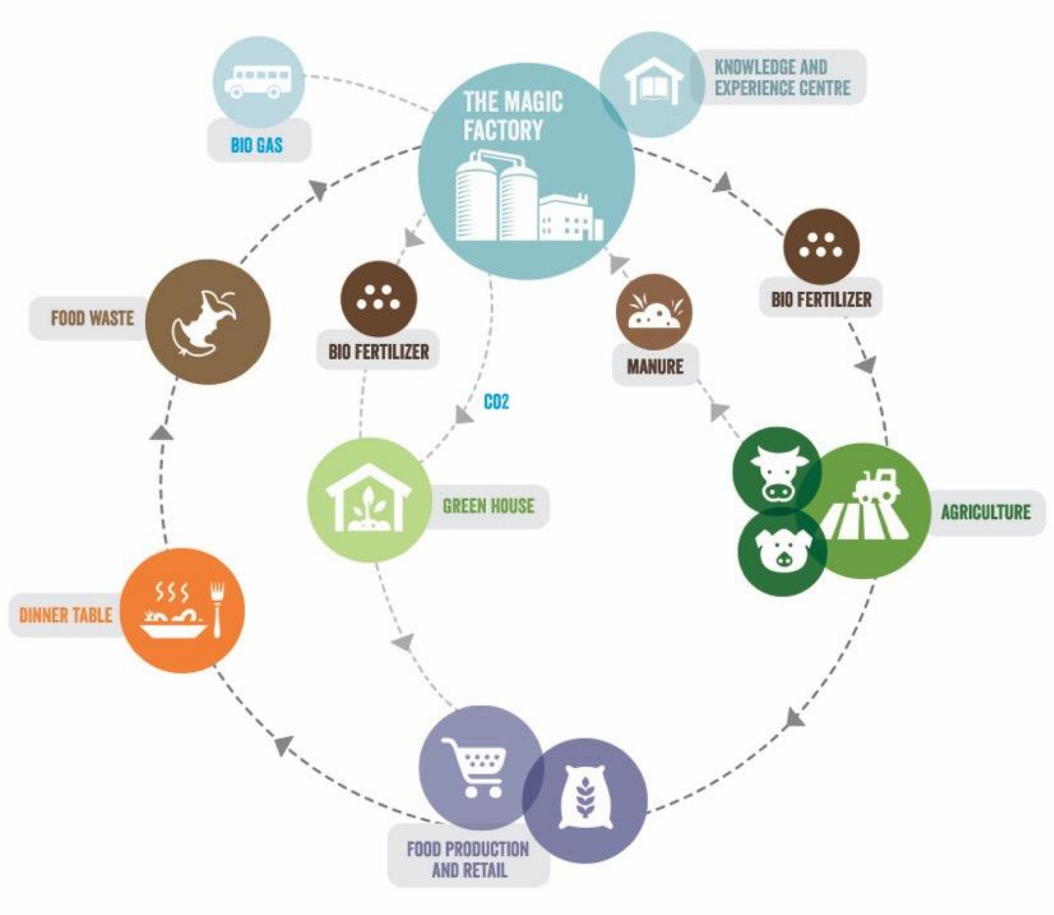

Figure 10.4. The circularity of the biogas plant – "The Magic Factory"

11. Republic of Ireland

The biogas industry has yet to take off in the Republic of Ireland. There are a number of reasons for this, including the only very recent introduction of the support scheme for renewable heat. Scale challenges and dispersed resource are a big factor for biogas development in rural Ireland. Improving the evidence base for sustainability and lowering the cost of grass production will be a key building block for any large AD based industry. A recent report published by the Irish Energy Agency (Sustainable Energy Authority of Ireland (SEAI)) identifies a number of barriers to the development of the industry in Ireland outside of cost competitiveness. The results were based on a survey of the supply chain in Ireland. Limitations in the available feedstock resource, unavailability of local heat loads for biogas-CHP systems, increased capital and operating costs, and increased patristic heat demand due to need for pasteurisation of slurry imports and investment risk are some of the barriers mentioned.

11.1 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. The main use of biogas produced in waste water treatment plants is the production of heat and electricity in onsite CHP units, and the thermal drying of dewatered digestate to produce a high grade biofertiliser. There are approximately 8 landfill gas projects and 19 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. The IRBEA, Renewable Gas Forum Ireland (RGFI), and Cre (Composting and Anaerobic Digestion Association of Ireland) provided the data on landfill, wastewater facilities and biogas plants in Table 11.1.

Table 11.1: Biogas production in the Republic of Ireland (data from 2018)

Plant type	Number of plants	Installed capacity
Sewage sludge	15	n.d.
Biowaste		n.d.
Agriculture	11	4.05 MW_e + 1MW_{CHP}
Industrial	4	n.d.
Landfills	8	29 MW_e
Total	**38**	

Source: RGFI, Cre and IrBEA, according to latest available data; n.d. no data

An SEAI report published in 2017 looked at the economic potential for further development of biogas and biomethane in Ireland. The report was overseen by a steering group, comprised of representatives from a range of relevant Government Departments, regulatory bodies and academic experts, and managed by SEAI. Stakeholder consultation, including a stakeholder workshop in September 2016 in Dublin, was an important component of the study. The report shows that the development of a sector focused on the use of food waste and animal manure can deliver societal benefits and increase biomethane and biogas production to a scale of approximately 12 PJ by 2050. Maximising the use of grass silage delivers a net benefit under favourable conditions. These include higher fossil fuel and carbon prices as well as lower silage production costs. Under these conditions the equivalent of 28% (~34 PJ) of Irelands current gas demand could come from biogas and biomethane by 2050. Grass silage is a resource with very large potential in Ireland but cultivation and supply chain emissions, as well as cost, may limit the accessible resource. Further work is underway to determine the greenhouse gas impact of grass silage production for biogas in Ireland. Gasification with methanation for the production of green gas for gas grid injection needs to achieve significant cost reductions to deliver a net societal benefit but the study finds that power to gas has the potential to increase renewable gas production substantially.

Existing 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) in theory allows for payment of three certificates to producers of gaseous biofuel with an energy value in excess of 35 MJ/Nm^3 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. However, at this stage there are no vehicles operating on biomethane and earning certificates in the Republic of Ireland.

A decision paper by the Commission for Energy Regulation (CER) in Ireland has granted Gas Networks Ireland (GNI), the operator of the Irish gas network, funding of €12.8m to install 13 CNG service stations in Ireland to reduce emissions from transport and facilitate gas grid injection of biomethane. A total network of 70 Compressed Natural Gas (CNG) filling stations, distributed on sites around the country, has been proposed by GNI. As many as 20,000 HGVs and 12,000 buses are being targeted to switch. Each station would be developed at a cost of around €1m each. Six CNG service stations were due to be built by the end of 2017. 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 in the grid with green gas by 2020, rising to 20% by 2030. This reflects interest from large users of natural gas in sourcing green gas to be used as a source of renewable heat and as a renewable transport fuel.

A Bord Gais report on the future of renewable gas in Ireland suggests that a realistic biogas industry could be based on 5% of cattle, pig and sheep slurry, 75% of poultry slurry, 50% of slaughter waste, 25% of food waste and 100,000 ha of grass land (2.2% of agricultural land). The report suggests that biogas should be upgraded to biomethane and gas grid injected. This would require approximately 180 rural digesters, 4 slaughter waste digesters and 4 municipal digesters; all at a scale of 50,000 tonnes/year of substrate. The investment cost was estimated at ca. €1,400 million. 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). However, at present there is one biogas upgrading plant with a gas grid injection point in Ireland, which is due to commence injection of biomethane into the grid in 2018. This will be effected through a virtual pipe system. The upgraded biomethane will be transported by truck from the biogas facility to an above ground installation where it will be injectd to the transmission gas grid.

SEAI commissioned a detailed study on biogas and biomethane in Ireland in 2017 (*Assessment of cost and benefits of biogas and biometane in Ireland* available in: https://www.seai.ie/resources/publications/). They examined a number of scenarios ranging from: waste-based AD (sewage sludge, food waste, slurries) increased biomethane (including for grass silage) and all AD feedstocks (with significantly more grass silage). All AD feedstocks would produce approximately 26% of natural gas and require 900 AD facilities with scale of 100kWe to 500 kWe for farm-based CHP systems to 3000 kWe for waste based CHP systems and 6000 kWe for waste based biomethane systems.

11.2 Financial support systems

Support to biogas in the Republic of Ireland includes for REFIT, a support scheme for renewable heat, and landfill taxes.

The existing REFIT3 scheme offered tariffs in 2018 as below:

- AD CHP equal to or less than 500 kW: 158.244 €/MWh_e

- AD CHP greater than 500 kW: 13.144€/MWh$_e$
- AD (non CHP) equal to or less than 500 kW: 116.045 €/MWh$_e$
- AD (non CHP) greater than 500 kW: 105.494 €/MWh$_e$

In late 2017 a Support Scheme for Renewable Heat for Ireland was announced. The Scheme Overview initially targets biomass and anaerobic digestion heating systems for non-domestic users. An ongoing operational support, for up to 15 years, will be applied to new installations or installations that currently use a fossil fuel heating system and convert to using anaerobic digestion heating systems. The first 1000MWh pa will be paid at 2.95c/kWh of energy produced from anaerobic digestion heating systems. From 1000 to 2400MWh pa will be paid at 0.5c/kWh, with any additional output not receiving a tariff, attempting to reflect the economy of scale associated with these systems. Under this phase of the scheme, the production of biomethane from anaerobic digestion and its injection into the natural gas grid will not be covered however; future iterations of the scheme are set to support such configurations. Final details of the scheme are yet to be announced.

A landfill levy of €75 /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. As of July 2015, this was required for populations of 500 persons. These regulations provide an incentive to digest the organic fraction of municipal solid waste.

