Biomass gasification in the Netherlands

Bram van der drift

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Acknowledgement

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Contents

Summary

This reports summarizes the activities, industries, and plants on biomass gasification in the Netherlands, see also Figure below. Most of the initiatives somehow relate to waste streams, rather than clean biomass, which may seem logic for a densely populated country as the Netherlands. Furthermore, there is an increasing interest for the production of SNG (Substitute Natural Gas) from biomass, both from governments and industry.

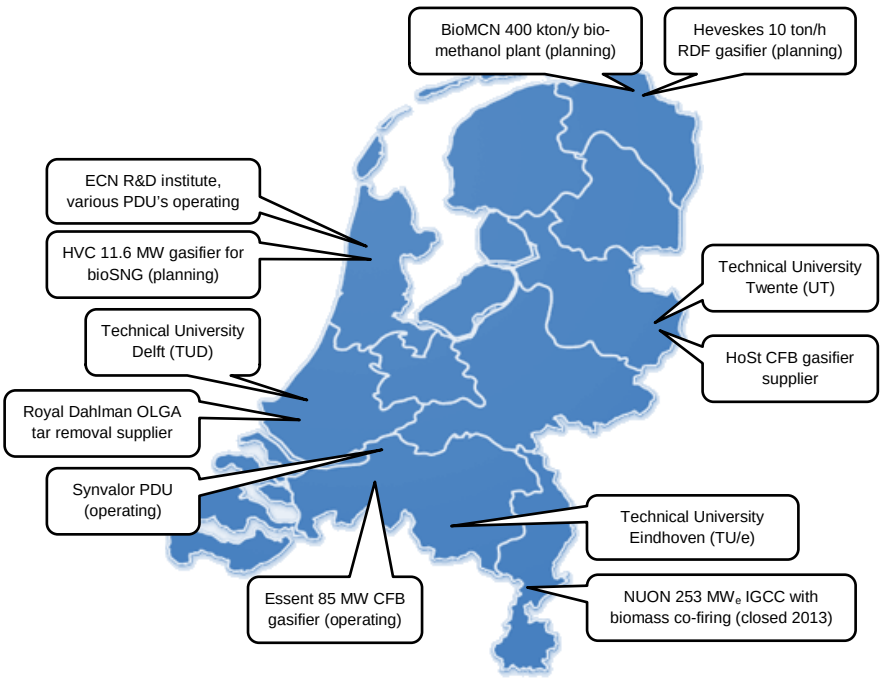

Figure 1: Biomass gasification in the Netherlands

1

Energy policy

In the Netherlands, the Ministry of Economic Affairs deals with energy and sustainability, but with a clear connection to EU policy. It is the vision of the Dutch government that economic growth and a more sustainable energy system can and should be combined. The Netherlands have a strong and innovative energy sector, and that is a firm basis for green growth [1]. Also the strength of the chemical sector is recognized. The combination of biomass for the energy sector and chemical sector is heading for the so-called “Bio-Based Economy”.

Energy in The Netherlands is dominated by natural gas. Approximately 44% (2011) of the primary energy consumption is from natural gas (www.cbs.nl). Over 60% of the national power production is based on natural gas [2]. The Netherlands is a large natural gas producer, but also imports and exports natural gas on large scale. The Netherlands has international gas connections, an LNG terminal and several large gas storage facilities. This construction sometimes is referred to as the gas “round-about”. There is a strong ambition to keep this position, although national gas production will become lower than domestic consumption approximately 15 years from now. Green natural gas may become of importance for the gas “round-about”.

The Energy Delta Gas Research (EDGaR) consortium connects enterprises and research in the Netherlands on the subject of gas and sustainability. It aims at strengthening Dutch gas industry and finances 29 multidisciplinary projects with a total budget of 42 million euro [3].

The renewable energy target for the Netherlands for 2020 was set at 14% according to European directive 2009/28/EG. This presently (2011) amounts 93 PJ/year final energy use, which is 4.3%. The largest part of this (74%) is produced from biomass [4]. Within the power sector only, 10% of the final consumption in 2011 is from renewable sources of which almost 60% is produced from biomass. Clearly, biomass is an important part of the renewable energy production in the Netherlands. Biomass is also expected to play an important role in the increasing contribution of renewable energy. Green Gas will be of significance, replacing natural gas in the existing gas grid. Green Gas will be produced both through digestion of e.g. manure and gasification of lignocellulosic biomass.

