NEW DUTCH RENEWABLE ENERGY SUPPORT SCHEME AND THE PROSPECTS OF GREEN GAS PRODUCTION IN THE NETHERLANDS

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ABSTRACT: Green gas from both digestion processes and large-scale gasification of biomass is considered as a promising renewable option in the Netherlands with high potential. On assignment of the Dutch Ministry of Economic Affairs, ECN and KEMA have estimated the costs of renewable gas (biomethane, green gas) production and injection into the natural gas grid. The result of this cost assessment was an advice to the Ministry, in order to determine the subsidy base, within the new Dutch renewable energy support scheme SDE, for a profitable operation of green gas projects starting in 2008 and 2009. The reference systems for green gas production were based on landfill gas, waste water treatment installations, co-digestion of manure with co-substrates in a 50/50 ratio at a farm scale, and digestion of organic waste fractions. As upgrading step four different technologies were considered: gas scrubbing, membrane filtration, Vacuum Pressure Swing Adsorption (VPSA), and cryogenic separation. Calculated reference prices for green gas varied between 27.7 and 84.0 €ct/Nm^3, depending on the reference system. Due to high production costs of co-digestion of manure and digestion of organic waste fractions at considered scale, only green gas production at landfill sites or waste water treatment plants have been qualified for SDE feed-in premium in 2008. Current costs and the persistence of existing barriers or obstacles are considered to limit future prospects of green gas in the Netherlands.
Keywords: Bio-energy policy, green gas, biogas

1 INTRODUCTION

Green gas is considered as a promising renewable option in the Netherlands. The annual Dutch primary energy consumption is 3300 PJ, with a natural gas contribution of more than 1500 PJ (46%). Almost 70% of natural gas is used in heat applications. The remaining 30% is used for electricity generation (23%), respectively for the production of chemicals (7%).

The Netherlands have a relatively long history concerning the production and injection of green gas into the natural gas grid. The first projects, upgrading landfill gas to natural gas quality are dated from the mid 80’s of the last century. However, new projects became less attractive as a result of lowering gas prices at the beginning of the 90’s, and with the introduction of green electricity concept in 1998, it became more profitable to convert biomass into green electricity. Recently, however, the new Dutch renewable energy subsidy scheme introduced an incentive for green gas production.

ECN and KEMA were commissioned to provide a detailed analysis of green gas production costs in the Dutch context. Detailed techno-economic data were collected from the suppliers of anaerobic digesters, gas engines, and the above-mentioned gas upgrading technologies. Special attention was directed towards the heat and power demands of the digesters and gas upgrading technologies, as these internal energy requirements have a considerable effect on the overall efficiency of green gas options. The collected data together with financial assumptions were used to estimate the subsidy base that enables commercial injection of green gas into the natural gas grid. Based on the ECN / KEMA advice, the Ministry has determined the level of subsidy for green gas in 2008 for different categories. In this paper both the ECN / KEMA advice and the Ministry’s decision are discussed in detail. Besides, attention is directed to future prospects of green gas in the Netherlands. Also information collected in the IEE project REDUBAR on barriers and obstacles are discussed, followed by some conclusions.

2 NEW DUTCH RENEWABLE ENERGY SUPPORT SCHEME

The new Dutch renewable energy support scheme, SDE, has been operational since April 2008. Contrary to MEP, the previous feed-in support scheme, which only supported the production of renewable electricity, SDE provides also a main category for subsidizing green gas. It is hoped that the SDE creates a level playing field between green gas and renewable electricity.

Per category, the SDE sets a fixed reference price based on the average production costs, given the duration of the subsidy. The actual feed-in premium varies as a result of annually determined correction values that correspond to the possible revenues of gas or electricity sales on the market. In other words, the annual SDE feed-in premium would be equal to the fixed reference price minus the yearly set correction value. This is the major difference between SDE and MEP, as the latter was based on a fixed feed-in premium. Another important difference between these two support schemes is the definition of an annual subsidy ceiling for new projects per category.

3 SYSTEMS FOR GREEN GAS PRODUCTION

In principle, green gas can be produced wherever a gas of biogenic origin with certain methane content becomes free. The most important examples are:

- Landfill gas resulting from waste landfills;
- Waste water treatment installations;
- Digestion of manure with co-substrates;

- Digestion of other biomass streams.

