BIOMETHANE INJECTION INTO THE GRID: RHI OPPORTUNITIES TO THE WASTE WATER TREATMENT SECTOR

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Abstract

With the amendment of the renewable obligation certificates (ROCs) on 2009 to the electricity produced by cogeneration units on waste water treatment plants (WWTP), a drastic decrease on the incentives for the WWT-sector creates an interesting opportunity to seek chances on the next renewable heat incentive system of 2011.

With the planned tariff for the injection of biomethane into the gas grid, a better and more feasible perspective is given to the sewage gas produced by sludge fermenters on WWTP. Through the upgrading of biogas into biomethane, injected gas will not only be prized with incentives but additionally handled with a price on the market; this creates -on the long term- an advantage for the WWT-Sector over the electricity fluctuating price being a more stable market with reliable profiting.

The presentation will focus on the biogas and sewage gas cleaning and upgrading methods with well-proven technologies which provide an alternative for the efficient employment of this fuel gas to maximize its potential on the UK renewable energy market.

Keywords

Biogas, Biomethane, Carbotech, Grid, Natural Gas, PSA, Schmack, Viessmann

Introduction

In Europe by far the most common method of using the sewage gas from WWTP is the production of electricity and heat with CHP plants or in boilers for the generation of heat. A disadvantage of CHP plants are the relative low efficiency, which in optimal cases the energy produced as electricity and heat will achieve a realistic performance of 80% while the rest can be regarded as lost energy. The UK government has realised, among other issues, this disadvantage and therefore the support scheme ROC for electricity production reduced in particular cases such as for sewage gas, with the purpose of a more effective usage of the gas produced, the upcoming Renewable Heat Incentives (RHI) intends to persuade the WWT-Industry to upgrade the sewage gas to natural gas quality for injecting it into the grid.

Therefore the most promising alternative for using biogas is the injection into the natural gas grid, not only because of the energy efficiency improvement but also the long term economical stability regarding the natural gas selling price towards the electricity price. With many alternatives for electrical production from conventional fossil resources to renewable sources (wind turbines, solar energy, hydropower, etc), the price development will steadily decrease while the natural gas prices with less alternatives of production/extraction becomes an attractive alternative for selling the generated gas from WWTP.

Through the decades of dependency from fossil fuels has brought positive and negative aspects, which from one side is the predicted shortage from natural gas in the near future but from the other side is the good infrastructure that countries like the United Kingdom with its gas grid has achieved. With one of the top networks in the world, the alternative of gas production through anaerobic digestion and the injection into the grid becomes an interesting role to the potential gas producers from sewage and biogas plants.

Overview of the Renewable Heat Incentives 2011

According to the proposed Renewable Heat Incentive from the UK Government, there are different scenarios which group the technologies to be supported. The RHI Level will depend strongly on this classification and is calculated per kWh renewable energy output. The modelling of the RHI was achieved through the potential of each technology that relates to the production of heat. Therefore each subsidy band is classified according to the size, resources and potential heat contribution in thermal watt-hour.

The technologies are classified under biomass boiler, biomass district heating, air source/ground source heat pumps, solar thermal, and the biogas for injection into the gas grid. As a result of this modelling, a thermal production of more than 70 TWh through all these resources is expected by 2020 which compromises between 12 -14% of the total heat consumption in the UK.

While implementing a successful strategy for replacing the conventional boilers with biomass boilers, this will contribute to more than 25 TWh of the RHI goals for 2020. The lowest production will be by the solar thermal technology with a contribution of no more than 3 TWh. In case of the biogas to the grid injection a contribution of almost 8 TWh is expected, although the transportation industry and the non-heat applications of natural gas could increase the potential use of this technology.

According to studies made by the NERA Economic Consulting[1], a comparison with the potential energy to produce and the cost of technology implementation and operation was analysed, giving as a result that the best economic balance results from the biogas upgrading and injection

[1] Radov,D., Klevnäs, P. and Lindovska M., 2010. Design of the Renewable Heat Incentive. *Study for the Department of Energy & Climate Change* [e-journal] Available through: Department of Energy & Climate Change Database [Accessed September 2010]

into the grid which under optimal conditions could achieve a cost of no more than £1 per MWh produced. The most expensive technology to implement and support is the solar thermal with an average cost of more than £150/MWh.