Since 2008, the new so-called SDE programme is in place, that subsidizes the producer of renewable energy: power, heat and gas. The total 2013 budget for subsidy is 3 billion Euro. The government is preparing an obligation system for power suppliers.

2

Essent/RWE

Company:	Essent/RWE
Website:	www.essent.nl
	www.rwe.com

Essent/RWE owns and operates a waste wood gasifier connected to a 600 MW_e coal-fired power station with 42% net electric efficiency. The plant is situated in Geertruidenberg and is called Amer-9. The coal plant co-fires biomass in two different ways. Approximately 25% (energy) of clean wood pellets are directly co-fired and another 5% is co-fired indirectly through a gasifier. The gasifier was built in 2000/2001 and did undergo several hardware modifications that were merely related to fuel feeding and gas cooling and cleaning.

Figure 2: The Amer-9 coal-fired power station with the waste wood gasifier (front-right)

The capacity of the gasifier amounts 85 MW_{th} and is a near-atmospheric Circulating Fluidized Bed (CFB) reactor based on Lurgi technology. The fuel is waste wood category B in the Netherlands, meaning that it contains painted wood, MDF, plywood as well as glass, metal and other inorganic materials. The gasifier is operated on preheated air and steam and operates at approximately 850°C. The gas is cooled in a water-tube cooler producing 310°C superheated steam. The gas then passes a cyclone, or actually two parallel cyclones, and is directed to the main coal boiler at 400-450°C.

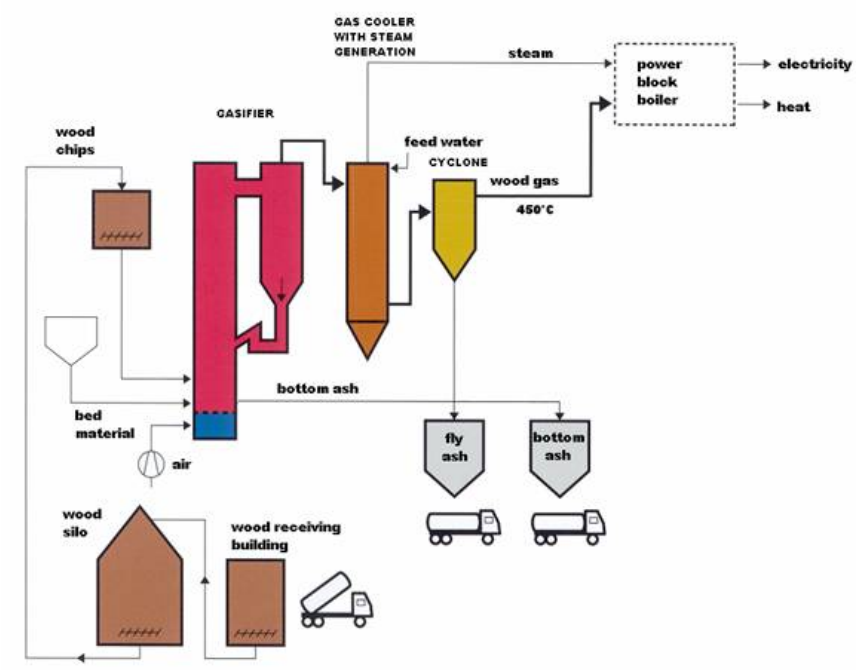

Figure 3: The system of the Essent 85 MW waste wood gasifier for indirect co-firing

The gasifier/cooler/cyclone plant operates approximately 5000 h/year. This has been limited mainly due to feeding issues and cooler fouling due to tar deposition.

The present subsidy on renewable power for the Essent waste wood gasifier will stop by the end of 2013. Currently, Essent is exploring the options to continue the operation of the gasifier, awaiting possible new rules/obligations on co-firing . Gasifying cheaper waste material is one of the options.

3

NUON/Vattenfall

Company:	NUON Vattenfall
Website:	www.nuon.nl
	www.vattenfall.com

NUON/Vattenfall operated a 253 MW_e integrated coal gasification combined cycle (IGCC) plant in Buggenum. The plant is called Willem-Alexander plant and had 43% net electric efficiency. It was built as a first-of-its-kind demonstration plant and contains the 28 bar Shell coal gasification process and Sulfinol acid gas removal. It started operation in 1993.

Figure 4: The IGCC plant in Buggenum, closed since April 2013

In 2002, NUON started test trials with biomass co-firing. The plant was modified to use wood dust up to 10% (energy) on a daily basis since 2006. Recently, tests were carried out to assess the possibility to extend the co-firing rate to as high as 70% on energy basis [5]. This was done by using “refined pellets”, which means pre-treated by either torrefaction or steam explosion. This pre-treatment was needed to be able to use the existing lock-hopper feeding system. The tests with 70% co-firing mainly showed upstream issues. At the same time, the production dropped.