In this paper (raw) biogas refers to a mixture of methane, carbon dioxide, and other gases, produced in a digestion process. Green gas refers to a purified gas with natural gas quality, produced from biogas or gasification of biomass. Green gas can be injected into the natural gas grid.

In green gas production systems different types of efficiencies are used:

- Energetic efficiency of the digester: This is the ratio between the energy content of raw biogas to the energy content of the digested biomass used for it.
- Methane efficiency: This is the fraction of methane in the biogas that ends up in the purified gas. A methane efficiency of 97% means, for example, that 3% of the produced methane would remain in the residue gas.
- Green gas yield or purification efficiency: This is the number of Nm^3 green gas that can be produced per Nm^3 raw biogas. The gross purification efficiency ignores the biogas used for internal processes like process heating, while the net purification efficiency compensates for the latter loss of biogas. The gross efficiencies of raw biogas to green gas for the most options are about 60%, and the net efficiencies below this value.
- Energetic efficiency: This is the ratio between the net energy output as green gas and the energy content of the digested biomass used for it.

3.1 Biogas production

Capturing and removing biogas from the landfills limit the autonomously occuring methane emissions from landfill sites. Biogas is produced by digestion of the organic fraction of (mainly) municipal solid wastes. This form of raw biogas production does not require any heat or electricity supply.

Recently, technological progress in anaerobic digestion of sewage water, industrial waste water, manure, and other organic materials has been important, especially related to the growth of manure co-digestion installations with a gas engine (CHP). These installations can be realised at relatively small scale (≤ 100 kW_e up to some MWe). The digestion process requires auxilliary heat and power. In combination with CHP, it can be supplied by a gas engine. However, green gas production requires heat and power to be supplied otherwise, e.g. electricity from grid and heat from combustion of a fraction of produced biogas in a burner.

3.2 Gas purification

The clean-up and upgrading of biogas to green gas take place in different steps. Gas clean-up includes removal of sulphur compounds, water, impurities such as higher hydrocarbons and ammonia. In the upgrading step the methane content of biogas is increased by partial removal of carbon dioxide. This is the most costly step of purification process.

Gas purification can take place through the following four technologies:

- Gas scrubbing;
- Membrane filtration;
- Adsorption (VPSA);
- Cryogenic separation.

3.2.1 Gas scrubbing

Gas scrubbing systems are very often used in different branches of the industry. In case of gas scrubbing with aqueous solutions carbon dioxide will be absorbed under pressure, and removed from biogas. Addition of special chemicals would highly increase the absorbtion capacity, as a result of chemical absorption. The process can be carried out at atmospheric pressure, and methane efficiencies up to 99.9% can be achieved, compared to 97-98% in case of absorbtion with water and under pressure. The regeneration of aqueous solution takes place by stripping of the solution with air at atmospheric pressure. Chemical absorbers are regenerated by heating. These absorbers require, therefore, heat that would become partly available again at a temperature level, usable for heating a digester.

3.2.2 Membrane filtration

The driving force for separation of methane and carbon dioxide in this technology is the difference in permeability of membrane for these molecules. However, the separation is not complete, as the difference in permeability is not large enough. As a result, a relatively considerable amount of methane will remain mixed with carbon dioxide. The methane efficiency of membranes is therefore around 80%. The available low-calorific gas could either be combusted to deliver the required heat for the digester (often with additional biogas to improve the calorific value of the residue gas), or it should be flared.

3.2.3 Adsorption (VPSA)

In Vacuum Pressure Swing Adsorption (VPSA) the driving force for separation of methane and carbon dioxide is the difference in adsorption capacity of a solid material like molecular sieves. Under pressure raw biogas is led through an adsorber. Carbon dioxide will be adsorbed, while methane will be purified by passing through the adsorber. The process consists of a cyclic adsorption and vacuum regeneration of adsorbers in a continuous process. This technology has a methane efficiency of about 97%.

3.2.4 Cryogenic separation

Cryogenic technology can be applied to separate methane and carbon dioxide due to differences in condensation and solidification temperature of these compounds. As a result of deep cooling pure liquid or solid carbon dioxide could be produced, which can be sold as a valuable byproduct to greenhouses. Methane efficiencies above 99% can be achieved. Cryogenic separation is the most innovative technology of the four. The first systems are commercially available. However, no systems are yet operational in the Netherlands.