By the injection of biogas into the grid, the WWT-Industry has an advantage towards the typical AD Biogas Plants because of the value of the input organic matter (resource) for the production of the gas. In the case of the biogas produced through the anaerobic digestion of organic waste, a risk of price increase is possible through the handling of demand & offer which could lead to expensive cost per ton of waste.

The proposal of incentive given for the injection of biomethane into the grid will be rewarded with 4.0 pence per kWh. As a guiding example, it can be supposed that the natural gas in the local grid has a calorific value of approximately 10.85 kWh; therefore the biogas has to be upgraded and conditioned for achieving the same energy value which results per every cubic meter an average of 43.4 pence only through the incentive support. Additional financial profits can be calculated with the buying price that the natural gas distributor will pay for the injected gas; with a guiding price of 1.4 pence per kWh a total of 58.6 pence will result per cubic meter of biomethane injected.

This simple calculation gives an overview of the possible profits that can be obtained through the biomethane injection. Nevertheless, it is also important to notice that the calorific values are different from region to region and as well as from the grid type; in the Gas Safety (Management) Regulation (GS(M)R), determines that the UK gas network operates with a range between 10.25 – 11.75 kWh calorific value. Another variable is the gas price which the local natural gas distributor is willing to pay or in any case, an established amount that could be specified by authorities such as the Ofgem for the UK.

Sewage Gas: The ideal Properties and Qualities

For the injection into the natural gas grid, certain guidelines have to be followed regarding the gas quality and concentration of its components which should be similar to the natural gas of the grid where the biomethane will be injected.

It is important to remark, that the process of biogas to biomethane compromises two main phases: the cleaning phase refers mostly to the removal of water, dust and toxic elements such as H_2S, Siloxanes, Mercaptans, Alkanes, BTX, etc. while the upgrading phase will gather only the methane enrichment process while removing mainly the CO_2-component from the biogas. Other gas components such as oxygen and nitrogen are usually difficult to remove specially in high concentrations; therefore it is important to keep the GS(M)R-allowed amounts of oxygen and nitrogen since the begging of the sewage gas production.

The following table describes a comparison with the different properties and qualities of each gas.

Table 1: Gas quality and requirements comparison

Component	Symbol	Sewage Biogas	Biomethane PSA-Schmack CARBOTECH	GS(M)R[2]
Methane	CH_4	55 – 70 %	80 – 99 %	as per $W_{s,N}$
Carbon Dioxide	CO_2	30 – 45 %	<1 – 3.0 %	--
Nitrogen	N_2	0 – 2.0 %	<0 – 2.0 %	--
Oxygen	O_2	0 – 0.5 %	<0 – 0.5 %	<0.2 %
Trace Elements				
Water / Dew Point	H_2O	Saturated	< 0.3 mg/m³ / <-60°C @5bar	--
Hydrogen	H_2	<200 ppm	<500 ppm	<0.1 %
Hydrogen Sulphide	H_2S	<150 mg/m³	<5 mg/m³	<5 mg/m³
Siloxanes	S_iO_x	<100 mg/m³	< 1 mg/m³	--
Hydrocarbons	C_xH_y	<100 ppm v	< 10 ppm v	--
Energy Content				
Gross Calorific Value	$H_{S,N}$	21.9 – 27.9 MJ/m³	31.9 – 39.4 MJ/m³	--
Wobbe Number	$W_{S,N}$	22.0 – 30.3 MJ/m³	36.85 – 52.5 MJ/m³	47.2 – 51.41 MJ/m³

Further requirements will depend on the network operator specifications based on the unified network code (UNC) and the network entry agreement (NEA).

Methane Enrichment Process through the Schmack Carbotech's Process

The process for upgrading biogas to biomethane can be achieved through different technologies which can be roughly classified as chemical or physical procedures. Schmack Carbotech's technology works as a physical process under the gas purification method of pressure swing adsorption (PSA).

With more than 50 years of experience working with its own patented PSA system, Schmack Carbotech has established an international recognition in the gas separation industry. Since the early 90's Schmack Carbotech as a pioneer on the branch, has designed and constructed cleaning and upgrading plants for biogas and sewage gas, contributing to the standards and technical definitions of biomethane.