Figure 11.1: 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))

11.3 Innovative biogas projects

SEAI Research Development and Demonstration fund (RD&D)

The RD&D Funding Programme invests in innovative energy Research, Development and Demonstration (RD&D) projects, which contribute to Ireland's transition to a clean and secure energy future. It focuses on technologies at higher levels of readiness and on other policy and market relevant research. Approximately 20% of SEAI RD&D funding over the last 10 years has been invested in the bioenergy/biofuels area. In 2017 alone SEAI funded several projects in the area of biogas and biomethane including:

- Development of policy and community-based business model underpinning distributed energy recovery from residual biomass involving multiple stakeholder types;
- ReBioGen - Development of policy and community-based business model underpinning distributed energy recovery from residual biomass involving multiple stakeholder types;

- Distribution System Optimisation & Mobile Pilot demonstration of Low temperature AD Technology;
- SLURRES – a low cost technology and business model to mobilise livestock slurries for community based Anaerobic Digestion (AD);
- Development of a Syngas Conditioning System To Enable Use of Pyrolysis for Energy Recovery from Biomass Wastes and Residue (PYROPOWER);
- Micro scale Anaerobic Digester for digesting cooked and uncooked food waste from households and small food businesses;
- Enabling the Bioenergy Sector to Understand and Assess Life Cycle Sustainability
- Planning Guidance Recommendations for the Bio Energy sector in Ireland.

In 2018 the funding scale of the RD&D programmme has increased and SEAI have partnered with 5 co-funding agencies. The 2018 Funding Programme provides the opportunity for applicants to submit proposals to either a thematic strand or open strand. The Open Strand provides an opportunity for applicants to propose projects within SEAI's legal remit which directly address the aims and objectives of the SEAI RD&D Funding Programme Call. A number of the themes focus on biogas including a theme calling for demonstration of small scale generation and aggregation of biogas suitable for grid injection

Science Foundation Ireland (SFI) MaREI centre for Marine and Renewable Energy

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 and renewable energy. The centre has cumulative funding of ca. €55M and includes for 6 Universities and 48 industrial partners. MaREI includes for a number of research themes including for Bioenergy. The objectives of the bioenergy research include:

- Assessment of the financially feasible green gas resource in Ireland including for biogas production from organic residues and from grass;
- Evaluation of the biomethane potential from various types of seaweed harvested at different times of year;
- Interrogation of the optimum methods of generating biomethane from seaweed including co-digestion with suitable substrates;
- Examination of 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;

In 2017 a new spoke "Sustainable Energy and Fuel Efficiency" (SEFE) was added to MaREI. This includes for eight additional industry partners, €1m in industry contributions and adds €2,176,614 in direct funding from SFI. The academic partners added include for Profs Henry Curran, Vincent O' Flaherty and Xinmin Zhan from NUIG and Prof JJ Leahy in UL. The expertise in bioenergy is broadened including for world class expertise across several technologies and disciplines.

The Causeway Project

The €25 million Causeway project won by Gas Networks Ireland (GNI) began construction of its first CNG filling station and its first biomethane grid injection plant. The demonstration work will be supplemented by academic input from Dr Rory Monaghan from the MaREI team in NUIG and Prof Murphy in UCC. This is an excellent example of commercialisation of innovative technologies and collaboration between industry and partner Universities.

Certification of Renewable Gas
The International Energy Research Centre (IERC) together with Deutsches Biomasseforschungszentrum (DBFZ), Deutsche Energie-Agentur GmbH (dena) - German Energy Agency and the MaREI Centre are in the process of finalising a report on Certification of Renewable Gas in Ireland.

GENCOMM
Dr Rory Monaghan (MaREI, NUIG) was a team leader that won EU InterReg NWE funding for the €9.34 million **GENCOMM** project that will demonstrate the use of hydrogen storage as a solution to renewable energy curtailment, and a means to integrate power, heat, transport and chemical sectors through hydrogen.

DIET
Dr Richen Lin (MaREI, UCC) won a Marie Skłodowska-Curie Individual Fellowship on the topic "**Direct Interspecies Electron Transfer** in advanced anaerobic digestion system for gaseous transport biofuel production". This is a €180k project from 2018 to 2020.

The Animal & Grassland Research and Innovation Centre Teagasc
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. Teagasc now operate a 0.15MW_e anaerobic digester at their facility in Grange, Co. Meath.

12. 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). More recently renewable energy accounted for 4.81% (14.2MTOE, million tons of oil equivalent = 165TWh) in 2016 of which 2.8 MTOE was bioenergy (3.4% from biogas plants and 2.6% from landfill gas). Landfill gas utilization has dominated biogas production over the last decade while biogas plants have started to make a significant contribution ever since 2010. The "Bioenergy Strategy 2030" targets bioenergy production to increase by a factor of more than 4.

12.1 Production of biogas

A total of 110 biogas plants are now in operation and produce almost 2,798 GWh equivalent per year of biogas. Landfill gas (LFG) contributes 26 % (827GWh/yr), biogas from sewage sludge 44.1%, and biowaste 25.3%. Biowaste mainly consists of food waste, food waste leachate, and digestible co-substrates. Table 12.1 shows Korean biogas production from different types of plants.

Table 12.1: Status of biogas production in Korea (data from 2016)

Substrate/Plant type	Number of plants	Production* (GWh/year)
Sewage sludge	49	1,234
Biowaste (co-digestion)	32	709
Agriculture	8	28
Industrial	-	-
Landfills	21	827
Total	**110**	**2,798**

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

Electricity generation from biogas plants amounted to only 139 GWh in 2016. There are 15 new biogas plants under construction to treat 4,764 tons of food waste and food waste leachate daily to produce 454 GWh biogas by 2017. The electricity generated from LFG reached 239 GWh in 2016. The electricity production is expected to increase to 1,937 GWh in 2020.

12.2 Utilisation of biogas

About 42% (1,172 GWh) of the biogas is utilized for electricity production. The main part (26.3%, 736GWh) 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 (14.8%). The utilisation of biogas as vehicle fuel was only4.2% of the total biogas production. The utilisation of biogas in Korea is summarized in Table 12.2.

The number of buses using CNG as a vehicle fuel reached 39,528 and the number of gas filling stations reached 201, including 6 biomethane filling stations. However, these biomethane filling stations only supply 0.2% of the total number of buses.

Table 12.2: Utilisation of biogas in Korea (data from 2016)

Utilisation type	GWh	%
Electricity*	1,172	41.9
Heat	736	26.3
Vehicle fuel	118	4.2
Flaring	413	14.8
Biogas sale	359	12.8
Total	2,798	100

* = including efficiency losses.

Biogas upgrading is carried out by water scrubbing, PSA and membrane at 5 wastewater treatment plants and 5 food waste leachate plants. One other food waste AD plant of biogas upgrading is now under construction. The biomethane is used mainly in city buses and municipal vehicles and grid injection. The standard for vehicle fuel and grid injection is similar to Swedish standards.

12.3 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 REC price has been around KRW 167,272/MWh (126 EUR/MWh) in December 2016.

12.4 Innovative biogas projects

Animal Manure to Biogas Project

- The Ministry of Agriculture, Food, and Rural Affairs has financially supported enterprisers with 70% of the total construction cost of AD plants treating 70-100 m^3 of manure per day.
- 6 AD plants are now under construction and 6 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 m^3. Research on biogas upgrading, system development for odour control, O/M manual development for the AD plant and application of digestate.

Figure 12.1: Nonsan Biogas Power Plant that is producing 2.55GWh electricity (1,782,000Nm^3 biogas) annually. Source: Kyeryong-Nonsan Livestock Farming Cooperatives, Chungnam, Korea

13. Sweden

In Sweden only 3 % of the total energy supply of 580 TWh is energy gases, which is rather low compared to many other countries in EU (Figure 13.1). Of the total energy use (388 TWh) 5 % is energy gases, mainly used in industry.

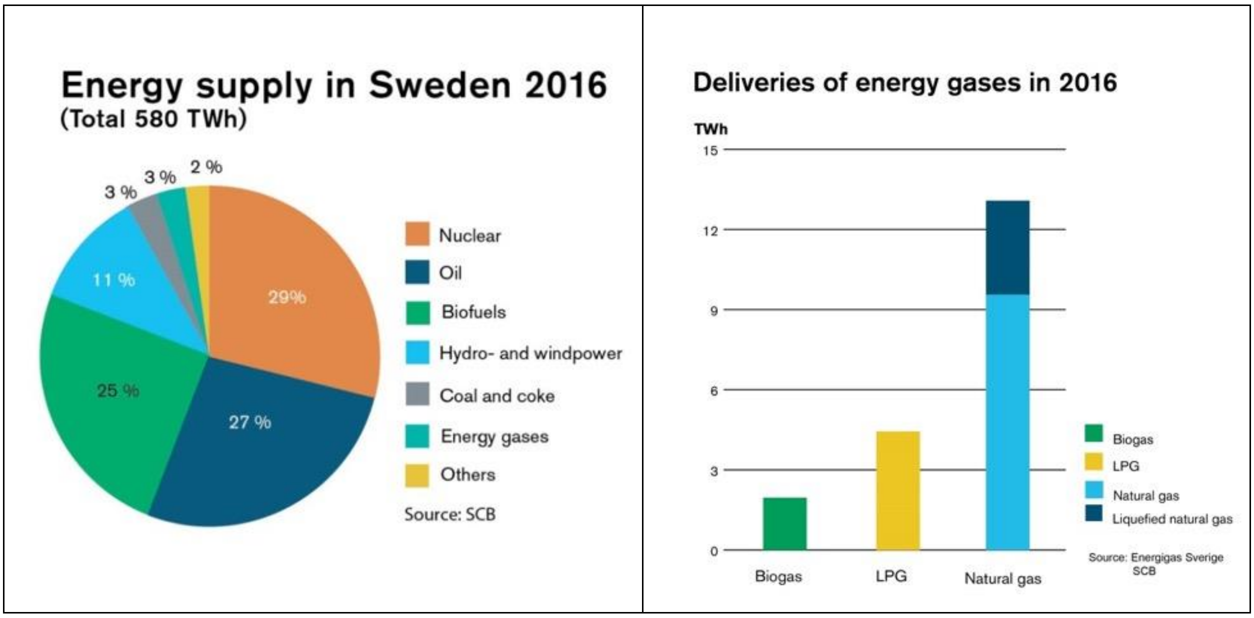

Figure 13.1: Total energy supply and deliveries of energy gases in Sweden 2016. Source: SCB and Swedish Gas Association.

