IEA Bioenergy
Technology Collaboration Programme

Green methanol from biogas in Denmark

a versatile transport fuel

Case Story

IEA Bioenergy: Task 37: 11 2020

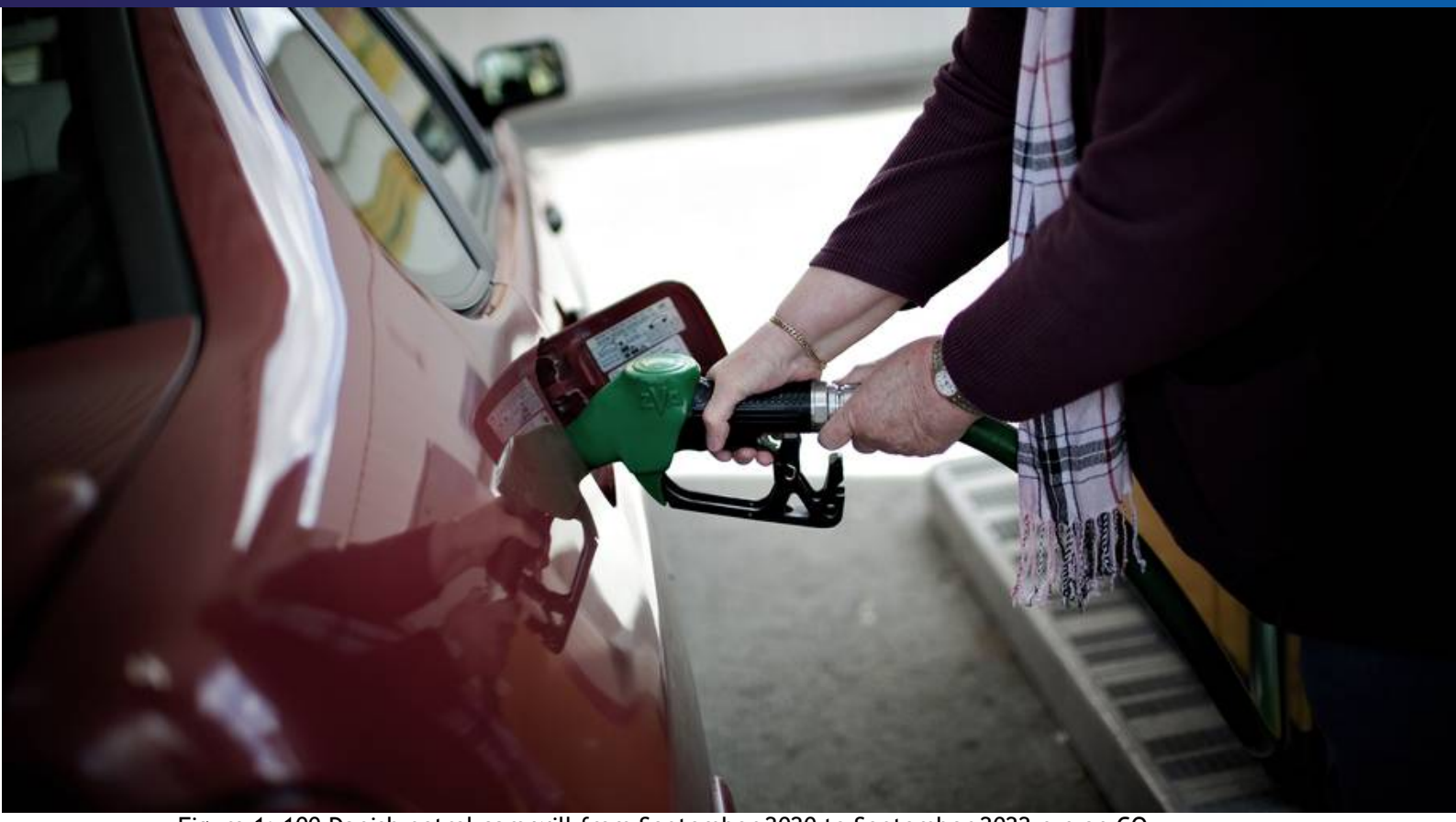

Figure 1: 100 Danish petrol cars will from September 2020 to September 2022 run on CO_2-friendly bio-methanol from biogas, as part of the project "Biomethanol M85 at Danish fuel stations," supported by the Danish Energy Agency's development program EUDP.