[2] Gas Safety (Management) Regulations 1994. (Schedule 3), London: Health and Safety Executive

The biogas upgrading plant from Schmack Carbotech consists mainly of the following steps:

- Biogas compression
- Biogas conditioning
- Methane enrichment
- Waste gas cleaning system

Sewage gas will be compressed to approximately 6 - 7 bar(a). After the pressurising step, the biogas will be conditioned for entering into the PSA system. The conditioning phase compromise the primary dry step to reach an approximate dew point of -2°C, this dewatering process will increase the capability to remove the contaminants through activated carbon. The final step of the cleaning phase will achieve a complete removal of typical trace elements like H_2S, NH_3 and Siloxanes generated during the biogas production.

Schmack Carbotech has patented a pre-filtering system for removing usual contaminants that can be found in the sewage gas produced from waste water treatment plants, such as BTXs, Mercaptans, long-chain hydrocarbons, silicon compounds (i.e. siloxanes) and CFCs, among others, ensuring the biomethane injected into the grid with the allowed limited concentrations of such toxic elements.

The methane enriched gas processed through the PSA-Carbotech patented technology is based on the physical adsorption phenomena where CO_2, H_2O as well as partially O_2 and N_2 are filtered from biogas while directing the flow through a vessel full of carbon molecular sieve (CMS). This type of screening is achieved because of the different size dimension that such molecules posses.

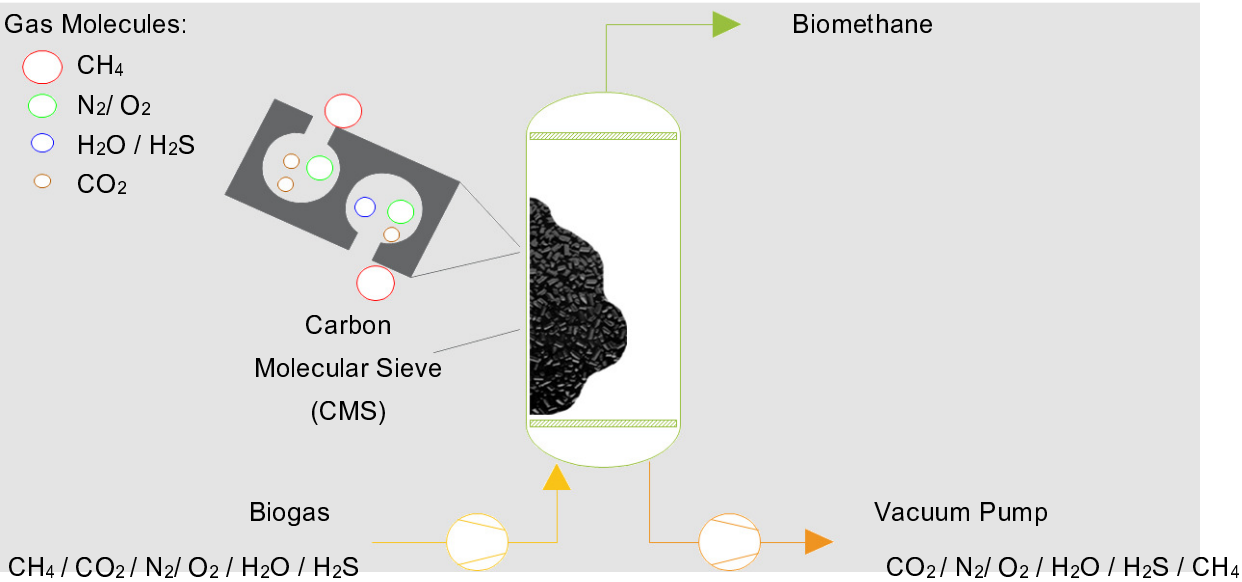

Figure 1: Schmack Carbotech's PSA-System

The pressure swing adsorption process works as a batch system with a pressure alternating-method:

- Pressurising the biogas into 6 bar-g increases the partial pressure of each molecule therefore having a higher load of adsorption from the CMS to the gas molecules. After the CMS adsorber in the vessel is saturated with the undesired gas, it is necessary to regenerate the adsorber content for reusing unlimited times.