3.2.5 Methane efficiency and the residue gas

Methane efficiency is not only of importance for the total green gas production of the system, but it has also influence on the usability of the residue gas. At low methane efficiencies up to about 90%, the residue gas can be flared, or it can be used for process heating. At efficiencies higher than 99% the residue gas might be emitted to the atmospher without limitations. However, at methane efficiencies between 90% and 99% the emission of methane, as a strong greenhouse gas, is a potential barrier. Direct flaring of the residue gas is not possible, due to low energy content, and neither can the residue gas be emitted simply to the atmosphere. Either the gas is combusted in a catalytic burner, or it is flared, after being mixed with a part of produced biogas. The former case would lead to extra costs, while the latter case would result in lower gas yields.

3.3 Gas injection

Before injection of purified gas in the natural gas grid, it is brought to the required pressure and specification, and it is odourised. The required pressure is dependent of the grid type in which the gas would be injected. The local gas grid in the Netherlands has a pressure from 100 mbar. This gas grid has the capacity for green gas injections up to circa 150 Nm^3/h. Higher volumes should be injected in the distribution grid, with a pressure of up to 8 bar. Some purification technologies, such as membranes and cryogenic separation work at pressures of about 8 bar or higher. In these cases, the gas can be injected in the distribution grid of 8 bar without any problems. On the other hand, gas scrubbing systems with chemicals work at atmospheric pressure, and VPSA works at pressures lower than 8 bar. In these cases injection in the 8 bar grid often requires an extra compressor, leading to extra costs and electricity consumption.

The quality criteria for gas injection in the local low-pressure distribution grid are given in the connection and transport conditions under the gas law, as published by DTe on 22 November 2006. However, there is still discussion about the risks of spreading of bacteria in green gas via the gas grid. This discussion might lead to additional requirements, such as a pasteurisation step, which results in additional costs. The latter is not taken into account within this study.

The specifications for injection in high-pressure grid is not clear yet. Therefore, the injection of green gas from installations with capacities higher than 150 Nm^3/h is not currently possible.

4 TECHNO-ECONOMIC ASSUMPTIONS

The price projections for feedstocks relevant for green gas production are summarised in Table I. Note that animal manure has a negative price, as it should be paid for its treatment. The techno-economic assumptions for green gas production based on four considered processes are presented in Table II to Table V.

Table I: Price projections biomass 2008-2012 [2]

	Energy content GJ/tonne	Price range €/tonne	Reference price €/tonne	Reference price* €/GJ
Animal manure**	1	(-30)-(-50)	-15	-15.0
Co-substrate	4.8	5 - 35	25	5.2
Input co-digestion	2.9	-	18.5	6.4

* The prices used within this study are based on the whole product and not only on the dry matter content of the product [1].
** This price is assumed for both manure and digestate [1].

Table II: Techno-economic parameters landfill gas [1]

	Unit	Reference value
Size of reference system	Nm^3/h biogas	154
Size equivalent bio-CHP	kW_e	300
Operation time	h/yr	6500
Digestion:		
Investment costs	€/Nm^3/h biogas	0
Fixed O&M costs	€/Nm^3/h biogas	0
Energetic efficiency digestion	%	-
Energy content substrate mix	GJ/tonne	n.a.
Substrate costs	€/tonne	0
Green gas production:		
Investment costs	€/Nm^3/h biogas	5240
Fixed O&M costs	€/Nm^3/h biogas	350
Methane efficiency	%	80
Heat and electricity demand:		
Heat demand	MJ/Nm^3 biogas	n.a.
Electricity demand	kWh/Nm^3 biogas	0.15

Table III: Techno-economic parameters sewage and waste purification installations [1]

	Unit	Reference value
Size of reference system	Nm^3/h biogas	154
Size equivalent bio-CHP	kW_e	300
Operation time	h/yr	8000
Digestion:		
Investment costs	€/Nm^3/h biogas	-
Fixed O&M costs	€/Nm^3/h biogas	-
Energetic efficiency digestion	%	67
Energy content substrate mix	GJ/tonne	n.a.
Substrate costs	€/tonne	0
Green gas production:		
Investment costs	€/Nm^3/h biogas	6260
Fixed O&M costs	€/Nm^3/h biogas	424
Methane efficiency	%	99.9
Heat and electricity demand:		
Heat demand	MJ/Nm^3 biogas	1.9
Electricity demand	kWh/Nm^3 biogas	0.13