The Buggenum plant was closed 1 April 2013. Low energy prices and high operating costs of the relatively small power station made profitable operation impossible.

4

BioMCN

Company:	BioMCN
Website:	www.biomcn.eu

BioMCN is a company in Delfzijl producing green methanol from biomass. They modified an existing natural gas based methanol plant (previously known as Methanor) and selected raw glycerin from biodiesel production as feedstock. After successful trials with 5% glycerine in a glycerine/natural gas mixture, bioMCN decided to modify the plant to be able to treat up to 50% raw glycerine in the feedstock, producing up to 200 kton/year of green methanol. Raw glycerine purification is an important part of the new plant.

Since 2010, bioMCN produces green methanol that enters the biofuels market mainly through MTBE. BioMCN already is the largest second generation biofuels plant worldwide, but they announced plans to expand the production with another 400 kton/year. They were granted 199 million euro for this through the European NER300 innovations programme, as announced December 2012 [6].

Figure 5: The bioMCN bio-methanol plant (left) and the raw glycerine purification plant (right)

The new biomethanol plant will convert max. 1.5 million ton waste wood annually into max. 400 kton bio-methanol. The new plant will contain torrefaction pre-treatment and

entrained flow gasification. Siemens will be the supplier of the gasification island. The initiative is called “woodspirit” and production is expected to start in 2017.

5

Royal Dahlman

Company:	Royal Dahlman
Website:	www.dahlman.nl
	www.renewableenergy.nl

Royal Dahlman is a Dutch company for filtration and separation solutions worldwide. Since 2006, Dahlman supplies OLGA tar removal technology. It started growing as a renewable energy company since then. In 2012 the US-based waste-to-energy project development company Synova LLC acquired a minority stake. This enabled Royal Dahlman to significantly accelerate its growth strategy in the field of renewable energy technology.

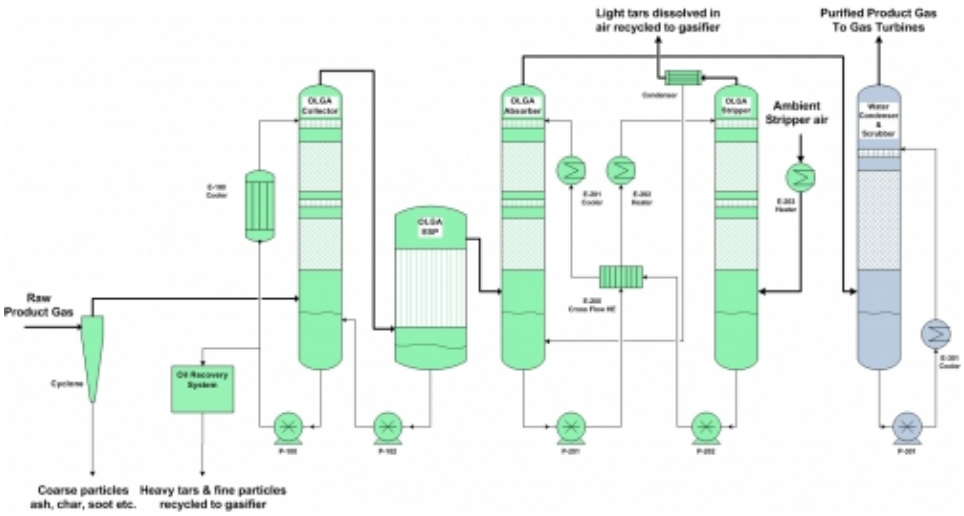

Figure 6: Schematic OLGA process for tar and particles removal

The OLGA tar (and particles) removal technology plays a central role in the renewable energy activities of Dahlman [7]. It has proven to be able to remove tars and particles from a fixed bed gasifier, an air-blown fluidized bed gasifier, and indirect gasifiers

reducing tar concentration from over 50 g/Nm^3 to tar dew points below 10°C [8]. OLGA has been tested downstream gasifiers operating on wood, waste wood, RDF, chicken manure, and many other waste/biomass feedstock. Important feature of OLGA is that it removes tars above the water dew point, thus enabling conventional water scrubbing downstream OLGA to remove e.g. ammonia and chlorine compounds without tar pollution of the water.