Green methanol and grey methanol

Methanol is the simplest alcohol with a chemical formula CH_3OH. It is a light, volatile, colourless, flammable liquid with a specific alcohol odor; it is highly toxic and unfit for consumption. Methanol has many uses (Figure 2) and is versatile as a fuel source with an energy value of 16MJ/l or 20GJ/t. “Grey” methanol, produced using natural gas as a feedstock, has emissions similar to other fossil fuels such as liquified natural gas (LNG) and marine diesel oil (MDO). Global methanol production currently amounts to about 80 million metric tonnes per year. “Green” methanol (or bio-methanol) may be produced via biological pathways (anaerobic digestion), thermo-chemical pathways (gasification) or electrofuel pathways (power to gas) as indicated in Figure 3. As a renewable fuel bio-methanol has a much lower global warming potential than fossil fuels and considerably lower greenhouse gas emissions when compared to methanol from fossil fuels (grey methanol) on a whole life cycle basis.

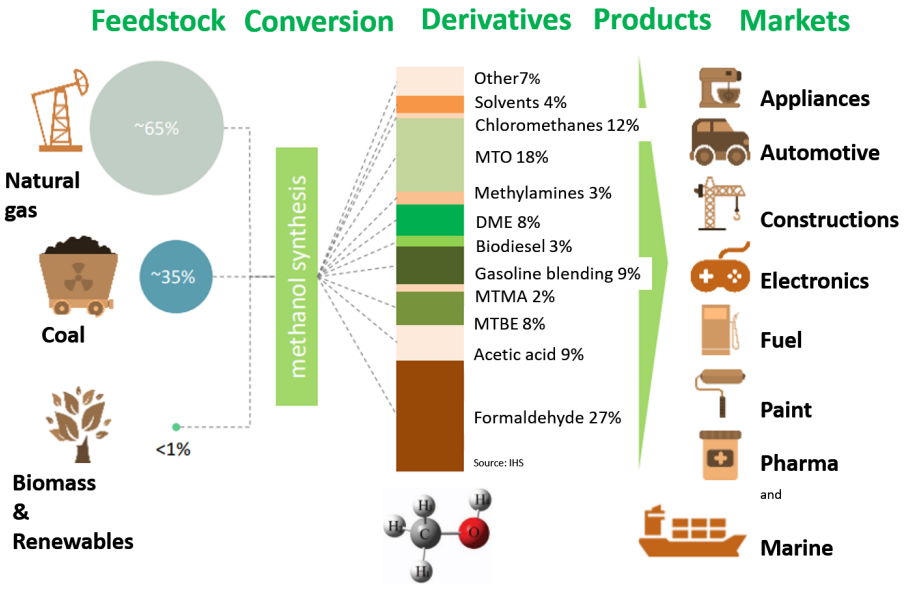

Figure 2: Methanol-feedstocks and markets; *Source: Methanol Institute*
MTO = methanol to olefins, DME = dimethyl ether, MTMA = Methyl Methacrylate, MTBE = Methyl Tert-Butyl Ether