The use of energy gases is about 19.5 TWh of which more than 90 % fossil gases (17.5 TWh natural gas, LPG and LNG) and about 10 % biogas/biomethane (2 TWh). Biogas and LNG use has increased, and natural gas use has decreased over the last 10 years. Most of the biogas is upgraded and used in the transport sector
Figure 13.2).

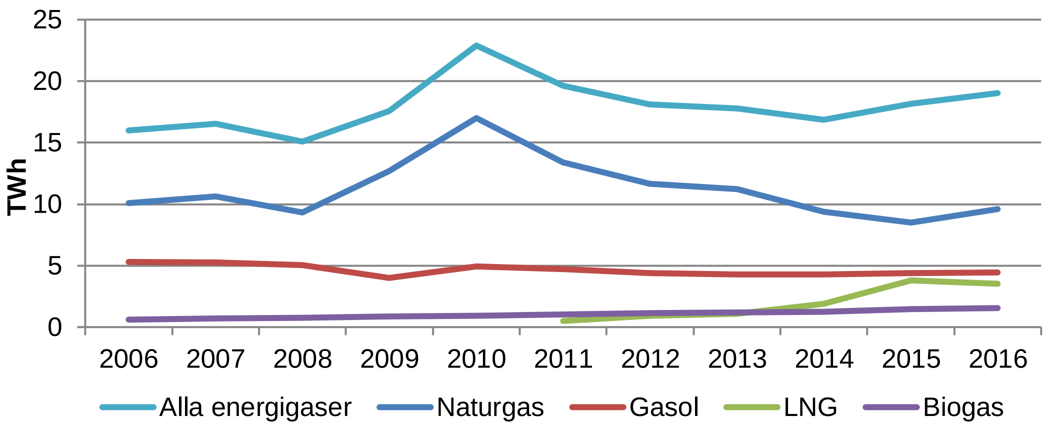

Figure 13.2: Use of energy gases in Sweden 2006-2016 (TWh). Gasol = LPG. Source: Swedish Gas Association.

The share of renewable energy in transport was 19 % of a total of 89 TWh in 2016. The recent years´ large increase of biofuel use is mainly due to a rapid increase of HVO at the Swedish market since 2011. The total share of methane in transportation (CNG/CBG) is about 1.6 TWh or 1.8 %. The average biomethane share in the methane mixture was more than 75 % in 2016, which have increased to more than 80 % during 2017.[25]

13.1 Production of biogas

There are 279 biogas plants producing in total 2 018 GWh of biogas. Most of the biogas is produced from different types of biowaste and residues in co-digestion plants (47 %) and from sewage sludge in 139 wastewater treatment plants (35 %) as shown in Figure 13.3.

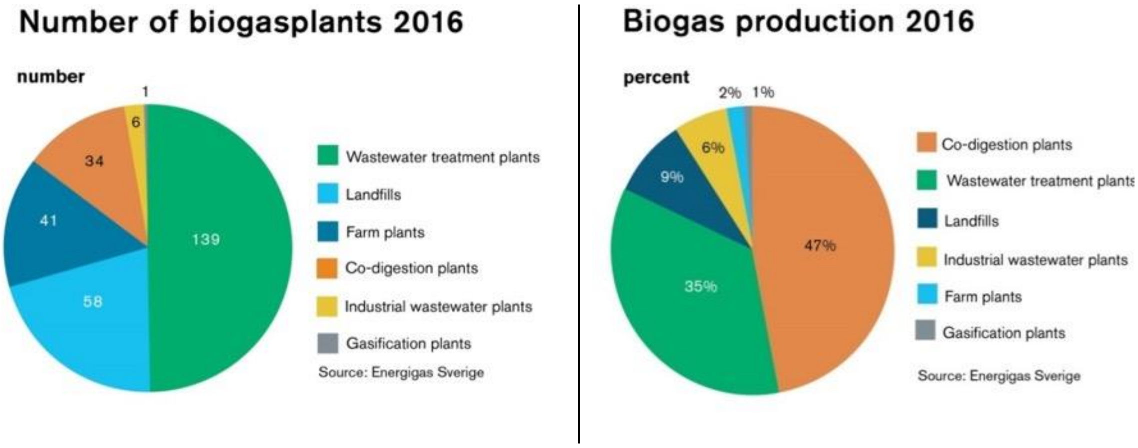

Figure 13.3: Biogas plants and distribution of biogas production in Sweden 2016. Source: Swedish Gas Association.

The use of biogas for transportation has increased rapidly over the last 10 years, whereas the use for heating has decreased. In 2016 64 % of the produced biogas was upgraded and mainly used as transportation fuel (Figure 13.4).

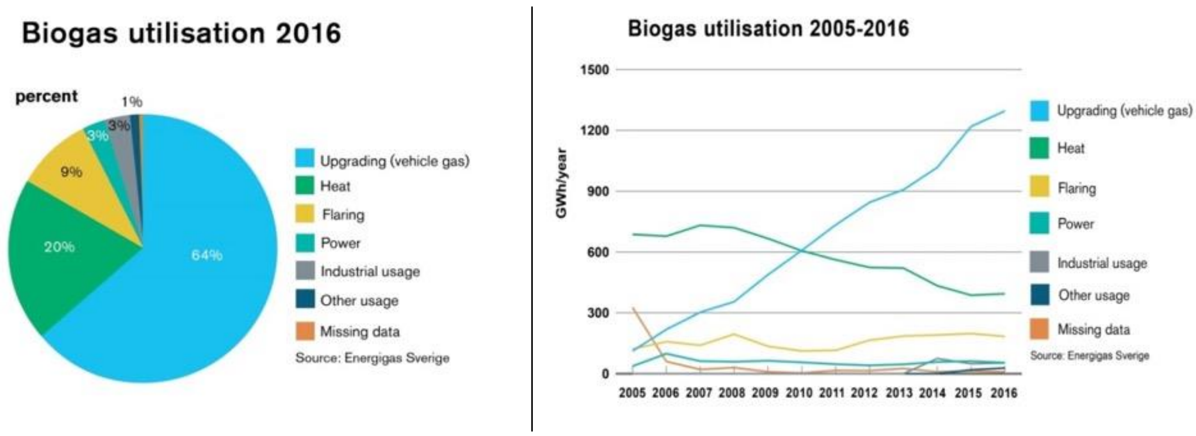

Figure 13.4: Use of produced biogas in Sweden 2016. Source: Swedish Gas Association.

There are 62 biomethane upgrading plants producing more than 1.2 TWh biomethane 2016. About 0.5 TWh of this is injected to the south-western gas network and in the Stockholm gas grid, the rest is used locally or trucked to fuelling stations. There are in total 13 injection sites. There is also one LBG plant producing 44 GWh LBG 2016.

[25] Source: Energimyndigheten, 2017. *Transportsektorns energianvändning 2016*.

Biomethane potential until 2030

The most recent biomass potential estimates for Sweden shows that the biomass production with the current conditions could be increased by 40-50 TWh per year[26]. This potential takes into consideration technical, ecological and economic restrictions, and also only includes waste, residues and biomass that do not directly compete with other agricultural or forest production. The available biomass corresponds to a domestic biofuel production of 22-32 TWh (if mainly biomethane in the higher range), in addition to electricity, heat and other co-products). This corresponds to about 1/3 of the current use of fossil fuels in road transport in Sweden.

When considering economic potential, a WSP study[27] from 2013 on the biomethane potential (estimating both digestion and gasification, including energy crops and forest residues) show that when keeping current policies and implementing currently discussed ones, the realizable potential is 9-12 TWh until 2030 (Figure 13.5). With improved policies, the potential increases to 11-22 TWh. With poor policies and bad economy, e.g. by introducing energy taxation on biomethane and only slow increase in oil price, the potential is not higher than the current production level (1.2-2.5 TWh).

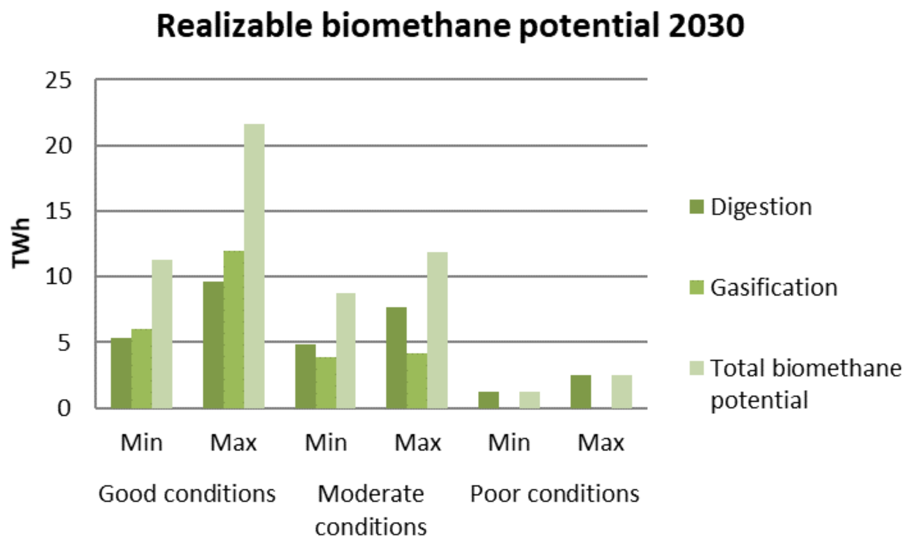

Figure 13.5: Biomethane potential 2030 in Sweden for three different scenarios depending on economic conditions such as policies and oil price. Source: Dahlgren, 2013, Realiserbar biogaspotential I Sverige 2030 genom rötning och förgasning.

