# "Chances for Bio-LNG"

Bakker, B.[1], Langerak, J.[1], Lems, R.[1], Dirkse, E.H.M.[1]
[1]DMT Environmental Technology
Tel. +31 513 636 789 Email: jlangerak@dmt-et.nl

## Abstract

An increasing effort is put into the utilization of organic waste streams in anaerobic digesters, producing useful products such as fertilizers and biogas. It becomes increasingly attractive to upgrade biogas to natural gas quality and consequently liquefy the gas to Bio-LNG. DMT Environmental Technology has been developing biogas treatment plants for over 25 years, closely following market developments.

Natural gas is one of the cleanest fuels available nowadays. The carbon footprint is low, and local emissions of NOx and SOx are virtually zero in comparison to other fuels. It can be combined with petrol or diesel to keep a high flexibility in fuelling. Using Liquefied Natural Gas (LNG) instead of Compressed Natural Gas (CNG) can extend the travel range of vehicles or trucks to "normal" mileages. Therefore LNG becomes even more popular in the United Kingdom (UK) and in the rest of Europe.

LNG is not only used for transportation but also as natural gas source for remote villages and/ or industries which are not connected to the gas grid. Bio-LNG is made from biogas and has a few considerable advantages over LNG. The purity of Bio-LNG is higher, giving it a better quality. Bio-LNG can be locally produced saving transport costs and carbon emissions. And finally it is made from waste sources and therefore 100% sustainable.

DMT Environmental Technology combines the newest biogas upgrading technology, using high selective membranes, with small scale liquefaction. The result is a plug and play, containerized system; Carborex® MS. This system can be used in combination with a liquefaction unit for Bio-LNG. The derived product is much more valuable than biogas or bio-methane gas. In this article a glimpse into the future of BIO-LNG is provided.

**Keywords:** Carborex® MS, Biogas, Bio-methane, Bio-LNG, Car fuel, Gas separation, Green gas, Highly selective gas membrane, Liquefaction, Membrane separation, Upgrading

## Introduction

There is an increasing drive to use cleaner fuels. Last years, the amount of cars, trucks, busses and other transport, which are driven by Compressed Natural Gas (CNG) or Liquid Natural Gas (LNG) have increased significantly. The big potential of gas driven cars is shown in the report of the Deutsche Energie Agentur (Peters et al. [1]). Peters predicts an increase of gas driven cars from 180.000 in the year 2013 to more than 1,12 million cars in 2020.

## Gas as clean fuel

The European Union (EU) has set the target to use 10% biofuels in the transport sector and overall a 20% share of energy from renewable sources by the year 2020. Despite being one of the cleanest fuels available, natural gas is still a fossil fuel. Alternatively, there are several biofuels on the market, for example, bioethanol, biodiesel and biogas. The main advantages of biogas compared to bioethanol or biodiesel are:

- Biogas is cheaper (£0,86/liter at tank station in Joure – the Netherlands, £1,28/liter for biodiesel and bioethanol fuel (E85) £1,20/liter for biodiesel (B30)) [2]
- Biogas when created from waste material does not compete with the food production chain.
- Upgraded biogas is the only biofuel which has better properties than its fossil counterpart, because biogas can be considered as almost 100% biomethane, whereas natural gas contains nitrogen, hydrocarbons and other compounds.
- As shown in figure 1, the emission of well-to-wheel is significantly lower for biogas than for bio-ethanol or biodiesel.

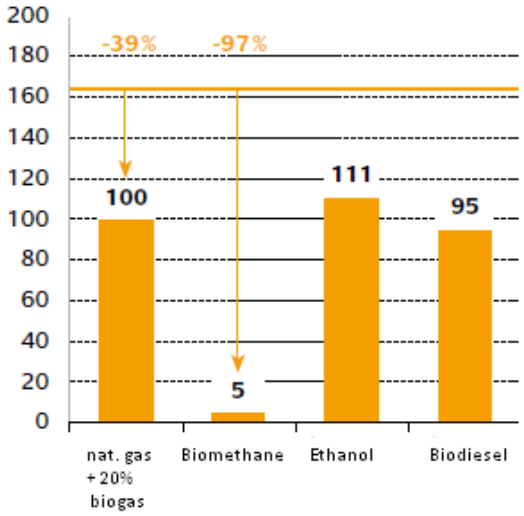


**Figure 1: Greenhouse gases emissions Well-to-Wheel in g $CO_2$/km**

Biogas will play an important role to realize the renewable energy target of the European Union. Biogas is already widespread used in the Netherlands [3]. Already 3000 vehicles for personal use, 2000-3000 business cars and 428 city buses are using green gas as fuel, and these amounts are only more and more increasing.

