UPGRADING BIOGAS TO BIO LNG

A new technique developed by Professor Bert Brouwers from the Eindhoven University of Technology makes it possible to upgrade low-quality biogas produced in a manure digester into high-quality BioLNG, a popular fuel for trucks, locomotives and barges. According to Bastiaan van den Engel from Encon Clean Energy in Rotterdam, the process is already profitable without subsidies.

Door Joost van Kasteren

Fermentation of manure and other organic material produces a biogas that contains only about 50% combustible methane. The remaining 50% consists mostly of carbon dioxide. After removal of small amounts of water and hydrogen sulphide (which produces a rotten egg smell) biogas can be used as a fuel in an adapted gas motor to make electricity and heat. However, because of the availability of cheap electricity from Germany, the price paid for electricity is low and also fluctuates. As a result, more and more companies are disconnecting their combined heat and power (CHP) generators from the grid.

Producing heat

“The production of heat remains the only serious option for using biogas from a digester,” says Bastiaan van den Engel at Encon Clean Energy in Rotterdam, The Netherlands. “But for this to be practical in economic terms you have to be assured of a continuous demand for heat, either on your own farm or from some other business in the area such as a greenhouse or a hotel. If there is no market for heat, the only other option currently open to farmers is to upgrade the quality of the biogas to a level acceptable so that it can be fed into the national or regional gas grid.”

Gas that is fed into the main, high-pressure grid must be compressed to a pressure of 30 to 80 bar, which is quite expensive. The biogas can also be fed into the regional, medium-pressure grid for which it only needs to be compressed to 8 bar. From there it is fed into the low-pressure grid (100 mbar) that brings it into houses and buildings. Then there are still other obstacles, says Bert Brouwers. “In the medium- and low-pressure grid demand fluctuates day by day and season by season. On a beautiful summer day there is almost no need for gas, so the regional administrator will not be willing to buy extra gas from farmers. In winter, when more gas is needed, demand fluctuates largely during the day. During the evenings and weekends demand is much higher than during weekdays days when people are at work or school.”

Upgrading biogas for transport use

Another option is to compress the upgraded biogas to a pressure of 80 bar to sell it as compressed natural gas (CNG) rather than feeding it into the grid. However, the market for CNG derived from biogas is limited. Although companies and institutions that use CNG as an alternative to petrol and diesel are willing to pay a reasonable price for it, the mileage range of vehicles with a full CNG tank is limited. As a result, CNG is not an attractive fuel for use for long haul freight by truck or barge.

Instead, Brouwers and van den Engel believe that from an economical viewpoint the better option is to process biogas to produce a liquefied natural gas (BioLNG). They have worked together to develop a small-scale system for the production of BioLNG designed to operate profitably for farmers pooling biogas collected from just a few individual farms as well as for contractors who collect biogas from a small number of farms.
First step

“The first step is to optimise the actual fermentation of manure,” says van den Engel. “Encon Clean Energy can provide a digester that inoculates itself by feeding half of the digestate produced back into the fermenter along with fresh manure. This reduces the residence of the manure to 10 to 15 days, and ensures that more than eighty percent of the organic matter in the manure is converted into biogas. We can produce 43 cubic metres of biogas from one cubic metre of cow manure, without having to add crop residues or other materials currently used for co-digestion. The installation, which has been developed in Germany, already operates profitably for dairy farmers processing manure from 70 cows and a pig farmer processing the manure from 1700 pigs.”

More value for biogas

However optimising the production of biogas does not address the question of how to get more value out of it. The answer to this problem came to Van den Engel via a chance contact with Bert Brouwers from the Eindhoven University of Technology. “Brouwers had developed a technique to separate raw natural gas into several components, resulting in – among other things – the separation of pure CO₂”, explains van den Engel. “Although the technique was originally developed for the oil and gas industry, it is scalable. As a result it can be used cost-effectively for processing smaller volumes than those normally used in the oil and gas industry. An additional advantage is that the device is easy to operate and requires virtually no maintenance, making it simple and safe for farmers or contractors to use.”