Another (but still valid) study from 2008 showed a technical biomethane potential of 15 TWh from anaerobic digestion of available domestic waste and residues[28], and about 10 TWh with restrictions. If including thermal gasification of forestry residues, the total biomethane potential is 74 TWh. Note that energy crops are not included in this potential, but may of course be significant, since there exists plenty of fallow or underused agricultural land in Sweden. So far, the use of energy crops for biomethane production is very limited due to economic constraints.

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[26] Börjesson et al, 2016.
[27] Dahlgren, 2013 *Realiserbar biogaspotential I Sverige 2030 genom rötning och förgasning*.
[28] *Den svenska biogaspotentialen från inhemska råvaror*. Avfall Sverige, Rapport 2008:02.

13.2 Utilisation of biogas

The Swedish biomethane market is to a large extent off-grid with small local or regional grids or stand-alone biogas gas plants and fuelling stations. A large part of the biomethane in Sweden is today transported on the road as compressed gas (200/260 bars) and to a small but increasing extent as liquefied gas (LBG). Local and regional gas grids gain more attention (for biomethane AND raw biogas) aimed to connect industries, cities and biomethane production plants with a LNG-terminal at the coast. The gas pipeline infrastructure is limited to the south-western part of Sweden where the transmission network is connected to European gas network via exit Dragör (connection with Denmark). There is also regional gas network in Stockholm, fuelled with locally injected biogas or shipped LNG. See Figure 13.6.

Figure 13.6: Gas pipeline infrastructure is limited to south-western Sweden and small local gas grids. There are two existing LNG import terminals and a couple of more planned. There is also one LBG plant.

Most of the biogas (64 %) is upgraded and used for road transport due to favourable support system. The market for methane as transportation fuel is now rather developed in Sweden but is highly dependent on increased policy incentives and long-term support systems to take the next step. The use of methane increased rapidly up to 2014 to have stabilized at around 1.6 TWh the last years (Figure 13.7). The biomethane share has however continued to increase and is so far under 2017 more than 80 %.

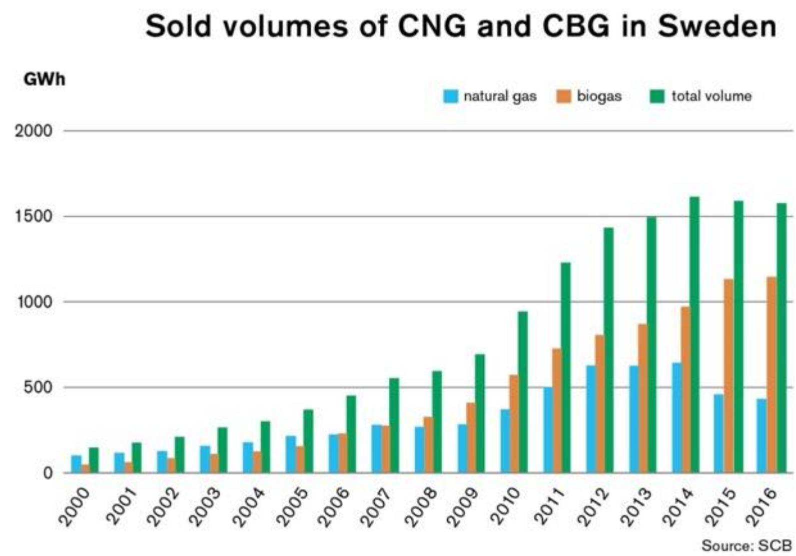

Figure 13.7: Sold volumes of CNG and CBG in Sweden 2000-2016 (GWh).

The number of gas filling stations has increased from less than 20 in year 2000 to about 170 stations end of 2016, plus 60 non-public stations. The number of gas vehicles has during the same period increased from just a few hundred to in total 54,439 by the end of 2016; 2,331 of these were buses (about 15 % of all buses) and 821 trucks (incl. approx. 50 LNG trucks) and the rest passenger cars and other light vehicles (Figure 13.8).

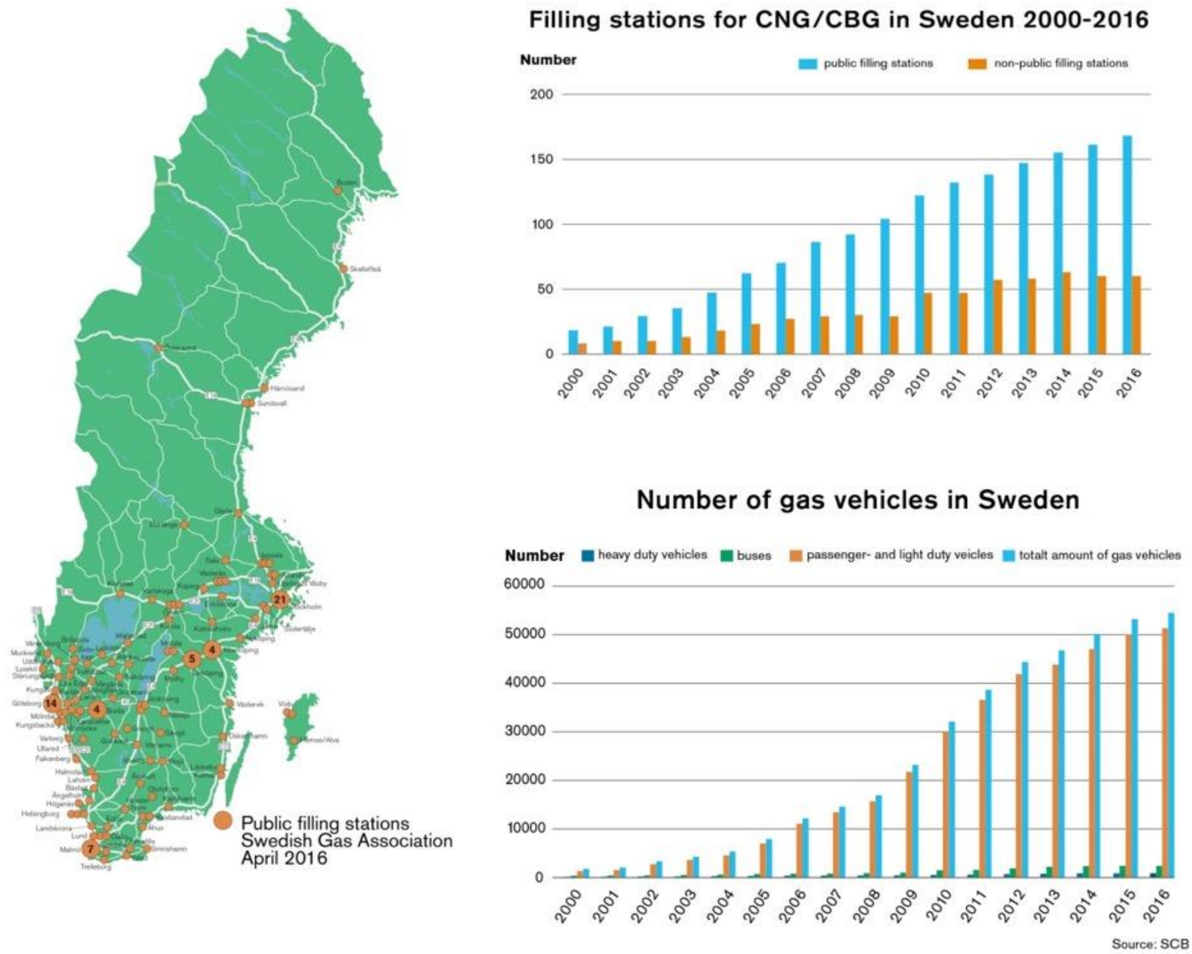

Figure 13.8: Number of CNG/CBG filling stations and gas vehicles in Sweden 2000-2016. Source: SCB and Swedish Gas Association.

Increased biomethane import presses Swedish producers but open up for increased biomethane market

As mentioned above most of the biogas in Sweden is upgraded and used for transport. The interest and use in industry have however increased over the last few years and is expected to increase. The last year´s increasing imports of biomethane, i.e. subsidised biomethane mainly from Denmark, has put downward pressure on the biomethane price and thus made it more competitive with natural gas in sectors where tax exemption is not effective, such as industry.

At the same time, as long contracts are renegotiated, or new customers are to be contracted the Swedish biomethane producers and suppliers now are facing a margin pricing that often does not cover the production costs. The situation is due to different support regimes in Sweden compared to other countries – in Sweden incentives are focused on the use of biomethane (of which the most important is the tax exemption) but often focused on production or injection in other member states. This means that imported biomethane can be double subsidised. In 2016 imports from Denmark totalled 0.155 TWh; this is expected to have increased in 2017.

13.3 Financial support systems

Ambitious energy and climate goals push for increased renewable energy, especially in transport. The government 2020 goals for renewables are already reached: 50 % of the total energy utilisation and 10 % goal in transports.

More important are the very ambitious long-term climate and energy goals that were adopted by parliament in 2017:

- Climate neutral energy sector by 2045 with at least 85 % GHG emission reduction in Sweden. From 2045 negative emissions.
- 100 % renewable electricity production 2040 (agreement between 5 of 8 parties in parliament)
- 63 % GHG emission reduction in non-EU ETS sector in 2030 and 75 % by 2040 compared to 1990
- 70 % GHG emission reduction in domestic transport (excl. aviation) by 2030 compared to 2010
- There is also a vision to have a fossil free transportation sector by 2050.