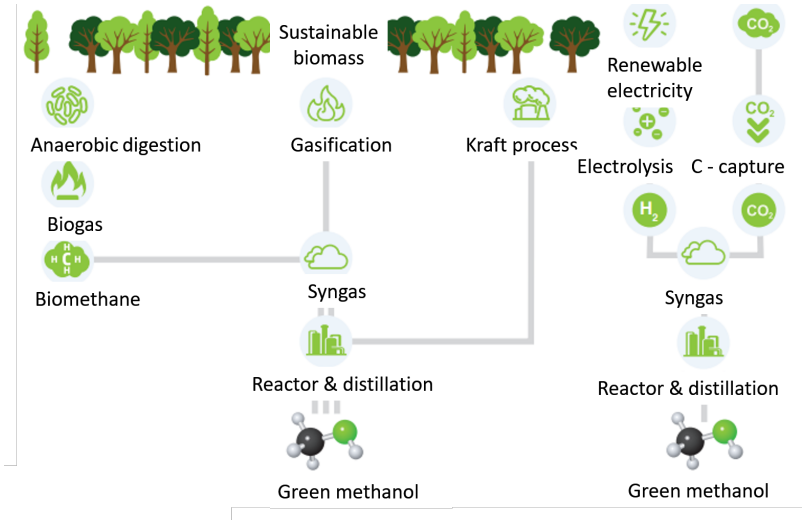

Figure 3: Green methanol production process from different renewable feedstocks; *Source: Methanol Institute*

The potential applications for bio-methanol as a liquid transport biofuel in a decarbonized world is significant, especially in haulage and heavy commercial vehicles. The Free On Board (FOB) price range in Rotterdam for green methanol is estimated between 500 and 600 Euro per tonne (c. €100/MWh). Large scale production of green methanol from biogas could be economically competitive with grey methanol from natural gas when the system is optimized utilizing circular economy systems (wastes to anaerobic digestion, curtailed electricity used for hydrogen and valorisation of O_2) and significant carbon taxes are imposed on fossil fuels.

Biogas conversion to green methanol in Denmark

In the **BioReFuel** project which runs from 2020 to 2023, Lemvig Biogas is assessing storage of electricity in the form of methanol obtained through conversion of CO_2 in the biogas and hydrogen via electrolysis of electricity (figures 4 & 5).

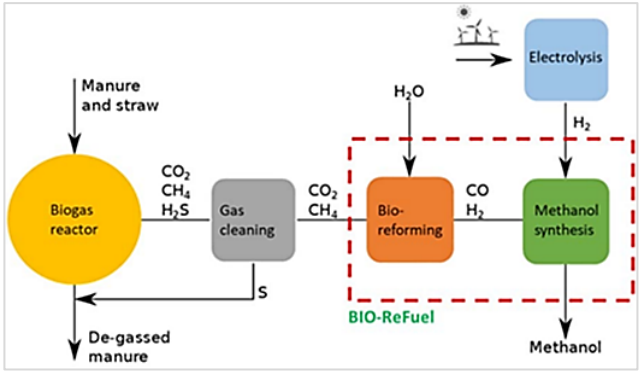

Figure 4: The process flow of bio-methanol production
Source: Lemvig Biogas

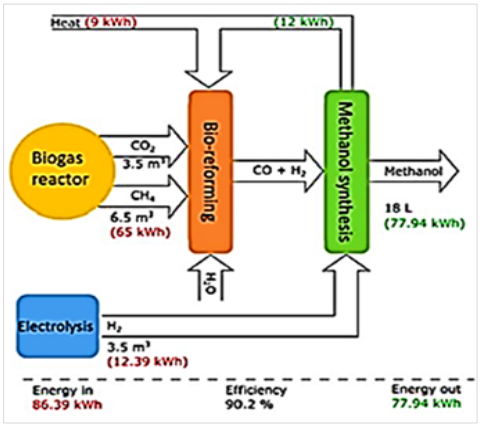

Figure 5: Energy balance
Source: Lemvig Biogas

In the **eSMR-MeOH** project (**Biogas for MeOH with electrical reformation**) Haldor Topsøe, Aarhus University and others are examining the production of green methanol based on biogas. The applied technology involves spliting biogas (into CO and H_2) using an electrically driven catalytic converter with additional energy injection in the form of hydrogen produced using electrolysis technology to convert the products of the split biogas into methanol (as per equation 1). Methanol synthesis is an exothermic reaction conducted between 200 – 300 ºC and 3.5 and 10 MPa as described as in Eq.1

$$CO + 2H_2 = CH_3OH \qquad \text{Eq. 1}$$

A large-scale pilot facility is under construction at the research centre in Foulum which is expected to produce 10 kg methanol per hour from 2022. The experience and the technology developed can be translated into an industrial system with the objective for the technology to be cost-effective at a scale suited to a large biogas plant. The circular economy system will be assessed solving questions as to to how to connect such a system to a renewable energy source (typically wind) and how to minimize waste. On completion of the project, the technology should have matured for immediate market integration as an original route for sustainable feasible methanol production.

