The Alkmaar 4 MW bio-SNG demo project

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1. Introduction

Natural gas provides nearly 50% of the primary energy used in the Netherlands. Even though energy demand could and should be reduced, meeting targets for the contribution of renewable energy and CO_2 reduction will be difficult without a large contribution of "green" gas, i.e. from renewable sources, to substitute fossil natural gas.

In a study performed in 2005 on behalf of the "Platform Biobased Raw Materials" Rabou et al. showed how it would be possible to meet a 30% target for the total contribution of renewable energy with a large share of green gas [1]. Two sources were considered: upgraded biogas from biomass digestion and Substitute Natural Gas (SNG) by methanation of product gas from biomass gasification. Nowadays, Power-to-Gas would probably be included as a third source.

In hindsight, the 2005 study was rather optimistic about the development and implementation of technology for bio-SNG production. In Güssing, a 1 MW bio-SNG demo plant has been built and commissioned in 2008, but it has not long been used as a production facility. In Gothenburg, plans for a 100 MW demo were discussed with among others ECN in April 2007. The size was later reduced by a factor 4, but realization still took longer than the 5 years aimed for and bio-SNG production started only recently.

From 2008, ECN together with Royal Dahlman and HVC Alkmaar (originally a local waste incineration company) developed plans to demonstrate MILENA gasification and OLGA tar removal technology at 12 MW scale. The idea was to produce power and heat initially and SNG eventually from clean wood. Market developments forced HVC to withdraw after 5 years of preparation and planning, but Gasunie (the Dutch gas transport company), local and regional government and several other companies joined as partners. This conference contribution gives the present plans and status.

2. Technology description

The Alkmaar SNG demo will be based on MILENA gasification and OLGA tar removal technology developed by ECN and Royal Dahlman, in combination with ESME methanation technology developed by ECN. Here only a short description will be given. More details and further references can be found in a book chapter [2] and an ECN report [3].

MILENA gasification technology was developed to convert biomass into product gas with low N_2 content without the need for an O_2 separation plant. This is achieved by indirect gasification in a fast fluidized bed, and combustion of remaining char with air in a separate bubbling fluidized bed. Heat is transported from the combustion reactor to the gasification reactor, and char from the gasification reactor to the combustion reactor, by bed material such as sand or olivine.

The gasification and combustion reactors are positioned within a single vessel, with the combustion reactor surrounding the gasification reactor (see Figure 1). This configuration makes it easy to reduce heat loss, and in future to increase the operating pressure from atmospheric to about 6 bar. Char and bed material are separated from product gas in a freeboard and flow to the combustion reactor through a downcomer.

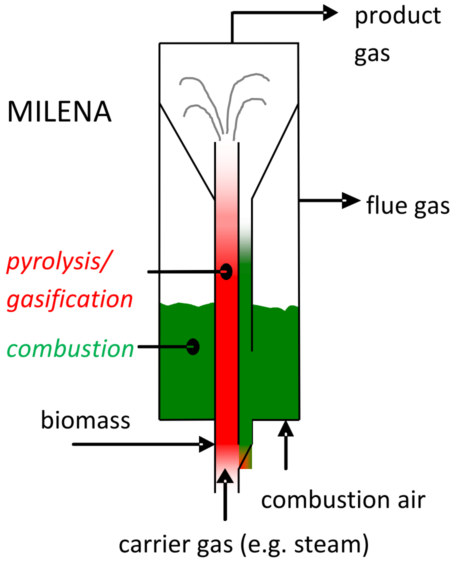

Figure 1. MILENA indirect gasifier with gasification reactor surrounded by combustion reactor.

The fast fluidized bed of the gasification reactor requires little steam or other gas for initial fluidization. This reduces heat demand of the process and results in product gas with relatively low moisture content, i.e. ~35%. This reduces cooling requirement to cool and dry the gas before compression to the pressure required for conversion to methane or other applications.

MILENA product gas is essentially pyrolysis gas mixed with products of reactions with steam. It contains considerable amounts of hydrocarbons, which contribute more than 50% of the gas heating value (see Table 1). The gas also contains about 40 g/m_n^3 tar, i.e. hydrocarbons heavier than toluene.

Table 1. MILENA product gas composition (dry basis) and contributions to product gas heating value.

	[% Vol]	[% Energy]
CO	34	25
H_2	24	15
CO_2	17	0
CH_4	15	31
C_2H_4	5	17
C_6H_6 (+ C_7H_8)	1	9
Other C_xH_y + NH_3, H_2S, etc	1	3
N_2 (+ Ar)	3	0

The high tar content of MILENA product gas can be handled efficiently by OLGA tar removal technology. It contains two tar removal stages, i.e. a quench column and an absorption column, and tar recovery stages. Tar is removed above the water dew point of the product gas, to prevent mixing of tar and water and thus reduce the waste water treatment effort. Still, the gas tar content can be reduced to a level where remaining tar vapour will not condense until the gas is cooled to below 0°C. Recovered tar can be fed to the MILENA combustion reactor to provide heat for the gasification process.

MILENA and OLGA technology are commercially available from Dahlman Renewable Technology (DRT), a subsidiary of Royal Dahlman. MILENA and OLGA have already been realized previously at the intended scale of the Alkmaar demo.