There is still no overall government strategy for meeting these goals, but a number of important steps and policies have been implemented or are being investigated in addition to the existing high CO_2 tax on fossil fuels and the green electricity certificate system as main drivers.

The Swedish Gas Association has a vision of "Green gas 2050" which includes the following goals:

- 50 TWh renewable gas production by 2050 and 100 % renewable gas in the national grid
- Climate neutral industry with gas
- Fossil-free land transportation with gas by 2030
- Cleaner shipping with gas
- Fossil-free heat and electricity with gas

The Swedish biogas industry has also formulated a proposal for a National Biogas Strategy with a specific target of 15 TWh biomethane/biogas use in 2030, of which 12 TWh to be used in the transport sector and 3 TWh in industry. Most of this biomethane should be produced in Sweden. The biogas strategy will be updated in 2018, with the aim that the government will implement a National Biogas Strategy.

Existing and coming drivers and support systems for biomethane market

The support system in Sweden is mainly focused on increasing the usage of biomethane as vehicle fuel. High CO_2 and energy tax on fossil energy and tax exemption for renewables has been the main driver so far together with local and regional investments for biomethane within public transport accompanied with previous investment support programmes (LIP/KLIMP).

Existing policies:

- CO_2 and energy tax exemption for biomethane as transportation fuel until the end of 2020. Corresponding taxes for petrol of about 0.72 SEK/kWh (~68 €/MWh) and 2.4 SEK/Nm^3 (~21 €/MWh).
- No CO_2 or energy tax on biogas for heating (including industry use) until end of 2018 – will be extended until end of 2020 (a proposal has been sent to the EC spring 2018 for notification). Corresponding tax on natural gas is 3.4 SEK/Nm^2 (~29 €/MWh).
- 0.40 SEK/kWh (~ € 0.043/kWh) production support for manure based biogas to reduce methane emissions from manure. Total budget 390 MSEK (2015-2023).

- A new temporary biomethane production support was presented spring 2018 by Government of in total 270 MSEK for 2018, as a response to the disturbed competition situation for domestic biomethane due to double subsidises for imported biomethane. It will be given to raw biogas producers for upgraded biogas from various substrates except waste water treatment sludge. The support will be up to 0.40 SEK/kWh (~ € 0.043/kWh) biogas. For biogas from manure this will be additional to the existing manure biogas support.
- A joint electricity certificate market between Norway and Sweden. The producer gets one certificate for every MWh electricity produced from renewable resources and electricity consumers must buy certificates in relation to their total use. Price span 2014-2015 140-190 kr/MWh (~15-20 €).
- *Klimatklivet* – local climate investment programme 2015-2023. Investment support (up to approx. 45 %) for all types of investments or measures that leads to high GHG emission reductions. The budget for 2018 is 1.5 Billion SEK/year (~0.14 Billion €) which is proposed to increase to 2.3 Billion SEK/year from 2020. A large part of the over 2 Billion SEK investment support that has been granted since 2015 so far has been given to biomethane investments and EV charging infrastructure.
- 40 % reduction of income tax for use of company NGVs until end 2019 (max 10 000 SEK)
- A new strategic plan for fossil free domestic transports was presented in May 2017 by the Swedish Energy Agency – a co-operation between all relevant authorities for transport. The work with the plan within the authorities and implementing proposed measures continues to 2019. Several proposals have been adopted by government.
- The government in late 2017 announced that it will conduct a broad enquiry about the future role of biogas and to investigate most suitable long-term policies for biogas and biomethane in Sweden after 2020, when the current EC state aid approval for tax exemption expire. The investigator Åsa Westerlund was announced late May 2018, and the proposals will be reported to Government in July 2019.
- A new "Bonus-Malus" taxation system for light vehicles from July 1st 2018. Bonus up to 60 000 SEK (~5700 €) for new low emission cars. Gas vehicles get a bonus of 10 000 SEK (~950 €). Malus in terms of increased CO_2 -based tax first three years for high emission cars (gasoline and diesel cars).
- Quota obligation for biofuels in gasoline and diesel from July 1st, 2018. The obligation is expressed as a minimum GHG reduction that each supplier must reach for all sold gasoline and diesel respectively by blending of sustainable biofuels. Reduction levels for 2018 are 2.6 % for gasoline and 19.3 % for diesel with an indicative reduction level of 40 % 2030. The current CO_2 and energy tax exemption for low blend biofuels will be replaced with full tax. High blends such as E85 or HVO100 and biomethane are not part of the obligation and are still eligible to tax exemption until end of 2020.

New but not yet implemented policies:

- Swedish Energy Agency will be responsible to co-ordinate the development not only of EV charging stations but also of gas filling stations.
- 200 MSEK support 2018-2021 for the establishment of a LBG innovation cluster – for promotion and demonstration of the whole production and utilisation chain in a region for LBG in heavy road and sea transport. The support will be based on a tendering process administrated by the Swedish Energy Agency.
- New legislation for environmental zones in cities will be implemented from 1st of January 2020. Cities should be able to put up restriction zones for polluting (noise and emissions) vehicles in three different restriction levels. Only new gas engines, hydrogen and electric vehicles are allowed in all three zones.

Previous investment support programmes being phased out:

- Investment grants for marketing of new technologies and new solutionsfor biogas during 2010-2016. Maximum 45 % or 25 MSEK (~3M€) of the investment cost.
- Climate investment grant for municipalities: Total budget 1,925 MSEK (~200 M€) until the end of 2018.

Uncertainties for the future biogas/biomethane market development

- Long term conditions and a biogas strategy from the government are missing. It is still not clear what the long-term support system will be for biomethane after 2020.
- Not harmonizing support systems between member states leads to double subsidized imported biomethane and results in a difficult competition situation for domestic biogas production.
- Uncertainty for biofuels and biomass fuels in RED II and ILUC
- Green gas concept not accepted or applicable for off grid LBG and in important support systems such as EU ETS, green electricity certificate system and climate investment programme (Klimatklivet), which is a barrier for large biomethane expansion in industry and long-distance transportation modes. A future biogas register, or Guarantees of Origin system might be the solution currently discussed between industry and authorities.

14. Switzerland

Since January 1st 2018, a total revision of the Swiss Energy Act is in force as part of the Energy Strategy 2050. Under this act, a significant development of new renewables is envisaged with an objective to ramp up production of electricity from new renewables from today's 3'600 GWh to 4'400 GWh in 2020 and 11'400 GWh in 2035. Accordingly, the Swiss Gas Industry is aiming at 30% renewable gases in the grid until 2030, which would correspond to 12'000 GWh compared with 600 GWh in 2016.

In order to promote this development, various instruments are planned or already introduced. For biogas plants with electricity and heat production, the previous feed-in tariff will be replaced by new financing options. In addition to one-off investment contributions, large plants are given the task of directly marketing the energy produced. The Swiss gas industry has created a biogas promotion fund as an important instrument for promoting renewable gases. In addition to investment grants for biomethane upgrading and power-to-gas plants, it also provides feed-in tariffs.

14.1 Production of biogas

In the three main AD sectors *sludge digestion*, biowaste treatment and agriculture, the number of biogas plants has increased by around 4% and the volume of biogas produced by 11% since 2016. Biogas production from the fermentation of industrial wastewater is almost constant. Biogas from landfills is marginal and continues to lose importance.The table below presents the state of the current biogas production in Switzerland including the shares of biomethane upgrading installations and biomethane fed to the gas grid.

Table 14.1: Status of biogas production in Switzerland (data from 2017)

Plant type	Number of plants	Biogas production* (GWh/year)
Sewage sludge	475 (22)	620 (163)
Biowaste (co-digestion)	28 (9)	337 (113)
Agriculture	106 (3)	364 (11)
Industrial waste water	23 (2)	85 (14)
Landfills	2 (0)	3 (0)
Total	**634 (36)**	**1'409 (301)**

* = produced raw biogas expressed as its energy content from the different plant types
Numbers in parentheses indicate share of biomethane upgrading.

Although the number of sludge digestions on municipal wastewater treatment plants remains almost constant, the trend of a slight increase for biogas produced is confirmed. This is mainly due to the increased use of co-substrates such as spent oil and food waste as well as the use of sludge pre-treatment methods and digester optimisation. Two-stage mesophilic stirred tank cascades with hydraulic retention times of 20-60 days are in use as the dominant technology for sludge digestion. The actual production in 2016 (620 GWh/y) represents 78% of the estimated sustainable potential (800 GWh/y) or 31% of the theoretical potential (2'000 GWh/y) from sewage sludge respectively. Due to the ban on agricultural use of sewage sludge, digested sludge is dewatered and incinerated. Processes for the recovery of phosphorus and partly nitrogen are under development but will not be implemented on a technical scale until 2016 at the earliest.

The number of biogas plants for the digestion of source separated household waste and industrial organic residues is growing only slowly, as most of these plants serve larger catchment areas and require longer planning and decision-making processes. However, an almost complete coverage of separate collection of green waste is foreseeable within the next decade. Together with the trend to divert existing flows of green waste from composting to biogas plants, a future growth is still expected for this sector. In addition to the so far dominant thermophilic fermentation in plug-flow fermenters, an increase in garage type fermentation plants is taking place. The actual production of biogas including biomethane (337 GWh/y) represents 61% of the estimated sustainable potential (550 GWh/y) from biowastes.