Driving on BIO-CNG means similar engine power and having similar speed as cars driving on their fossil counterpart and can provide certain benefits, e.g. cars on BIO-CNG have free access to environmental zones.

## LNG potential

Natural gas and biogas can be compressed (CNG) or liquefied (LNG), which reduces the volume significantly. LNG and CNG are common fuels for transport due to their low carbon footprint and low local emissions of $NO_x$ and $SO_x$. However, LNG is favorabele because:

- LNG reduces its volume by a factor 600 (600 $m^3$ to 1 $m^3$) [4], whereas CNG has a volume decreasing by a factor 200-250 [5].
- LNG can therefore be easily transported by ships or trucks because of its bigger volume decrease compared to CNG.
- LNG instead of CNG extends the mileages.
- It is relatively easy to convert LNG to CNG, so a combination of Liquid and compressed gas tanks stations (LCNG) are possible.
- LNG is liquefied to -162 °C. During this process remaining oxygen, carbon dioxide, water and sulphur compounds are further eliminated, leaving an even cleaner product.

Liquefaction of natural gas is currently mainly carried out at large scale and transported by ships and trucks to LNG-terminals, where it is further processed. In 2011, the Netherlands has opened its first LNG-terminal in the Rotterdam harbor at the Maasvlakte. It is forecasted that the Netherlands will be the main producer of natural gas until 2025 in the European Union, but after 2025 the Netherlands will have changed from net producer to net importer [6]. This means that the Netherlands need to prepare an infrastructure for LNG-gas. Similar activities are performed all over the world.

This development will give an extra impulse to the production of Bio-LNG.

## Decentralized/local LNG production

BIO-LNG has higher methane content than its fossil counterpart, because it doesn't contain higher hydrocarbons [7]. BIO-LNG produced from biogas has roughly the same chemical formula as liquid natural gas, relatively pure methane but without the higher hydrocarbons present in LNG.

BIO-LNG is a 100% biofuel and can be produced at any place where anaerobic digestion occurs. This means that any farmer, community, or city can produce its own BIO-LNG giving the following benefits:

- Good distribution. Transport can be carried out by trucks and ships. Due to its volume decrease by liquefaction, relatively large amounts of gas can be transported. No

necessary complex gas piping network, and no compressor needed to transport gas into the network.
- Due to transport by trucks, a BIO-LCNG tank station can be built without connected to a gas grid. The costs of these types of tank stations are only 25 % of a normal LCNG station, because there are no high costs for gas grid connections and additional compressing steps. [8]
- BIO-CNG created from BIO-LNG has no pollutants and is 100% methane gas in compressed form, it does not contain 15% nitrogen as fossil CNG does.
- Farmers, cities, communities can be self-providing and are independent of a central network
- The availability of BIO-LNG at each community will keep the price low.
- Fuel will be available in regions where there are no fossil fuels available.
- If biogas is produced from household waste, taxes or levy of waste per household could be reduced. In this way, the community profits from the closed cycle.

It is for these reasons that this article focuses on small-scale production of bio-LNG. A gas upgrading technique and liquefaction of biogas for small scale is discussed. Eventually, a costs estimation is made.

## Choice of the upgrading system

Raw biogas contains 30-45 % of $CO_2$, $H_2S$ and other compounds that have to be removed before liquefaction to BIO-LNG. Removing these components can be performed by several biogas upgrading techniques. Each process has its own advantages and disadvantages, depending on the biogas origin, composition and geographical orientation of the plant. The upgrading systems taken into account in this article are pressurized water scrubbing (PWS), catalytic absorption/amine wash (CA), pressure swing absorption (PSA), highly selective membrane separation (MS-HS) and cryogenic Liquefaction (CL) which are the most common used upgrading techniques. Table 1 shows a comparison of performance for these techniques at 8 bar injection.