Fermentation of manure produces a digestate – a semi-solid substance – as well as biogas. The digestate can be dewatered in a press and dried further by indirect heating to 400 °C using, for instance, the heat from the exhaust pipe of a gas-powered motor. “Drying the digestate offers several advantages,” says van den Engel, “Firstly, the water vapour that is released contains ammonium phosphate, which can be recovered and used again. In addition, the digestate can be dried to produce 90 percent dry matter. This greatly reduces its weight when transporting it over long distances. The dried digestate can also be used as fuel for a pyrolysis process to produce syngas, a mixture of CO₂ and hydrogen. The syngas can be turned into liquid fuel or feedstock for the chemical industry. The pyrolysis residue can be used as a solid fuel.”
Liquefying carbon dioxide

The technique developed by Brouwers consists of a number of steps. Once the biogas has been stripped of water and other harmful components, such as hydrogen sulphide, it is compressed to 85 bar and then fed through a membrane – a molecular sieve – that separates the flow of biogas into pure methane and a mixture of methane and carbon dioxide containing about 20 percent methane. To recover this remaining methane, the mixture is further purified by feeding it through a Joule-Thomson throttle valve. The thermodynamic principle behind the use of a Joule-Thomson valve for rapid expansion / cooling of gas goes back 150 years, and the technology behind it involves little more than incorporating a narrowing or a clot in the gas pipe. The Joule-Thomson valve takes advantage of adiabatic expansion – in which the gas mixture is rapidly expanded without exchanging heat from the surrounding atmosphere – to produce rapid cooling. During the purification process, the biogas is cooled to below the temperature at which carbon dioxide condenses. The gas stream, which now contains a fine mist of small droplets, is subsequently passed through a rotational particle separator (RPS), to separate the gas and the liquid droplets.

The RPS consists of a fixed steel cylinder that contains a rotating cylinder inside. This second cylinder contains dozens of smaller tubes, each with a diameter of a few millimetres, soldered together. In the separation process the gas/liquid mixture is introduced tangentially (sideways) into the top of the outer cylinder, and begins to swirl like a cyclone. Larger drops of liquid CO₂ fly against the wall of the outer cylinder and form a stream of liquid, which can be drained off. The swirling of the incoming gas/liquid mixture also makes the second cylinder rotate around its axis. This, in turn, creates a centrifugal force in the small tubes contained in the cylinder, and causes very small droplets of CO₂ to hit the wall inside the small tubes, forming a film of liquid CO₂ that can be collected at the lower end of the rotating cylinder. The process, which uses only small amounts of energy, results in clean liquid CO₂ and clean methane. The entire installation is very compact, with weight and volume– at least ten times smaller than existing gas-liquid separation technology.
The RPS invented by Brouwers was first used almost thirty years ago in a tabletop air purifier, made by Philips. Although the air purifier is no longer made, Brouwers further developed the RPS into a device for separating gas/liquid mixtures, which is attracting interest from the oil and gas industry. The device – a breakthrough technology – is now being commercialised by Brouwers' own recent start-up company, Romico, which will soon start producing the device on a commercial scale.

Condensed Rotational Separation (CRS) is a combination of rapid decompression (cooling) and separation of natural gas and CO₂ droplets (mist) was developed for the oil and gas industry. Raw natural gas can contain up to 70 percent carbon dioxide (CO₂). The CO₂ is often separated out on the rig and re-injected into the soil. However, because of the high pressures involved, the separation reactors are normally large and heavy. Thanks to the high flow rates used in CRS, the separation can be carried out using a much smaller installation, reducing the weight and volume of the CRS installation by a factor of ten – an important consideration on an oil rig.

The purified methane can also be liquefied on an offshore drilling platform, and collected by LNG tankers. This would eliminate the need to build expensive pipelines, and makes it economically feasible to produce LNG from smaller fields. The liquefied CO₂ can be re-injected and used for enhanced oil recovery (EOR) to extract extra oil and/or gas from the well.