The OLGA technology has been developed by ECN. ECN owns the patents and still owns and operates a lab-scale (2 Nm^3/h) and pilot-scale (200 Nm^3/h) OLGA test facility. Royal Dahlman supplied two commercial OLGA systems (both approx. 2000 Nm^3/h) to customers in France and Portugal for 1 MW_e CHP plants. Several new projects are on their way, one of which is a waste-to-energy project in the UK [9,10] and another one is an initiative in Alkmaar in the Netherlands that will produce bio-methane (SNG: Synthetic Natural Gas) from woody material [11], see also Chapter 9. Both projects include MILENA gasification technology, also developed at ECN, see Chapter 11.

Figure 7: OLGA tar removal technology, from left to right: 2 Nm^3/h at ECN, 200 Nm^3/h at ECN, 2000 Nm^3/h in France and 2000 Nm^3/h in Portugal

Recently (May 2013), Royal Dahlman acquired a license for the MILENA gasification technology. Since Dahlman also supplies OLGA tar removal technology, this enables them to supply the larger part of a biomass/waste gasification plant, ensuring proper integration between the parts.

6

Synvalor

Company:	Synvalor
Website:	www.synvalor.com

Synvalor is a new Dutch company, founded by Jacques Polvervaart, who previously owned the company Polow Energy Systems BV (PES for short) . PES supplied a so-called Torbed gasifier plant to a Dutch client in Nieuwdorp near Vlissingen in the Netherlands. This plant was based on the technology of Torftech, that also later became the basis for the torrefaction technology developed by the company Polow Energy Systems, who merged later with Topell BV to Topell Energy BV.

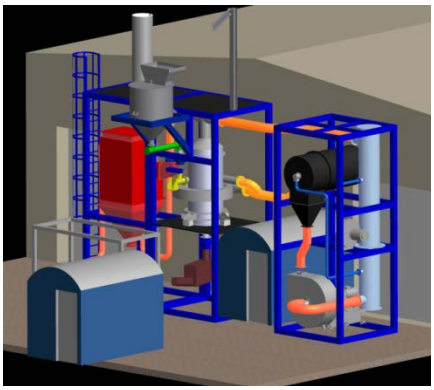

Figure 8: The Synvalor pilot gasifier

Synvalor develops a new multi-stage vortex reactor for the gasification of all kind of fuels, but specifically difficult fuels. It aims at producing low-tar producer gas for e.g. gas engines. The goal is to keep the investment below 2500 Euro/kW_e. The technology is called Synvator®. Synvalor built a pilot test facility of approximately 50 kW_e capacity and has been tested with wood dust, wood chips, reed, grass, straw, and digestion residue. Synvalor is confident about the technology and is working towards two plants in Europe.

Synvalor cooperates with Dordtech for the power production. Dordtech is specialized in CHP generators, including the application of low-calorific gases.

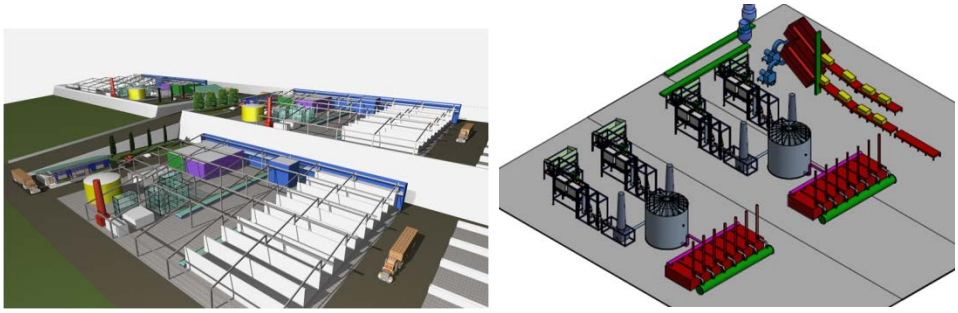

Figure 9: Two planned Synvalor gasification plants in Italy (left) and Serbia (right)

7

Torrgas

Company:	Torrgas
Website:	www.torrgas.nl

Torrgas is initiated by the founders of Topell Energy. Topell Energy has been awarded by both Bloomberg and The World Economic Forum for the meaningful contribution of its innovative torrefaction technology to the enhancement of the environment. A-Hak is a strategic investor in Torrgas. The company aims at developing gasification technology for torrefied biomass fuel. The strategy of Torrgas includes the upstream integration with torrefaction assets overseas to secure a long-term supply of high quality, homogeneous biofuel. Torrgas aims to integrate its gasifiers and torrefied biomass value chain with both CHP's and catalytic conversion of the syngas.