For small scale BIO-LNG production the following aspects are important

- High purity of the outlet stream, up to 99% methane.
- Simplicity and easy handling, customer can just connect this gas stream to the upgrading inlet and start. (the plug and play principle)
- Flexibility, system should be capable of handling fluctuations in gas stream volumes
- No chemicals involved and no waste streams
- Energy efficiënt

**Table 1: Comparison of performance for various upgrading techniques (result at 8 bar) [9]**

| | PWS | CA | PSA | MS-HS | CL | |
|---|---|---|---|---|---|---|
| Produced gas quality | 98 | 99 | 97 | 99 | 99.5 | % |
| Methane slip | 1 | 0.1/0.8[1] | 3 | 0.3-0.5 | 0.5 | % |
| Energy efficiency[7] | 96/99[2] | 93-96 | 93 | 98 | 93 | % |
| Electrical use | 0.23-0.25 | 0.15/0.35[3] | 0.25 | 0.21-0.24 | 0.35 | kWh/m(3) biogas |
| Reliability / up time | 96 | 94 | 94 | 98 | 94 | % |
| Gas fluctuation allowed | 50-100 | 50-100 | 85-100 | 0-100 | 75-100 | % |
| CAPEX | 2000 | 2150 | 2250 | 1800 | 2300 | €/m3 (4) |
| OPEX | 6.1 | 6.5 | 6.7 | 5.5 | 7.1 | Euro ct/m3 (4) |
| Bio Methane loss | 110.000 | 95.000[1] | 194.000 | 55.000 | 91.670 | €/year (4) |
| Foot print x height | 0.15 x 12 | 0.17 x 12 | 0.18 x 4 | 0.1 x 2.5 | 0.12 x 3 | m2 /m3xm(6) |
| Maintenance needed | Medium | Medium+ | Medium+ | Low | High | |
| Operation ease | Medium | Medium+ | Complex | Easy | Complex | |
| Waste streams | Water | Chemicals | Carbon | None | None | |

From table 1 it can be concluded that a membrane system is the most suitable option. The membrane system have high methane purity at the outlet, high energy efficiency, high uptime, the widest range of fluctuations allowed, no waste streams and moreover, a simple system where gas the stream can easily be connected in a plug and pay manner. Main disadvantage of membrane systems are that they are sensitive to pollution by organic compounds, which can decrease efficiency. However, by applying a proper pre-treatment in which these compounds are eliminated, then this disadvantage can be nullified.

DMT Environmental Technology has developed the Carborex ®MS membrane system which fits all the requirements for small scale biogas upgrading.

## Carborex® MS multistage principle

The principle of membrane separation is that the components of a gas mixture are separated by the difference of solution diffusion through a polymer, which is coated on a porous layer.