Green methanol produced on biogas reduces CO_2 emissions from gasoline cars

Metanol is a well known fuel used in motor sports. M85 is a fuel blend of 85 percent green methanol, produced from biogas, and 15 percent gasoline. When used in gasoline cars the CO_2 emissions can be reduced by 70%. The project **"Biomethanol M85 on Danish fuel stations"** will test M85 over the time period 2020 and 2022; the results will be used to promote and encourage the use of sustainable methanol (produced from biogas) in private cars. This may give car owners in the near future a choice to refuel with M85 at the Danish petrol stations.

It is anticipated that by 2030 around a half million electric cars will be running on Danish roads, alongside a fleet of about 1.6 million traditional petrol cars. Therefore, in parallel with the electrification of the car fleet, a solution to reduce CO_2 emissions from existing petrol cars is needed. The project tests the M85 blend on newer car models, with turbo and direct petrol injection. The cars undergo a minor technical change, so that they run optimally on the M85 blend. The technical change involves reprogramming of the engine control with ECU flashing (in car computer), or the installation of a Flex-Fuel kit. Unexpectedly, the test car (a Peugeot 107 1.01 City car) was found to run on pure methanol and any mixture of methanol with gasoline without losing power or torque. A French Plug 'n Play Flex Fuel Kit allows the car to operate as a full-fledged Flex Fuel Vehicle (FFV). The modified cars can still be refueled with gasoline fuel if a M85 filling station is not within reach.

Five existing petrol stations in Denmark, located in Copenhagen, Skanderborg, Resenbro and Roskilde offer pumps dispensing M85. Further service stations are under consideration at Aalborg, Ringkøbing / Skjern and Aarhus. Several Danish municipalities have shown support for the project by making their own cars M85 compatibile with an overall ambition of highlighting to their own citizens how they can green fuel in their existing internal combustion engine cars. The methanol (converted from biogas) is presently sourced from Equinor at Tjeldbergodden, Norway. According to the Danish Methanol Association, the annual Danish potential of 48 PJ biogas is sufficient for methanol to replace the Danish consumption of gasoline. If methanol is also used for storage of wind power, the entire transport sector can be fueled - with no loss of tax revenue.

Green methanol from biogas – the future.

In 2004, the energy company Elsam presented its vision *Fra benzin til Venzin*, highlighting a shift in the Danish energy sector from CHP to CHP and transport fuels. In 2010, DTU published an analysis on how 6 PJ methanol / year can be produced at a large-scale plant, based on six different raw material combinations, one of which was biogas. It is economically advantageous to use all of the biogas (CH_4 & CO_2) for methanol production as this saves the cost of traditional bogas upgrading. In this process CH_4 & CO_2 are converted in an electrically heated reformer to synthesis gas (CO, CO_2 & H_2), which is then used for methanol synthesis, with an overall reaction as per Eq. 2. This equation requires a biogas with 75% CH_4 and 25% CO_2, however usually biogas comprises 60% CH_4 & 40% CO_2. This imbalance can be overcome in two ways: limit the reaction of CO_2 to 25% of the biogas and/or utilize H_2 as per Eq.1 to react with the remaining CO_2.

$$3\ CH_4 + CO_2 + 2\ H_2O \rightarrow 4\ CH_3OH \qquad \text{Eq. 2}$$

In 2020, Energinet.dk published its analysis *PtX in Denmark before 2030*, where green methanol from biogas is used as a calculation example, suggesting a price of DKK 200 / GJ (c. €96.6 /MWh). Danish experts estimate that the price can be lower for plants producing around 1000 tons per day (or 6 PJ per year). The Haldor Topsøe company recently indicated that the company is ready to produce green methanol from biogas in decentralised facilities connected with large-scale biogas plants without the need for government support.

IEA Bioenergy Task 37 "Energy from Biogas" http://task37.ieabioenergy.com

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