The technology is based on Torbed® technology developed by Torftech Ltd. The technology has also been used and demonstrated for torrefaction by Topell Energy and for gasification of non torrefied biomass by Polow. The extremely turbulent environment in the Torbed creates a very intense contact between the hot process gas and the feed material, yielding a highly efficient and quick heat-to-mass transfer. Torrgas has been granted a national grant for the realization of a 10-15 MW (input) gasification demonstration plant in the Netherlands and an environmental permit for this first plant was issued recently.

8

Heveskes

Company:	Heveskes
Website:	www.heveskesenergy.nl

Heveskes Energy is a Dutch company supplying the Japanese JFE technology for waste gasification. This is an oxygen-blown slagging technology demonstrated in Italy. Heveskes has been granted a national subsidy for the realization of a 10 ton/h RDF gasification plant near Delfzijl in the Netherlands. It is expected to start gas production in 2014. The concept is part of a larger plan with multiple gas producers, several gas cleaning steps and multiple gas users of syngas for combustion, syngas for chemistry, and pure hydrogen.

In 2012 Heveskes Energy has created a consortium with ESD-SIC (produces syngas as co-product), Groningen Seaport (local Harbour Authorities), ECN, Volker Wessel and Gasunie in order to determine in more detail the technical and commercial feasibility of the so-called Green Grid, a distribution-system throughout the industrial area for sustainable syngas and hydrogen. This initiative has stimulated new plans in the region for the production of various types of base-chemicals, like ammonia and propylene glycol.

Figure 10: Heveskes demonstration plant will supply gas to chemical complex in Delfzijl

9

HVC

Company:	HVC
Website:	www.hvcgroep.nl

HVC is a Dutch waste and energy company. Over 50 municipalities in the West of the Netherlands are the shareholders of HVC and at the same time supply waste. On multiple locations in the Netherlands, HVC recycles 600 kton/year, composts 200 kton/year, incinerates over 1000 kton/year, and combusts 170 kton/year waste wood in a CFB combustion system producing 25 MW_e. Furthermore, HVC operates several digestion systems of which one in Zwolle upgrades the gas to 3 MW natural gas quality and injects the gas into the 40 bar natural gas grid.

Figure 11: HVC incineration plant in Alkmaar (left), CFB combustion plant in Alkmaar (centre) and the gas upgrading section of the digestion plant in Zwolle (right)

Several years ago, HVC recognized Green Gas (other words: bioSNG or bio-methane) as an attractive energy carrier that can be produced from e.g. waste wood. HVC selected the MILENA gasification technology for this purpose. Several tests have been performed with the pilot-MILENA on the premises of ECN to obtain confidence in the technology, to get familiar with the technology, and to generate the required design data for an 11.6 MW input capacity demonstration plant.

A consortium is formed to be the owner of the demonstration plant. The consortium consists of HVC, Gasunie, Royal Dahlman, ECN, and the province of Noord-Holland. The

Dutch gas company Gasunie sees Green Gas as an important component in their long-term ambitions.

The 11.6 MW demonstration plant will be located on the HVC premises in Alkmaar in the Netherlands. It will operate on waste wood and consists of MILENA gasification technology and OLGA tar removal technology, both developed by ECN. The tar free gas will be fired in a dedicated boiler to produce renewable power through an existing steam cycle. It is expected to be started up late-2014. Part of the tar-free gas will be upgraded to bioSNG. The demonstration plant will be the stepping stone to more commercial and large-scale bioSNG plants.