Another application of CRS-technology is the production of LNG from gas that is distributed via the high-pressure grid. To feed it into the regional grid the pressure of the gas has to be lowered to 8 bar. Using a Joule-Thomson valve the gaseous methane is liquefied and can be used as transport fuel. “This is already common practice in the United States,” says Brouwers. “Thanks to the emergence of shale gas a third of the trucks in America drive on LNG. The same could happen in the Netherlands.”
More liquefying

Purified methane, at a pressure of 80 bar, can be fed into the Dutch high-pressure grid. This is currently a profitable option if the payments of the national Subsidy Scheme for Sustainable Energy (SDE) are taken into account. Although these SDE subsidies vary, they can increase from 60 cents to over a euro per cubic metre. “Although this sounds like a favourable option, selling the purified methane as a ‘green gas’ will make the farmer dependent on subsidies,” says van den Engel. “But when the subsidies come to an end 12 years from now, in 2026 the price for green gas will plummet to 16 cents per cubic metre. A better option is to cool the methane down quickly to -170°C, to produce liquid methane.”

The whole process of cooling and separation in a RPS is known as Condensed Rotational Separation (CRS). Brouwers. “CO₂ can be used in the food industry, for example, to produce the bubbles in soft drinks, and as a gaseous fertiliser in greenhouses. Increasing CO₂ levels in a greenhouse atmosphere makes tomato and other plants grow 10 to 15 percent faster. The BioLNG can be used as clean transport fuel.”

Bioticket to sell biofuel

Although CRS installations are technically feasible, the question remains as to whether the process can be carried out economically on the small scale serving just five or six farms. Van den Engel is confident that it can be. Calculations carried out by students from the Eindhoven University of Technology indicate that BioLNG will cost around 78 eurocents per kilogram, without taxes. The price at the pump is currently about 96 cents, including 20 cents of excise duties and taxes. So will it be government excise and taxation policies that determine whether it will be profitable to produce BioLNG from manure? “Not entirely,” says van den Engel. “European regulations stipulate that by 2020 at least ten percent of the energy for transport must come from renewable sources. Companies that use more than ten per cent biofuel can sell their surplus to other transportation firms via biotickets. Under EU-regulations BioLNG is a considered to be an advanced biofuel, meaning it does not compete with food or feed. As a result it can be sold in the form of biotickets for 50 cents per kilo on top of the price at the pump.”

Also in the long term the market demand for BioLNG is expected to grow, not only as a fuel for freight transport, but also as a fuel for barges on inland waterways and public transport. A study published by the Provinces of Groningen and Friesland showed that switching to the use of BioLNG in diesel locomotives would be ultimately cheaper than electrifying the rail network in those regions.
Overall, the outlook for generating BioLNG from manure looks optimistic. The process is technically feasible, and there is a growing demand for advanced biofuels that do not compete with food and feed. “This is reason enough to encourage the BioLNG project to continue”, says Jan Westra, advisor Biobased New Energy for the Eindhoven City Region. “As part of the BioenNW ‘Delivering bio-energy to North West Europe’ project, it meets the objective of adding value to residual biomass that is difficult to process. Its deployment of advanced technology also fits in very well with the Eindhoven region’s aim to become one of the world’s high tech hotspots. Although high tech and manure might seem to be an unlikely combination, this is an example of the kinds of combinations we need for a sustainable future.”

Upgrading of biogas to BioLNG is one of the five business cases that are to be developed as part of the framework of the Interreg IVb project BioenNW, ‘Delivering Bio-Energy to North West Europe’. Five regions (Paris, Birmingham, Aachen and Eindhoven) are cooperating to promote innovative technologies to process and add value biomass residues. Each of the five regions has a Bio-Energy Support Centre. The City Region of Eindhoven (SRE) serves as the Bio-Energy Support Centre in the Netherlands. Development of the business case is done in cooperation with Encon Clean Energy and Romico.