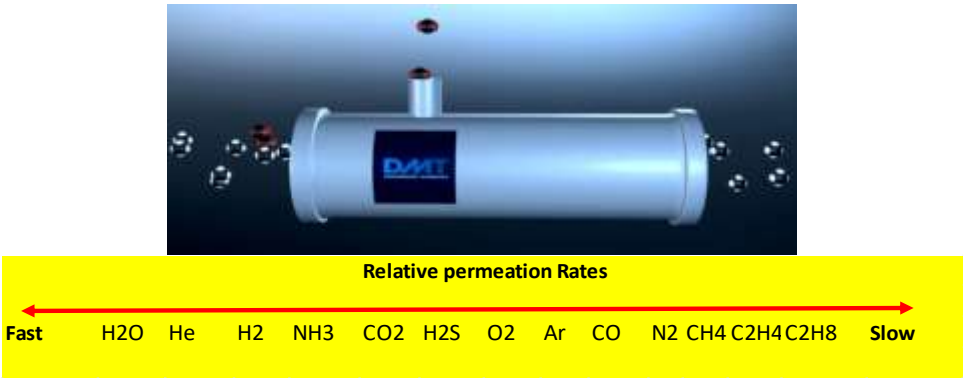


**Figure 2: Carborex® membrane and relative permeation rate of the membrane**

The most important aspect of membrane separation systems is the total recovery rate of the methane. Longer contact time of the gas with the membranes result in higher $CO_2$ removal, although it also results in methane loss. Methane loss is the percentage of methane that is lost to the environment. As can been seen in figure 3, this phenomena can be overcome by using a two-stage or even better a multistage membrane system. Methane recovery of 99,6 % can be obtained, whereas 98,0% of the $CO_2$ is removed, leaving around 2,0% of $CO_2$ in the outlet biogas.

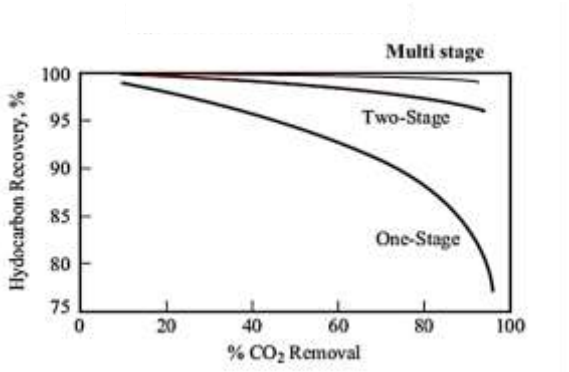


**Figure 3: Plot of Hydrocarbon recovery vs. % $CO_2$ removal.**

To eliminate $H_2S$, water and other compounds the system consists of a gas pre-treatment, consisting of an activated carbon filter, and gas condition including filters, heat exchanger and condensate remover.

## Liquefaction

Liquefaction is not a new technology. There are various systems available, varying from cascades with various consecutive loops, mixed refrigerant cycles, or gas line pressure expansion in combination with nitrogen expansion. In all cases expansion of a gas is the main cooling mechanism. Cryogenic liquefaction has some important benefits which are comparable to upgrading.

- Simplicity, easy handling according to the plug and play principle
- Robust installation, uptime is high and low maintenance required
- Small scale installation
- Energy efficient
- No chemicals involved or waste streams

DMT Environmental Technology has investigated the different technologies and developed a BIO-LNG process that incorporates the best options and DMT expects to start up a first Small scale BIO-LNG plant in 2014.

## Configuration of the BIO-LNG system

The final configuration will consist of a combination of the Carborex ®MS biogas upgrading system with the biomethane liquefying system and is shown in figure 4. Gas is created at the digester through anaerobic digestion. Then the gas is cooled and it passes through an activated

carbon filter to remove $H_2S$, solid particles and other compounds which can damage the membranes. Next, the gas is led through the Carborex® MS membrane system and a very clean gas with a methane concentration up to 99% is produced. This is processed by the liquefaction process. The biomethane is liquefied at -140 °C and stored in a storage tank before it is transported by a truck to a fuel station nearby.

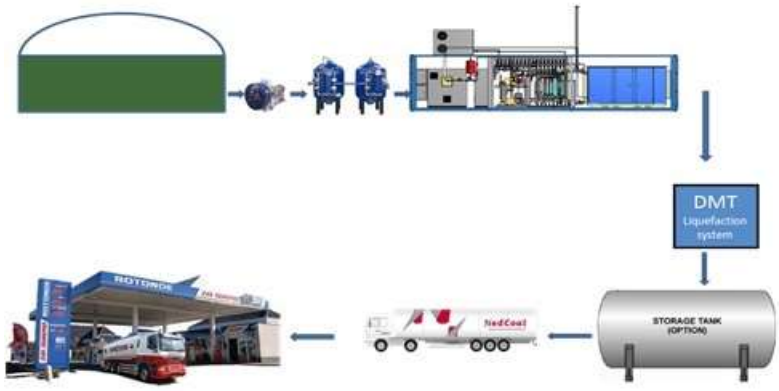


**Figure 4: Configuration digester to tank station**

## Economic perspective BIO-LNG

With the Carborex ®MS and liquefaction system it will be possible to create BIO-LNG for 250-400 euro per ton. The investment costs, maintenance, energy costs and personal are included in this estimation and are based on previous studies. [9-10]