Although great potential for agricultural biogas was identified in 2017, the implementation of biogas plants in this sector is still a long time coming. This is mainly due to the still unclear future financing models. Around 50 farms are in an evaluation or planning process for a biogas plant but are still holding back on the decision. It is unclear whether the development will tend towards larger collective plants with up to several dozen participants, or whether more small decentralised plants will be built. Approaches are also being pursued to combine decentralised systems for liquid farmyard manure with centralised systems for solid substrates. The number of agricultural AD installations is expected to grow considerably, highly depending on the tendency towards small and decentralized or rather large and centralized installations. The actual production of biogas and biomethane of the 106 agricultural AD plants in operation (364 GWh/y) represents 9% of the estimated sustainable potential (4’000 GWh/y) from agricultural residues and manure.

In 2016, a study showed a still considerable potential for small-scale applications for anaerobic digestion of industrial wastewaters. Consequently, a series of feasibility studies were initiated which will probably result in a small additional number of new AD installations in the near future. The actual production (85 GWh/y) however covers more than 90% of the estimated sustainable potential from industrial wastewaters. The phasing-out of landfill biogas is still in progress with only 2 installations running, both expected to shut down within the next decades. In total, the actual production of biogas (1’409 GWh/y) represents some 27% of the estimated sustainable potential (5’300 GWh/y) or 4% of the theoretical potential (39’000 GWh/y) for biogas or biomethane production, not accounting for any future power-to-gas options.

14.2 Utilisation of biogas

The trend in biogas use away from heat and electricity towards the feeding in of biomethane and direct use as fuel has consolidated in 2017. Meanwhile, 36 biomethane upgrading plants provide almost as much energy as is produced as electricity or heat from biogas. The total biomethane production equals 301 GWh/y or 21% of the total biogas produced. This represents a 27% growth of this sector. Most new installations are based on membrane technologies for biomethane upgrading. A growing demand can also be identified for local biomethane upgrading for direct vehicle fuelling although these installations are still few in numbers. Biomethane accounts for around 25% of total sales of gas as fuel. Table 13.2 gives an overview over biogas utilisation in 2015.

Table 14.2: Utilisation of biogas in Switzerland (data from 2017)

Utilisation type	GWh/yr	%
Electricity*	333	24
Used Heat	326	23
Grid injection	301	21
Parasitic (heat, electr.)	245	17
Flaring	n.d.	<1

* = excluding efficiency losses

14.3 Innovative biogas projects

Agricultural Biogas from solid Manure

At the beginning of 2018, the first agricultural biogas plant in eastern Switzerland was connected to the electricity grid, which exclusively treats solid farmyard manure. In a 4-lane garage type fermenter plant around 2500 tons of solid manure from cattle and turkey husbandry are processed annually. Added to this are small amounts of horse manure and fruit residues. The electricity generated is fed into the grid. The heat produced is used to heat the turkey barn and adjacent residential buildings. The plant represents a promising model for the Swiss market for decentralised harnessing of the potential of solid farmyard manure and agricultural residues.

www.renergon.ch, Garage type fermenter technology provider

Figure 14.1: Garage type Fermenters at the Tuttwil Biogas plant ©U. Baier
left: Garage Fermenters (4), right: percolate tank with gas holder, CHP container

Zürich Werdhölzli direct catalytic methanation pilot plant

Catalytic methanation of carbon dioxide in biogas to methane is one of the most promising new technologies to not only upgrade biogas to biomethane but as well enhance biomethane production by 40%. In 2017 a 1000-hour practical testing of a fluidized bed catalyser was conducted at the Werdhölzli biowaste digestion and wastewater treatment plant in Zurich. The test successfully demonstrated the technical feasibility of the technology as well as its economic viability. Calculations showed that the costs for direct methanation are roughly the same as in conventional biogas upgrading plants.

www.psi.ch, ➔ ESI platform

Figure 14.2: Catalytic Methanation Pilot Rig at Werdhölzli Biogas Plant, Zürich ©U. Baier

15. 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.

15.1 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 15.1 to give an indication how the production is distributed. For electricity and heat production, see Table 15.2. Biogas upgrading to biomethane with subsequent gas grid injection is included in the figures, corresponding to approx. 900 GWh.

Table 15.1: Status of biogas production in The Netherlands (data from 2015)

Plant type	Number of plants	Installed electricity capacity (MWe)	Upgrading capacity (Nm3 biomethane /h)
Sewage sludge	80		
Biowaste + industrial	50 (biowaste and industrial together		
Agriculture	97		
Landfills	not reported		
Total	**268 (assuming 41 landfills)**	**133****	**10.000**

* a large installed heat capacity is also available from the CHP units installed for electricity production, which is not included in this column.
** average full load hours 4169/a for agricultural production plants

Table 15.2: Status of biogas final utilization in The Netherlands (data from 2015)

Plant type	Electricity production (GWh/year)	Heat production (GWh/year)
Sewage sludge	206	335
Biowaste + industrial	346	849
Agriculture	550	622
Landfills	46	57
Total	**1148**	**1863**

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 Nm^3 of biogas (63% CH_4 content), which corresponds to around 7 TWh. In 2030, this could potentially increase to 4,600 million Nm^3 biogas, which corresponds to almost 30 TWh. This will only be possible by developing several big gasification plants in the future.

15.2 Utilisation of biogas

In the Netherlands, 80 % of the produced biogas is utilized, corresponding to around 3.2 TWh delivered, as either heat, electricity or automotive fuel, as seen in Table 15.3.

Table 15.3: Utilisation of biogas in the Netherlands (data from 2014)

Utilisation type	GWh	%
Electricity*	1148	36%
Heat*	1863	58%
Automotive fuel	approx. 197	6%

* = excluding efficiency losses.

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[29].

15.3 Financial support systems

In the Netherlands financial support is offered by the *SDE+ sceme the feedinntariff* support system for renewable energy. 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 15.3) 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 15.3 the tariffs are guaranteed minimum income, which means that the scheme only pays out if energy prices are lower than the prices in the feed in tariff for a certain category. In 2016 there was 9BEUR available in this system. In 2017 the available budget is 12 BEUR. A special category in it will support small scale manure digesters.

15.4 Innovative biogas projects

Mono-manure digestion is a new development in the Netherlands. The digester at Den Eelder was the first of its kind in the Netherlands.

At Den Eelder, the cows poo green electricity

The Den Eelder farm's website proudly boasts that 'our cows poo electricity and heat!' Just to clear the air: thanks to a closed circuit and a mono-digester, the farm runs on green energy produced from its own manure. However, owner Ernst van der Schans does not believe he has found the goose that lays the golden egg: "Don't expect this to make you wealthy."

In the early nineteen-eighties, Mr van der Schans started farming near Well-Ammerzoden, in the province of Gelderland. In 1990, he branched out to dairy processing, a rather energy-intensive process. He now has a relatively large dairy farm, with around 500 cows.

Mono-digestion or co-digestion: Soon, the idea of generating biogas sprang to mind. This was not just about using this renewable energy himself, the goal was also to reduce methane emissions. "In the beginning, we were not sure if we should use a mono-digestion technique - where it is only manure that is converted into biogas - or a co-digestion technique, in which other products are also fed into the digester.

[29] http://www.ngvaeurope.eu/european-ngv-statistics

Start small: In 2012, Ernst van der Schans finally decided to go for a Microferm mono-digestion system, with a 66 KWe cogeneration unit (CHP). "There were several reasons for this", says Mr van der Schans. "We didn't have to add a cost item to our books for the supply of co-products. We did not have to produce any additional manure for the digester, and we just wanted a simple, small-scale installation. So, we started small, with 7,000 tons of manure every year."

Closed cycle: Ernst van der Schans is happy that he opted for mono-digestion. "It suits our farm. We like using a closed-cycle system. In addition, we prefer not to have any external products or animals on our site. We also wanted a simple logistical process."

Level floors: "We use manure shovels once an hour to remove manure from the animal enclosures. A small amount of this fresh manure is pumped into the digesters every five minutes. This is important. The fresher the manure, the more methane and gas is produced. By using fresh manure, we also reduce methane emissions from the manure storage facilities, allowing us to make an additional contribution to climate policy."

- Technique: mono-digestion
- Input (per year): 15,000 tons of fresh cow manure
- Capacity: 66 kW electricity / 700 kW heat
- Net output (per year): 500,000 kWh_e /yr and 1,500,000 kWh_h/yr

Figure 15.1: Den Eelder farm's biogas plant

16. United Kingdom

UK Government is still supporting the roll out of AD in England and the devolved administrations of Northern Ireland, Scotland and Wales but cuts to the amount of financial support continue. The Renewable Heat Incentive continues to support injection of biomethane into the grid and will permit developments for up to 250GWh per annum. (95% of new projects are in range 30 – 60 GWh/annum). The new tariff guarantee mechanism is subject to possible digression at 25% per quarter. Around 48 projects have applied for the tariff guarantee as of 1 August 2018 and there is enough funding for them all to go ahead. These projects must be installed and operational by 31 January 2019. Government has introduced sustainability criteria to ensure that there is at least 60% life cycle GHG savings for all feedstock except plants which digest wholly waste or animal manure /slurry.

16.1 Production of biogas

As of the end of 2016, there were 94 AD plants treating food waste (218 MWe) and 279 farm plants (273MWe). The number of new plants has increased rapidly since 2005, along with gas production. Growth in 2016 came from the biomethane-to-grid side of the industry – plants injecting biomethane into the gas grid. The electricity generation from AD in United Kingdom increased by 50% during the period 2014-16. By the end of 2016, 2.6 TWh/yr of biomethane was being injected into the gas grid and by the end of 2017 this had increased to 3.8 TWh/yr. These statistics have been compiled from various sources. No complete set of biogas production is collected by any organization.

Table 16.1: Status of biogas production in the UK to the end of 2016.