Table IV: Techno-economic parameters co-digestion of manure [1]

	Unit	Reference value
Size of reference system	Nm^3/h biogas	270
Size equivalent bio-CHP	kW_e	600
Operation time	h/yr	7500
Digestion:		
Investment costs	€/Nm^3/h biogas	4400
Fixed O&M costs	€/Nm^3/h biogas	290
Energetic efficiency digestion	%	67
Energy content substrate mix	GJ/tonne	2.9
Substrate costs	€/tonne	18.5
Green gas production:		
Investment costs	€/Nm^3/h biogas	3800
Fixed O&M costs	€/Nm^3/h biogas	375
Methane efficiency	%	99.9
Heat and electricity demand:		
Heat demand	MJ/Nm^3 biogas	1.9
Electricity demand digester	kWh/Nm^3 biogas	0.10
Electricity demand purification	kWh/Nm^3 biogas	0.15

Table V: Techno-economic parameters digestion remaining biomass sorts [1]

	Unit	Reference value
Size of reference system	Nm^3/h biogas	225
Size equivalent bio-CHP	kW_e	500
Operation time	h/yr	8000
Digestion:		
Investment costs	€/Nm^3/h biogas	7800
Fixed O&M costs	€/Nm^3/h biogas	890
Energetic efficiency digestion	%	67
Energy content substrate mix	GJ/tonne	n.a.
Substrate costs	€/tonne	0
Green gas production:		
Investment costs	€/Nm^3/h biogas	5200
Fixed O&M costs	€/Nm^3/h biogas	400
Methane efficiency	%	99.9
Heat and electricity demand:		
Heat demand	MJ/Nm^3 biogas	1.9
Electricity demand digester	kWh/Nm^3 biogas	0.10
Electricity demand	kWh/Nm^3 biogas	0.15

The size of the reference system for each category is consistent with the reference system assumed for renewable electricity for that category. For co-digestion the reference size of the digestion unit would be comparable to a bio-CHP of 600 kW_e. Besides, the production capacity of 270 Nm^3/h biogas is roughly the maximum capacity, from which the produced green gas could still be injected in the local low-pressure network; the only option at the moment.

In case of both landfill sites and waste water treatment plants the produced raw biogas is in fact a residual product, available for free for further upgrading. For both categories the potential for new installations in the Netherlands is limited, and the currently operating installations are in many cases combined with CHP systems. For these two categories only those investment and O&M costs are taken into account that are additional to the default situation, which is flaring of either landfill gas, or biogas.

As reference for the forth category (remaining biomass sorts), the digestion of VFG (vegetable, fruit, and garden wastes) was selected. Only those investment and O&M costs are taken into account that are additional to the default situation, which is composting the VFG.

In order to select a gas purification technology for the reference system, cost calculations were carried out for all the four previous discussed purification technologies. Beside the criteria such as the lowest costs, and commercial availability, also the following aspects were taken into account:

- VPSA has the limitation that 3% of the produced methane will remain in the residue gas. As methane is a strong greenhouse gas, there is a risk that its emission would not be accepted. This means that additional costs should be made to combust the residue gas. These costs are not considered within this study and therefore render the current cost estimations optimistic.
- Cryogenic separation has the potential advantage that a solid or liquid stream of pure CO_2 would be produced, with potential commercial value. However, the technology is quite new and not proven yet, at least in the sense that there are no existing installations with gas injection with a few years of experience (although there are some stand-alone installations).
- Landfill gas contains oxygen and nitrogen in concentrations by which gas scrubbing cannot technically be applied.

Based on all these aspects, membrane filtration was selected as reference technology for landfill gas upgrading. The system requires no heat, and the required electricity would be taken from the grid. For the remaining three categories gas scrubbing was selected as reference technology. This option is commercially as well as technically a proven technology, and does not seem to have major disadvantages that would impose a barrier for widespread implementation. The required heat for this technology can be delivered by combusting a part of the raw biogas in a burner. The residual heat from this process can be used for heating the digester (in case of gas from waste water treatment plants, additional heat would be required). Also for these categories the required electricity would be taken from the grid.