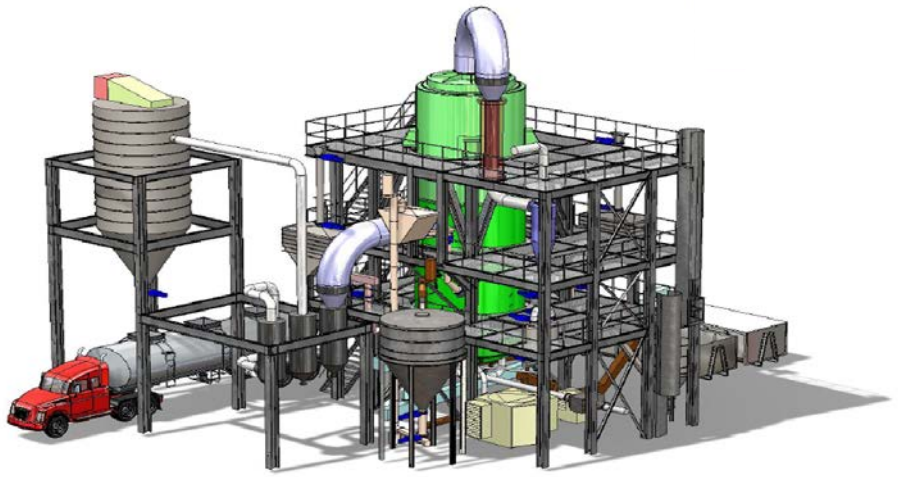

Figure 12: The 11.6 MW waste wood demonstration plant in Alkmaar with bioSNG slip-stream, expected to be started late-2014

10

HoSt

Company:	HoSt
Website:	www.host.nl

HoSt is a medium sized Dutch company supplying bio-energy systems based on digestion, combustion, and gasification. The gasification technology is an air-blown Circulating Fluidized Bed (CFB). The strength of HoSt is the gasification of difficult fuels that generally show severe problems in more conventional combustion systems, generally related to slagging and fouling. In the CFB gasifier, the temperature can be controlled and kept low enough to prevent melting. In the standard gasification system supplied by HoSt, the syngas is cooled to approximately 500°C and particles are separated by a series of cyclones.

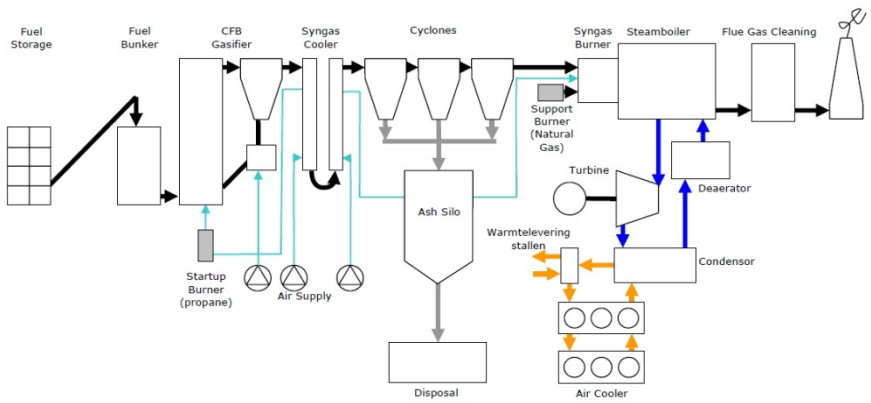

Figure 13: HoSt gasification system for difficult fuels with CFB gasifier and syngas boiler

HoSt supplied two gasification systems for chicken manure to a Dutch client and a Portuguese client. Another system was supplied to a Romanian customer operating on sunflower husks. In the Dutch and Romanian plant, the syngas is burned in a boiler at high-temperature with a HoSt burner design to produce steam/heat. The Portuguese

plant is equipped with an OLGA tar removal system and connected to a 1 MW_e Caterpillar gas engine.

HoSt has been granted a national subsidy for the realization of a 3 ton/h paper rejects gasification plant on the site of a paper mill in the Netherlands. Paper rejects consist of approximately 40% biomass, 55% plastics and 5% ash/metals. This plant will consist of a CFB gasifier, gas cooler, cyclones, boiler and steam production.

Figure 14: HoSt CFB gasifier in Portugal (left), the Netherlands (centre), Romania (right)

11

ECN

Company:	ECN
Website:	www.ecn.nl

ECN is the Dutch Energy research Institute. Although it has been founded in 1955 as nuclear energy institute, it now focuses on renewable energy (wind, solar, biomass) and energy efficiency. The mission of ECN is to develop knowledge and technology to enable a more sustainable energy system.

Biomass gasification is an important topic within ECN for almost 20 years now. It can be separated into two distinct parts: fluidized bed gasification and entrained flow gasification.

11.1 Fluidized bed gasification

A 0.5 MW Circulating Fluidized Bed (CFB) gasifier test facility was erected in 1995. Many different waste and biomass fuels were tested. The technology now is commercialized by the Dutch company HoSt for mainly difficult fuels, see Chapter 10. Several years later, the OLGA tar removal technology was invented at ECN. Two OLGA test facilities have been realized at ECN on a 2 and 200 Nm^3/h scale. The OLGA technology has been licensed to Royal Dahlman in 2006, see Chapter 5. Both test facilities at ECN are used to increase the level of know-how and to test new findings.