- The regeneration step will be realized through a vacuum system where the trapped molecules in the CMS will be drawn while the adsorber is brought below atmospheric pressure. Through this process is ensured the complete reuse of the CMS adsorbers.

The PSA unit consists of 4 – 6 vessels filled up with adsorbent materials, basically carbon molecular sieve. During normal operation each adsorber operates in an alternating cycle of adsorption, regeneration and pressure build–up for creating a continuously coordinated upgrading process.

The PSA-processed biomethane is optimal for the gas grid injection and for using it as vehicle fuel, in comparison with other methods of methane enrichment from biogas, during the adsorption phase not only is the removal of gases but also an extra drying step is achieved. Advantage towards the conventional gas scrubbing technologies, is that the product gas leaves the PSA unit in high dry conditions as a result the biomethane dew point reaches -50°C in atmospheric pressure. A further drying step of the grid injection or for the tankers is therefore not necessary.

Through the removal of CO_2 from the biogas with the typical methane enrichment processes, an automatic increase of methane load per cubic meter will occur but at the same time inevitably will also increase the load concentration from oxygen and nitrogen in the product gas. With the Schmack Carbotech's PSA-adsorbers, is not only the CO_2 captured but also a partial removal of oxygen and nitrogen will occur, this will then result in a less or equal load of oxygen and nitrogen in the biomethane per cubic meter.

During the gas separation step in the PSA System, there will be a product gas (biomethane) and a by-product gas (off gas). The off gas will contain mainly CO_2 but also the partial removed amounts of oxygen and nitrogen and a methane slip.

The methane content in the Carbotech's PSA off gas will be less than 3%, however for optimising the system and increasing the efficiency of the energy input/output balance can be optionally implemented an off gas cleaning system (ZETECH$_4$®) where methane is completely oxidised for not discharging it into the atmosphere. During the off-gas cleaning process, great amounts of heat are created while the oxidation of methane, Schmack Carbotech's patented ZETECH$_4$®-technology recovers the heat produced and can be used for any purpose.

For the waste water treatment plants, an attractive alternative for implementing a biomethane to the grid injection project will be a constellation together with a CHP plant, where part of the sewage gas will be designated to the production and own consumption of electricity and heat while the rest of the gas to be processed and injected into the grid as biomethane.

Biomethane to the Gird: Matching the Natural Gas Properties on Site

After processing the biogas into biomethane, it is necessary another system which will measure and prepare the biomethane to match the local natural gas quality and pressure.

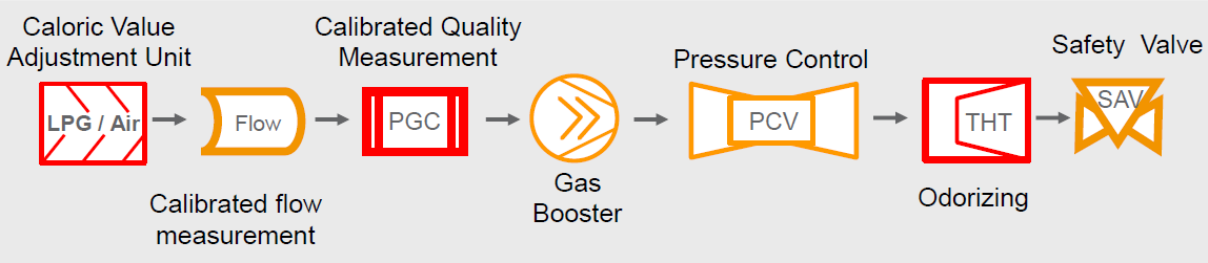

Figure 2: biomethane to the grid injection-process chain

The Biomethane to the Grid Plant will comprehend different steps described as follows:

- Gas conditioning
- Amount and quality measurement
- Compression
- Odorizing Unit

Gas Conditioning

Natural gas delivered in the United Kingdom is a mix of methane with other flammable hydrocarbons such as butane, propane or ethane which results in some cases to a higher calorific value as what biomethane can contain. For allowing the injection into the grid, the calorific value as well as the Wobble Index from the biomethane should be equal to the local gas in the network, which if needed, through the mix of small portions of LPG in the biomethane can be achieved.