ESME methanation is especially designed to allow conversion of biomass into green gas, i.e. sustainable methane, with record-high efficiency by making clever use of the unique characteristics of product gas from indirect biomass gasification at moderate temperatures. The high content of hydrocarbons in product gas (see Table 1) means that less energy is turned into heat in reactions which produce methane than would be the case for syngas consisting mainly of CO and H_2.

The ESME lay-out needs no gas recycle to moderate heat production. Instead, it uses two pressure stages: the first one operates at the level equivalent to direct coupling to a (future) pressurized MILENA or similar biomass gasifier. The second one allows to reach low H_2 content by methanation at high pressure. The compression work for the second stage is limited, as before compression the gas volume is reduced by removal of most of the CO_2 and H_2O.
The catalysts used in the process require deep gas cleaning, but that should not result in hydrocarbon removal. Keeping the catalysts active also requires measures to prevent polymer or carbon formation from unsaturated and aromatic hydrocarbons, such as C_2H_4 and C_6H_6.
In ESME, reactors with Hydro-DeSulphurization (HDS) and pre-reforming catalysts take care of these challenges. The HDS catalyst converts organic sulphur compounds into H_2S or COS, which can be removed more easily, and hydrogenates unsaturated hydrocarbons. The pre-reforming catalyst converts the aromatic hydrocarbons and produces methane. ECN performed a 500 hrs test of the first pressure stage with commercial catalysts. Real product gas was used at kW scale, to prove the concept and check whether catalyst activity would suffer from the conditions applied [3].

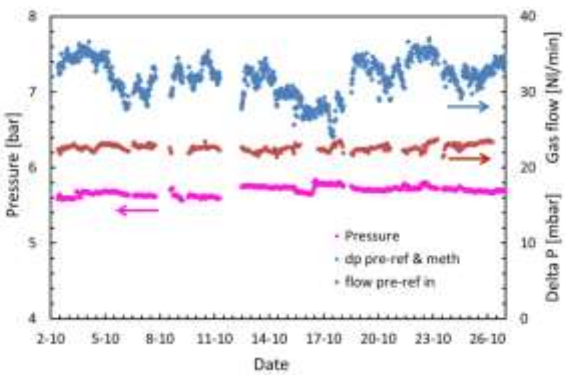

Figure 2. Pressure in, pressure drop over and total gas flow through pre-reformer and two methanation reactors during 500 hrs test.

Figure 2 shows that the pressure drop over the pre-reformer and methanation reactors varied, but did not increase over time. It shows that polymer or carbon formation are negligible, which was also confirmed by post-test inspection of the catalysts.
The next step in the development is a bio-SNG demo which will include a high-pressure stage and upgrading to make the gas suitable for injection into the gas grid.

3. Consortium and plans

A consortium consisting of Gasunie, Royal Dahlman, ECN and PDENH (Participation fund for sustainable economy North-Holland), together with the municipality of Alkmaar and the province of North-Holland, is preparing the realization of a 4 MW_{th} green gas demo plant. The demo project aims to prove the industrial feasibility of MILENA biomass gasification, OLGA tar removal and ESME methanation technology. The green gas produced by the demo will be fed into the regional gas distribution grid so that Dutch households can directly benefit from the replacement of fossil natural gas by green gas. It is expected that by 2030 green gas will satisfy gas demand for around two million Dutch households.
The demo plant is planned on the Energy Innovation Park (www.energypark.nl) in Alkmaar. At the same location InVesta, an expertise center for biomass gasification, is being realized by a consortium consisting of the municipality of Alkmaar, the province of North-Holland, TAQA, and ECN. InVesta has the ambition to facilitate the development of biomass gasification technology in the broadest sense from pilot scale to industrial feasibility. This is often the most difficult phase in the industrialization of innovative technology. By sharing facilities and through shared R&D projects the development of world-

class innovative technology will be accelerated in a cost effective and efficient way.

InVesta is expected to house a range of gasification technologies, as well as various technologies in the value chain from biomass preparation to green gases and liquids and bio-based chemistry. The various gases produced by the MILENA/ OLGA/ESME installation will also be made available for R&D purposes in InVesta. In this way, interested parties that join InVesta can benefit in varying consortia from the available infrastructure as well as the various demonstration installations to speed up development of their own innovations.

The Energy Innovation Park will also be a great environment to further test the various applications of biomass gasification, e.g. for green methane, be it through injection in the gas grid or through green gas fueling stations for automotive purposes.

4. Status

The consortium has agreed on the budget which will be available to build and operate a 4 MW_{th} green gas demo plant near Alkmaar. Part of the operating costs will be covered by a subsidy granted for the production of green gas.

The MILENA and OLGA part of the demo will be of a size realized earlier, but of improved design and intended for many years of operation. For the ESME part, it will involve several new steps: a 1000-fold upscaling, addition of CO_2 removal, a high-pressure stage, a gas dryer, quality control and grid injection.

Basic engineering by DRT, ECN and several specialist companies has started beginning of 2016. The basic design phase should give an accurate cost estimate and provide the consortium the information needed to take the final investment decision.

5. Acknowledgement

Part of the ESME technology development was co-financed by grants of the Energy Delta Gas Research (EDGaR) program [4]. EDGaR is co-financed by the Northern Netherlands Provinces, the European Fund for Regional Development, the Ministry of Economic Affairs and the Province of Groningen.

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