BIO-LNG is very interesting for the transport sector. Latest figures shows that an extra investment of € 35.000, - is needed to buy a LNG truck instead of a diesel version. However, the price of LNG (at the moment) is significantly lower[11]. In less than 5 years (90.000 km) return of investment can be achieved. Moreover, the diesel price is fluctuating, whereas the price of LNG is much more stable.[11]

An extra impulse will be the introduction of so-called 'biotickets'. Simply subscribed, a bioticket is the proof of a certain amount of renewable energy inserted in the society. Who delivers green gas as a fuel for transport, can receive such a ticket. All suppliers of fuels are nowadays obliged to add 5 % of renewable energy to their current fossil fuels. The European Union has set the target to add 10% of renewable fuels before 2020. Every supplier who delivers more renewable fuels than the set target by the EU will receive biotickets in return. The values of those biotickets have not been published, but are determined at each transaction. Groen gas [12] has published the single and double bioticket prices of the period 2009-2012. The average value of the bioticket was €0,21/kg biogas produced. When biogas is created from second generation biofuel the value was even higher.

The difference between first and second generation biofuels are that first generation biofuels are derived from sugars or vegetable oils producing bioethanol through fermentation [13]. Second generation fuels have been generated from any non-food source of organic material, like plant material, wood, food crop waste, animal manure or material. These materials do not compete with food chain production. [13]

Third generation fuels are based on improvements in the production of biomass. Special engineered energy crops such as algae as its energy source could be considered as third generation biofuel. [14]

## Conclusions

The European Union has set a target of a 10% share of renewable fuels in the transport sector by 2020, the upcoming market of BIO-LNG could play a major role in achieving this target. Bio-LNG is clean and has no pollutants, $NO_x$ or $SO_x$ formed after combustion.

There are many opportunities for bio-LNG, especially for the transport sector as ships and trucks can use bio-LNG as their fuel. Because of the volume decrease, relatively large amounts of fuel can be easily transported. This favours decentralized production. Farms, cities or communities can have their own digester with upgrading system and liquefaction, which saves the construction of complex pipeline networks and expensive compressors for bio-LNG.

With the Carborex ®MS system of DMT environmental technology, gas from digesters can be easily upgraded. The outlet stream is pure, the uptime and flexibility will be higher. This is a highly efficient technology which does not use chemicals and has no waste streams.

DMT combines the best available technologies in their development of a BIO-LNG process. DMT expects to start up a first Small scale BIO-LNG plant in 2014. BIO-LNG can be produced for €250-400,-/ton and the upcoming bioticket market can make production of BIO-LNG even more interesting.

## References


1. **Peters D, Rumpke CA, Kalinowska D, Erdgas und biomethan im kunftigen kraftstoffmix, Deutsche Energie-Agentur GMBH, 2011**
2. **Provincie Gelderland, VCC OOST, www.fuelswitch.nl**
3. **GGM, A cooperation between all green gas industries in the Netherlands www.groengasmobiel.nl**
4. **Chevron Human energy, http://www.chevron.com/deliveringenergy/naturalgas/liquefiednaturalgas/**
5. **Gazprom, http://www.gazprominfo.com/articles/compressed-natural-gas/**
6. **Government of the Netherlands, http://www.government.nl/issues/energy/gas**
7. **Holland Innovation Team, Quality of LNG and bio-LNG for application as transport fuel, 2011, http://www.bio-lng.info**
8. **Holland Innovation Team, Feiten en cijfers BIO-LNG, 2009**
9. **Lems R, Dirkse EHM, Next generation biogas upgrading using high selective gas separation membranes – showing the Poundbury project – , 2012**
10. **Broeils M, Chances for small scale biogas upgrading in Sweden, University of Van Hall larenstein**
11. **www.lng24.com**
12. **Groengas, Biotickets voor groengas, 2012**
13. **UN report; sustainable Bioenergy: a framework for decision makers: april 2007**
14. **Chisti Y, Biodiesel from Microalgae; Biotechnology Advances 25 (2007), p. 294-306**