Approximately 10 years ago, the MILENA gasification technology has been invented. One of the important design criteria for the MILENA was to have complete conversion, where the ash is essentially carbon-free. This not only improves efficiency, but also avoids safety issues as experienced with the CFB gasification technology. MILENA is a so-called indirect gasification technology with two coupled reactors producing two gases: an essentially N_2-free producer gas and a more-or-less conventional flue gas. Reactor design is such that the MILENA-technology is suitable for a wide range of fuels, ranging from wood to grass, and from RDF to coal. ECN owns and operates two test facilities of 25 kW and 0.8 MW capacity. Both are connected to OLGA tar removal

facilities. MILENA technology has been licensed to the Indian company Thermax and the Dutch company Royal Dahlman.

Figure 15: MILENA gasification technology at ECN: the technology scheme (left), 25 kW test facility (centre), 0.8 MW test facility (right)

MILENA gasification and OLGA tar removal technology are crucial components in the planned 11.6 MW demonstration plant in Alkmaar (see Chapter 9). ECN has a complete biomass-to-bioSNG system at lab-scale, consisting of MILENA, OLGA, several gas cleaning reactors and three methanation reactors. This facility is used to generate the required knowledge to select the right combinations of technologies, catalysts and operating conditions for a bioSNG-system. The facility will soon be expanded to separate valuable chemicals from the raw gas prior to conversion. Bio-benzene and bio-ethylene are the main target molecules.

Figure 16: Lab-scale bioSNG test facility coupled to lab-scale MILENA gasifier and OLGA tar removal

11.2 Entrained Flow gasification

Entrained Flow gasification work at ECN is merely based on experience in pulverized fuel combustion and biomass co-firing. One important test facility is called LCS, which can be used both to simulate pulverized fuel combustion and gasification. It operates at temperatures up to 1700°C and, contrary to a conventional drop-tube oven, has a real burner zone with corresponding extreme gas conditions. The LCS is equipped with probes where gas samples can be collected (up to 2 seconds residence time) and solid deposits can be collected on cooled or non-cooled surfaces. It generates valuable information on slagging and fouling in entrained flow gasification and is used frequently to e.g. select the right fuel combinations and/or fluxing material.

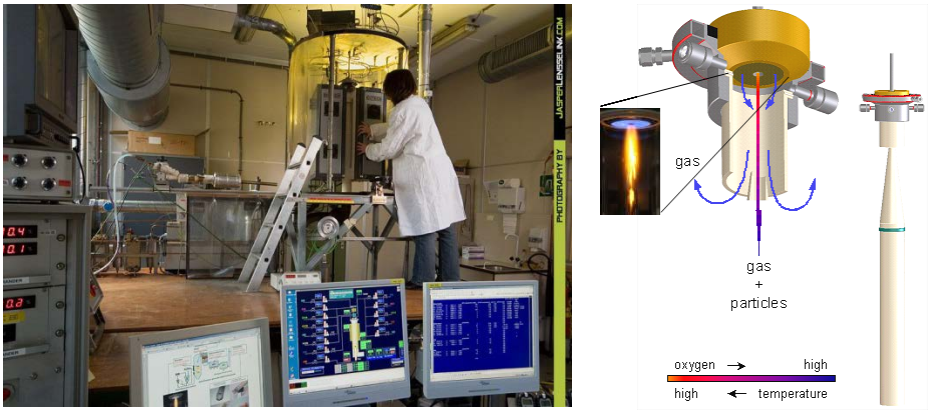

Figure 17: The LCS test facility to simulate Entrained Flow gasification

Entrained flow gasification is developed to convert coal and refinery residues. It is characterized by very high temperatures, small fuel particles, and short gas residence times. Because of the high temperatures, a syngas is produced that hardly contains hydrocarbon molecules like methane. This is why the entrained flow technology is a serious candidate for BtL concepts (Biomass-to-Liquids) to produce biofuels and bio-chemicals. Feeding biomass to entrained flow gasifiers however, is not easy. Since biomass is hard to pulverize, biomass needs to be pre-treated. ECN developed torrefaction technology to convert biomass to a fuel that can be pulverized like coal. ECN and Andritz together develop the torrefaction technology. A 1 ton/h torrefaction and pelletization demonstration plant is operated in Denmark [12].

12

Universities

In the Netherlands, three Technical Universities have or had activities ongoing in the biomass gasification area: Eindhoven, Twente, and Delft. Presently, only the Technical University of Delft has facilities available for biomass gasification. In Twente the focus is more on pyrolysis and in Eindhoven they switched to torrefaction as the main topic in thermochemical conversion..