Substrate/Plant type	Number of plants	Electricity generation (GWh/year)	Capacity (MW_e)
Sewage sludge[1]	162	950	257
Biowaste	98[2]	n.d.	n.d.
Agriculture	279[2]	20,804[1]	3,378[1]
Industrial	n.d	n.d.	n.d.
Landfills	442[1,3]	4,703[1]	1,062[1]
Total	**987**	**26,457**	**4,697**

Sources: [1]DUKES (2018)[30]; [2]National Biogas Portal, National Non Food Crops Foundation (NNFCC); [3]Anaerobic Digestion and Bioresources Association (ADBA)

16.2 Utilisation of biogas

The production of heat from biogas is beginning to gain momentum with 117 operational plants. These had received payment through Renewable Heat Incentive and generated 134 GWh of biogas heat between November 2011 and December 2016. Biomethane production has increased rapidly over the last six years from 0.01 TWh in 2012 to 4.13 TWh in 2017 with the greatest increase since 2015.

[30] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/450298/DUKES_2015_Chapter_6.pdf

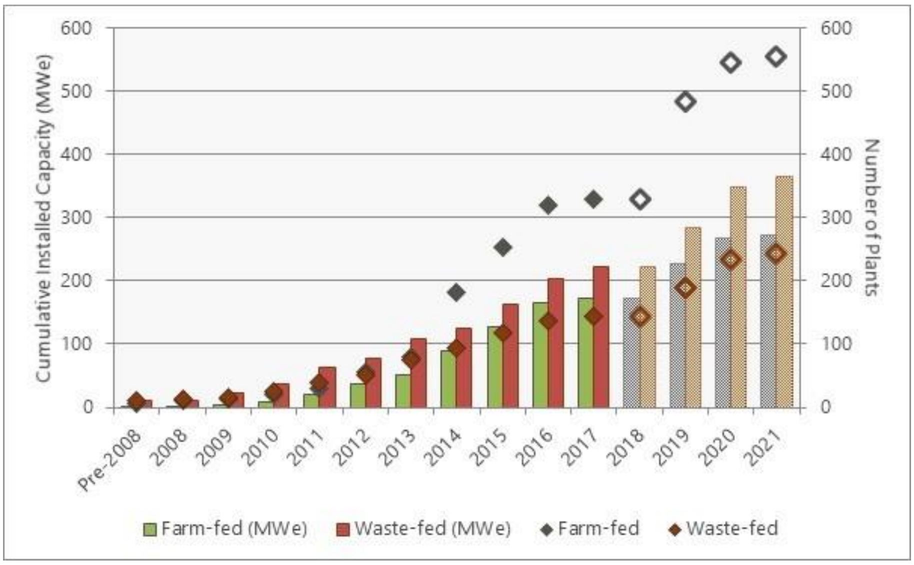

Figure 16.1: Growth of the UK's AD sector. (*Source: National Non Food Crops Centre (2018) AD deployment in the UK*[31])

By the end of 2016, 117 biogas plants had received the RHI (renewable heat incentive). Between November 2011 and December 2016, the latest available figures show a total of 134 GWh of biogas heat was generated. According to UK government data (BEIS RHI) approximately 1453GWh of equivalent heat was generated from the gas produced by the 42 installations which receive the RHI payment. There is no data yet for 2017.

Biomethane production is increasing steadily within the UK. Figure 15.2 shows how the cumulative number of biomethane plants has increased from 20 to 100 between 2014 and the present. The number of plants built each year has slowed since the reductions of government support but is predicted to recover with a return to the payment levels award up to 2015.

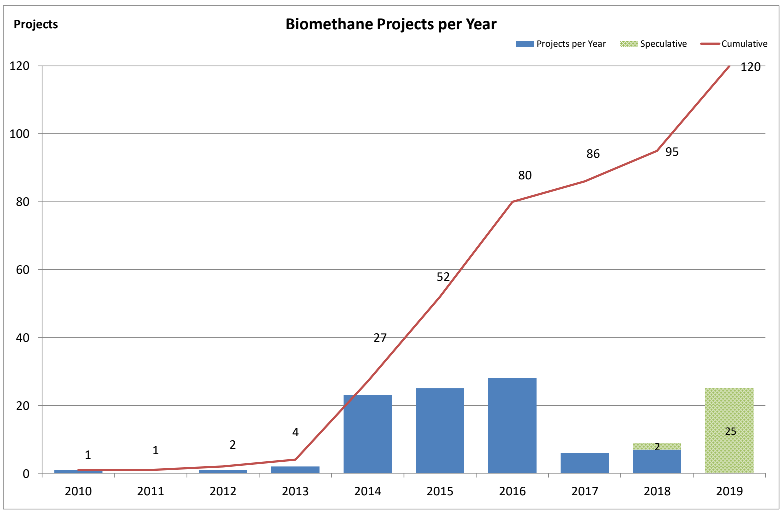

Figure 16.2: Annual Biomethane to Grid and RHI (Renewable Heat Incentive). (Source: John Baldwin CNG Services 2018 derived from[32]*).*

[31] https://www.nnfcc.co.uk/publications/report-anaerobic-digestion-deployment-in-the-uk

[32] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/450298/DUKES_2015_Chapter_6.p

16.3 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 fixed price/kWh over a fixed period to small-scale electricity generators (under $5MW_e$). Only these facilities under 5 MW_e capacity and completed after 15 July 2009 have been eligible for FITs. This tariff closes on 31st March 2019, but applications can still be made up to that date.

Table 16.2: The Feed in Tariff (pence/kWh) with guaranteed price for a fixed period[33]

Tariff band	Tariff (1st April 2018 – 30th June 2018)
≤250kW	4.60 p/kWh
>250-500kW	4.36 p/kWh
>500-5000kW	1.61 p/kWh

The Renewables Obligation (RO) has now closed. The Renewable Heat Incentive (RHI) will continue to provide a fixed income (per kWh) to generators of renewable heat and producers of renewable biogas and biomethane.

Following a delay of more than a year, the RHI regulations finally came into force on the 22nd May 2018 which reset the tariffs back to the levels at the start of 2016.

Table 16.3: Renewable heat incentive (pence/kWh) for various sources. Increases due to inflation linkage.

Technology/category	Reset tariff	Tariff before reset
Biomethane Tier 1 - first 40,000 MWh	5.60 p/kWh	3.30 p/kWh
Biomethane Tier 2 - next 40,000 MWh	3.29 p/kWh	1.95 p/kWh
Biomethane Tier 3 - remaining MWh	2.53 p/kWh	1.49 p/kWh
Small biogas combustion (<200 kWth)	4.64 p/kWh	2.97 p/kWh
Medium biogas combustion (200 kWth<600 kWth)	3.64 p/kWh	2.33 p/kWh
Large biogas combustion (≥600 kWth)	1.36 p/kWh	0.89 p/kWh

The Renewable Transport Fuel Obligation (RTFO) places a statutory requirement on fuel suppliers who supply more than 450,000 litres per year to customers. This is to ensure that a set percentage is purchased from renewable and sustainable sources either through their own supply or through the purchase of Renewable Transport Fuel Certificates (RTFCs). Fuel companies must deliver 4.75% of their supply from renewable fuels. The Renewable Transport Fuels and Greenhouse Gas Emissions Regulations 2018 came into force on 15th April 2018. This extends the RTFO to 2032 and raises the percentage of renewable fuel which suppliers must provide to 9.75% by 2020. An increase from 15p/kWh at the start of 2018 to 18.7p/kWh at the start of June 2018 has the potential to double the size of the market in just two years.

In the period from 15th April 2016 to 14th April 2017, 0.6 million litres of biomethane were supplied as a transport fuel under the RTFO. This, however, was just 0.04% of all renewable fuel. No later data are yet available

[33] www.fitariffs.co.uk/eligible/levels

16.4 Innovative biogas projects

Bore Hill Farm

Figure 16.3: Layout of the biodigester Bores Place Farm (Photo: Thomas Minter, Malaby Biogas)

This innovative and multi-award-winning plant was initiated in 2009 to provide a more environmentally beneficial alternative to the 'disposal' (as it was then) of biodegradable municipal and commercial organic waste, especially food to landfill. It was conceived and planned as a multi-phase development on a parcel of disused land, adjacent to the main road, on which there was a range of semi-derelict farm buildings and a farmhouse which had been empty and overgrown for a number of years. The restoration works of the first phase focussed on the conversion of the derelict buildings into zero carbon premises. The second phase saw:

1. Construction of the biogas plant began in 2011 and started production in May 2012. It was designed to process 17,000 tonnes/year of food waste which had previously been sent to landfill.
2. Further innovation was an experimental "Direct to AD" local food waste collection from local schools, pubs, canteens, farm shops and a specialist rare breed pork butcher using buckets which were collected twice a week.
3. The plant has an integrated and much-used Visitors Centre which is used as an educational and industry development resource to focus minds on waste reduction and sustainability among children, the local community and industry regulators and professionals. Future phases include development of a combined R&D and Training Centre, commercial buildings and 80-100 low carbon houses

Current Outputs*:*

- Sufficient biogas to operate two CHP under the Feed in Tariff Scheme to supply electricity for 2,500 homes.
- Digestate to return organic matter to the soil

- Recycling of nutrients as fertiliser and their replacement of mineral fertiliser.
- This plant set a model to produce biogas, for education and involvement of the local community in the integration of AD into the sustainable development of sites for mixed uses

Basic data 2018:

- Make up of feed stock: 30,000 tonnes Commercial & Industrial food production waste
  Digester capacity: 2,800 m^3
- Digestate storage: 1,400 m^3
- Gas output: 440 m^3/hour
- Electricity output: 1.03 MWh

Contact: Bore Hill Farm Biodigester, Deverill Rd, Warminster, Wilts BA12 8FB T: 01985 216976 www.malabybiogas.com

17. Summary and Conclusions

Biogas production in the IEA Bioenergy Task 37-member countries is clearly dominated by Germany with more than 10,000 biogas plants. None of the other member countries have each more than 1,000 biogas plants (see Figure 17.1).