Analytical Measuring Instrumentation

The Biomethane to the Grid Plant is equipped with reliable and calibratable analytical instruments installed along the whole chain of process for measuring all the properties, quality and volume that biomethane should posses before injecting it into the grid. The instrumentation is calibratable for regularly verifications from the network operator.

Compression

The grids are designed principally as a transportation system of gas, which are able to carry natural gas across Europe and even intercontinental. The infrastructure is therefore complex and classified according to the delivery purpose: international, national, regional and local; the pipeline of each classified network has different pressures that are required to match before the

entry connection of the injection plant. The typical pressure ranges where biomethane is injected are between 2 - 70 bars.

Odorizing

Biogas after cleaned and upgraded has an imperceptible smell, therefore must be odorise as a safety requirement for leakage detection. The odorant type accepted by the GS(M)R is a mixture of mercaptan and sulphide derivatives.

Summary and Conclusions

There is a great potential that the waste water treatment industry has for the sewage gas upgrading and injection into grid or as vehicle fuel, the infrastructure and experience on the sewage gas production from WWTP plays an important factor and exemplary for the consolidation of the biomethane production and commercialization in the United Kingdom.

However, it is important to remember that the biogas cleaning and upgrading technologies have technical and economical limitations which should be kept in mind while implementing a biogas or sewage upgrading project:

Oxygen and Nitrogen Gas

Through the commonly known cleaning and upgrading technologies such as the physical and chemical scrubbing systems as well as the membrane process, are not able to remove these components and might even enrich the gas with more oxygen and nitrogen. The PSA system is able to partially remove them but is strongly dependant on the CO_2 concentration. Sewage gas has under normal circumstances low traces of oxygen and nitrogen, ideal for the injection into the gas grid. In case of higher amounts of oxygen, possible leakages in compressor blower's system are usually the cause.

Contaminants

Before delivering the sewage gas to the cleaning and upgrading plant, a pre-cleaning system should be available for removing the high concentrations of toxic elements such as H_2S or Siloxanes which are typical in the sewage gas production. The cleaning step from the different type of biogas upgrading plants usually is designed for the fine desulphurization (i.e. concentration reduction from 200 ppm to 3 ppm). The BUP from Schmack Carbotech has a patented fine-filtering system especially for sewage gas, removing not only the H_2S but also contaminants in the range of BTX, chlorinated hydrocarbons, CFCs, alkanes, thiols and siloxanes, nevertheless the concentrations should be kept under ppm level.

Feasibility

Biogas projects involving the cleaning, upgrading and injection into the grid are a proven technology with more than 15 years of experience in countries such as Sweden, Germany and Switzerland. With over 45 biogas upgrading plants in Europe, a common constant which determines the success of implementing a project is mostly the size of the plant.

Due to the reliability is needed from a biogas upgrading plant and as well the injection into the grid with the required quality and flow, it is essential to set up a reliable, well-proven control and monitoring system which brings the confidence and safety needed to the authorities as in any other industrial energy production plant. Such systems are consequently expensive and will not depend on the size of the plant, i.e. the smallest plant should have the same equipment as the biggest plant, and therefore smaller plants will have higher capital and operational expenses per cubic meter of raw gas to be upgraded and consequently carrying a tighter feasibility to the project.

Taking into account the Renewable Heat Incentives to be implemented in April 2011 for biomethane injection, the minimum size of a standard upgrading plant including the injection into the grid is recommended with more than 250 m^3/h of sewage gas production this can be compared to a 500 kW-size of CHP plant.

Schmack Carbotech Gas Processing Plants

Biogas and biomethane are high explosive gases which should be processed and handled with all the safety measurements necessary for a safe operation. Therefore biomethane to grid injection and biogas upgrading plants from Schmack Carbotech are equipped with highly sophisticated equipment and designed with safety valves for pressure and flow, telemetry equipment for remote monitoring and control, gas chromatographer for quality measurement and robust metering equipment for volume and energy measurement with high accuracy.

With more than 15 years of experience in the field of biogas upgrading and almost 40 plants built worldwide, Schmack Carbotech has achieved international experience and consolidated as pioneer in the industry of biomethane gas injection.