12.1 TU/e: Technical University Eindhoven

Recent PhD studies have been finalized:

- Lopa Devi, Catalytic removal of biomass tars; olivine as prospective in-bed catalyst for fluidized-bed biomass gasifiers [13]
- Carlos Vilela, Primary methods in biomass gasification for gas conditioning and cleaning [14]
- Kiran Kumar, Particulate fouling of dry and liquid coated surfaces [15]
- Christiaan van der Meijden, Development of the MILENA gasification technology for the production of Bio-SNG [16]
- Liselotte Verhoeven, Radical tar removal: numerical modeling of tar conversion in a partial combustion reactor [17]

12.2 UT: Technical University Twente

Recent PhD studies have been finalized:

- Pavlina Nanou, Biomass Gasification for the Production of Methane [18]

12.3 TUD: Technical University Delft

Recent PhD studies have been finalized:

- Marcin Siedlecki, On the gasification of biomass in a steam-oxygen blown CFB gasifier with the focus on gas quality upgrading: technology background, experiments and mathematical modeling [19]
- Xiangmei Meng Biomass gasification: the understanding of sulfur, tar, and char reaction in fluidized bed gasifiers [20]

The University in Delft owns a 100 kW_{th} Circulating Fluidized Bed (CFB) gasifier that can operate on steam/oxygen and air. It is equipped with a high temperature filter (up to 850°C). In a slip-stream, catalytic reforming, catalytic filters and a water-gas-shift reactor are available for research.

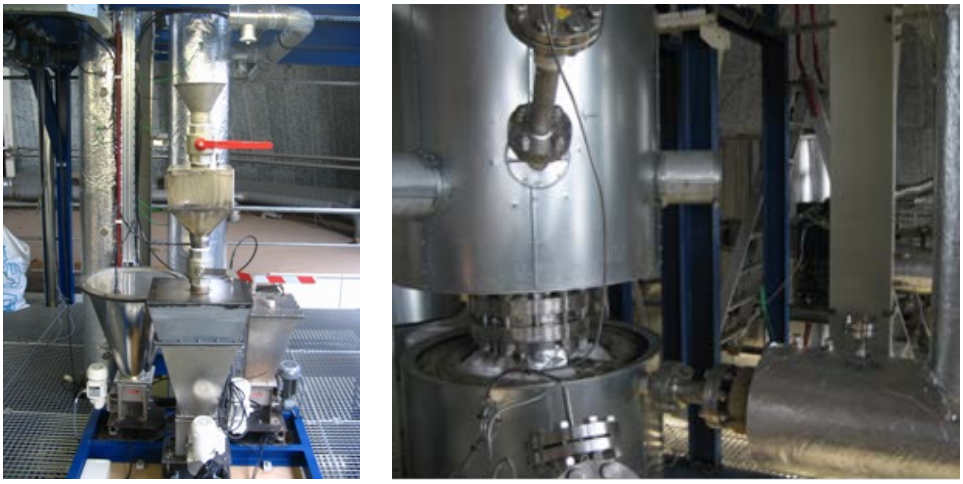

Figure 18: The 100 kW_{th} biomass gasification test facility of Delft University (left) and high-temperature filter (right)

13

Conclusion

This report summarizes the activities, industries, institutes, universities, and plants concerning biomass gasification in the Netherlands. It is the result of several decades of developments, incentives, and cooperation. More recently, biomass and waste gasification activities in the country are encouraged through the concept of bio-based economy. This is a scenario where several Dutch strong points are combined: innovation, harbors and trade, energy infrastructure, and the very large chemical and petro-chemical sector. The bio-based economy is expected to create economic growth and green jobs. Biomass gasification is an important part of this future in the Netherlands, since it connects new green fuels to existing infrastructure and industry. Synthetic Natural Gas (SNG) forms a special category in the Netherlands through which the Dutch gas industry can strengthen its national and international position. It may also form a basis to accommodate peak power from e.g. wind turbines in the so-called power-to-gas concept.

Since the Netherlands is a relatively small and densely populated country, biomass production is limited. The focus therefore is on waste and imported biomass. The latter explains the focus on torrefaction in the Netherlands as a method to reduce logistic issues and costs of biomass in the Netherlands. The largest initiative is from bioMCN where torrefied biomass will be gasified. Biomass waste is the fuel for most of the other Dutch gasification activities summarized in this report.

14

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ECN

Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 LG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ ecn.nl
www.ecn.nl