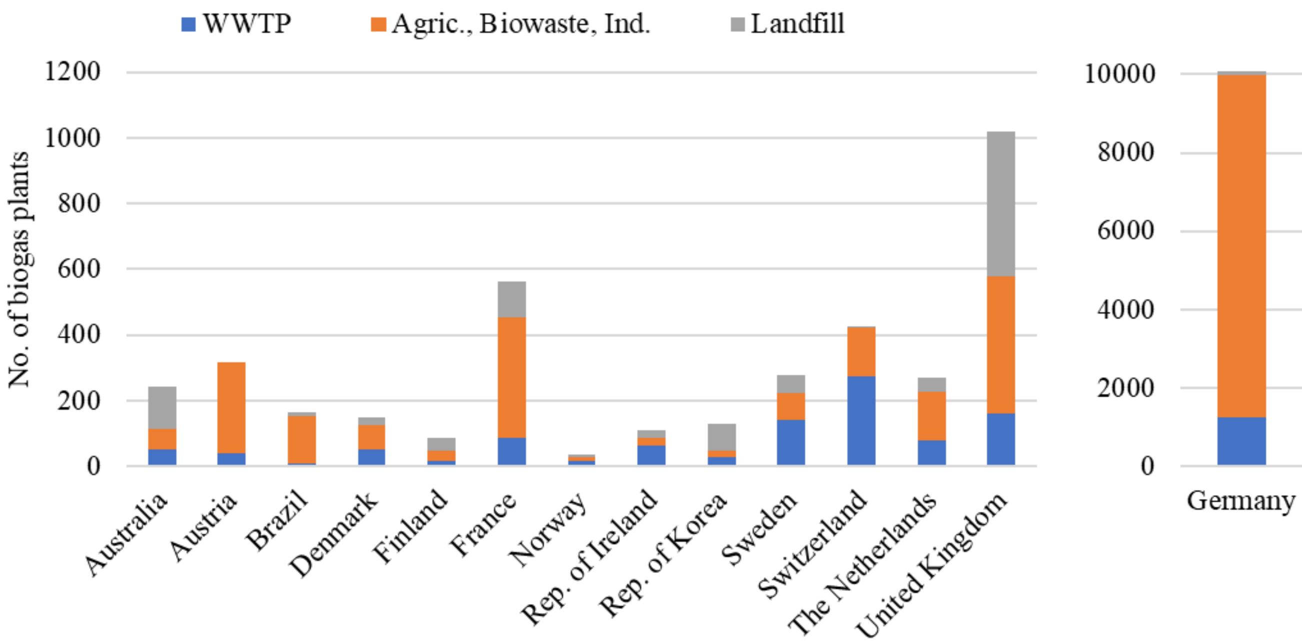

Figure 17.1: Number of biogas plants in operation in the IEA Bioenergy Task 37 member countries (2016).

The annual biogas production is around 100 TWh in Germany, 23 TWh in the UK[34], 5.5 in France, around 5 TWh in Brazil and 4 TWh in the Netherlands. Remaining countries show production rates in the range of 0.5-2 TWh (see Figure 17.2). In countries like South Korea, the biogas produced in landfills is the largest source, while landfill gas is only a minor contributor in countries like Germany, Switzerland and Denmark, indicating the low level 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 in most countries mainly used for generation of heat and electricity, except for Sweden where approximately half of the produced biogas is used as vehicle fuel. Germany is second in absolute numbers. Many other countries, such as France, The Netherlands, Denmark and South Korea, have emerging markets for biomethane as an automotive fuel.

[34] Only biogas for electricity generation, excluding landfills and biomethane plants (estimation production potential 2.5 TWh end 2016) and renewable heat (RHI, negligible amounts)

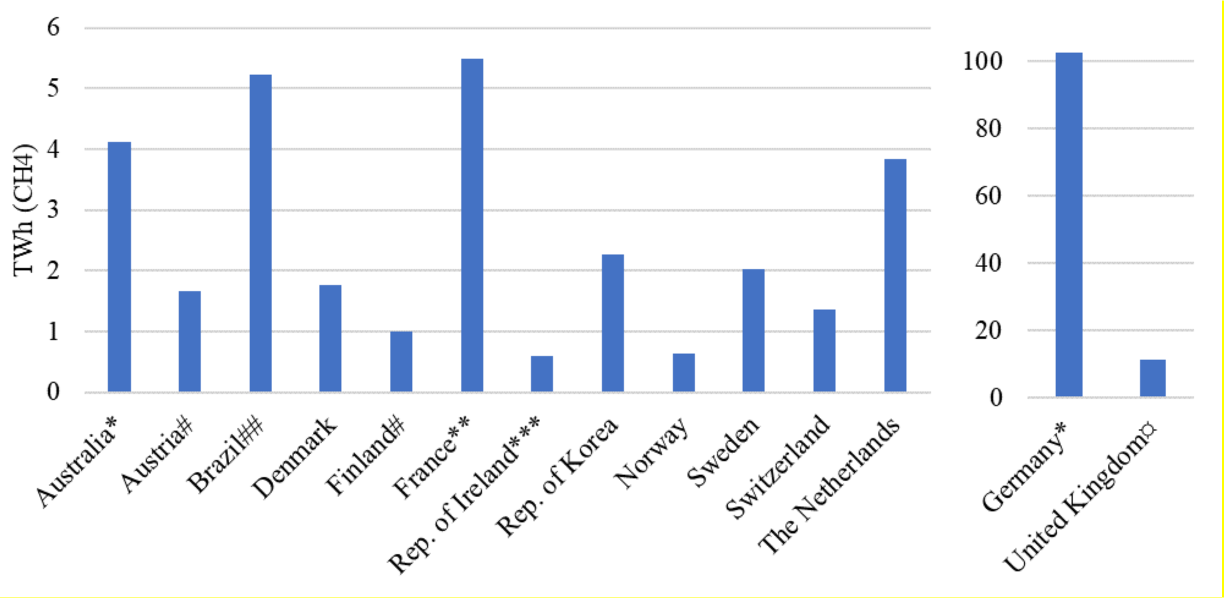

Figure 17.2: Annual biogas production in the IEA Bioenergy Task 37-member countries.

* = Calculated from the reported electricity production and an assumed efficiency of 35%.
** = Calculated from the reported electricity production and 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
##=Calculated from the reported or estimated raw biogas production in volume (m3/y) and an assumption of 64 % CH4 content.
¤ = Calculated from the reported electricity production and an assumed efficiency of 35%. Excluding landfill.

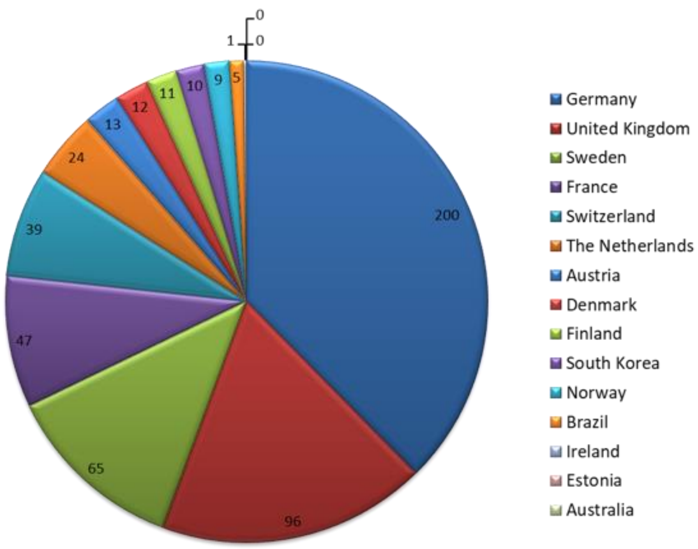

Figure 17.3a: The distribution of the reported operational biogas upgrading units in the IEA Bioenergy Task 37-member countries (end 2017). The labels are in the order from the largest to the smallest. Data for Denmark, Korea and Norway are from 2016.

The amount of biomethane produced and the number of biogas upgrading plants is increasing. In Figure 17.3a the distribution of 532 biogas upgrading plants among the IEA Bioenergy Task 37-member countries is shown; the technologies used is indicated in Figure 17.3b.

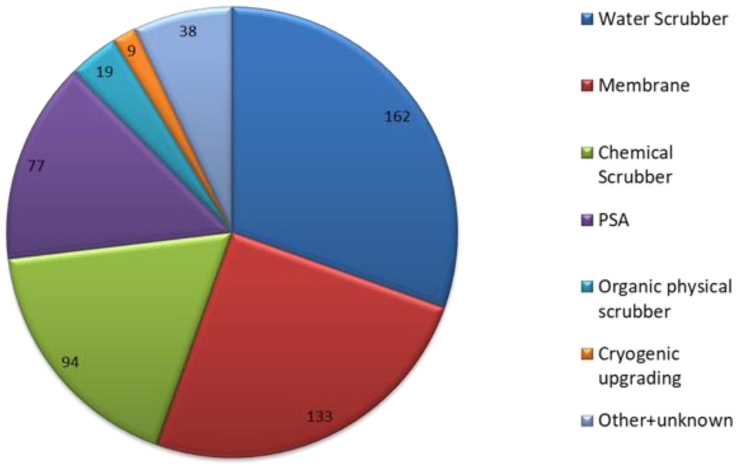

Figure 17.3b: The distribution of upgrading technologies for the reported operational biogas upgrading units in the IEA Bioenergy Task 37-member countries. The labels are in clockwise order from the largest Water Scrubbing (162) to the smallest.

The two countries in the recent past with the most applications of biomethane, Germany and Sweden, have stagnant markets. As a result, UK has now taken over the second position from Sweden. France and Switzerland are examples of other countries with significant growth.

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 will grow, as is the case 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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