5 FINANCIAL ASSUMPTIONS

The financial assumptions for green gas production based on four considered processes are presented in Table VI. In contrary to combined digestion-CHP systems, the green financing regulation (a soft loan measure) can be applied to green gas systems. This is due to the innovative character of green gas systems. Also EIA, an investment-related tax reduction measure, can be applied to biogas-to-green gas section of the green gas systems. This explains the differences in the amount of EIA applicable to the first two, and last two systems in Table VI.

Table VI: Financial assumptions [1]

	Landfill gas	Waste water treatment	Co-digestion of manure	Digestion remaining biomass sorts
Equity share (%)	20	20	25	20
Interest (%)	5	5	5	5
Return on equity (%)	15	15	15	15
Project return (%)	6	6	6.4	6
Loan duration (yr)	12	12	12	12
Economic life span (yr)	12	12	12	12
Corporate tax (%)	25.5	25.5	25.5	25.5
Green financing	•	•	•	•
Amount EIA (% of investment costs)	100	100	46	40

6 RESULTS

An overview of the ECN / KEMA advice for reference prices is presented in Table VII. Landfill gas and sewage / waste water treatment are clearly the low-cost green gas production options.

Table VII: Reference prices green gas 2008-2009 based on the ECN / KEMA advice [1]

	Landfill gas	Waste water treatment	Co-digestion of manure	Digestion remaining biomass sorts
Duration subsidy (yr)	12	12	12	12
Maximum operating time (h)	6500	8000	7500	8000
production costs (€ct/Nm^3)	34.7	26.7	82.2	70.3
Contract costs (€ct/Nm^3)	1.0	1.0	1.8	1.8
Reference price (€ct/Nm^3)	**35.7**	**27.7**	**84.0**	**72.1**

The Ministry of Economic Affairs has decided to set a maximum reference price of 44 €ct/Nm^3 natural gas equivalent for energy production from biomass, taking into account the cost efficiency of the different categories in relation to their future potential and expected cost reductions. As the calculated reference prices for co-digestion of manure, and digestion of remaining biomass sorts are much higher than the maximum price set by the Ministry, these categories are not qualified for SDE feed-in support. The Ministry has endorsed the advised reference price of 27.7 €ct/Nm^3 for green gas from waste water treatment, and set it as the reference price for the remaining two categories. The reference gas price for 2008 is set at 14 €ct/Nm^3 [3].

Note that the production of green gas is relatively new, thus more cost reduction is expected compared to renewable electricity, based on experiences in the first projects (learning-by-doing). Besides, based on an indicative analysis, the production costs for installations on a larger scale are substantially lower than those calculated within this study.

7 PROSPECTS OF GREEN GAS PRODUCTION IN THE NETHERLANDS

The Dutch Platform New Gas (PNG) has proposed a transition route for natural gas substitution in the Netherlands [4]. Based on this transition route, 1 to 3% substitution can be achieved by green gas from biogas in short term. Biogas can be produced in small-scale projects from locally or regionally available biomass streams, and be injected in local and regional gas grids. In 2020 up to 8-12% substitution and in 2030, 20% substitution might be achieved. By then, green gas would mainly be produced by thermochemical gasification of biomass. The feedstock for such large-scale and centred installations would be based on imported sustainable biomass. The produced green gas, or bio-SNG (substitute natural gas), would be injected in the national high-pressure gas network. Green gas production from gasification of biomass has been an important ECN research area for several years. The currently built 1 MW Milena indirect gasifier pilot at ECN will be operational in 2008, with a producer gas very suitable for upgrading to bio-SNG. Other countries very active in this field are Austria, Switzerland, and Sweden.

However, in order to promote green gas, many technical and organisational obstacles and barriers still have to be removed. Some major barriers for the Netherlands are [4][5]:

- Lack of quality requirement for green gas on national level;
- Lack of a system to control / monitor green gas quality;
- No obligation for the gas distributors to accept green gas;
- Lack of a certificating system in order to support development of a green gas market;
- Most of the landfills are already used in CHP application;
- Low acceptance by local authorities and environmental organisations.

8 CONCLUSIONS

- The new Dutch RE support scheme (SDE) stimulates for the first time renewable gas beside renewable electricity.
- ECN / KEMA have ascertained the production costs of green gas for different systems based on anaerobic digestion. These costs range between 27.7 and 84.0 €ct/Nm^3.
- Due to high production costs of co-digestion of manure and digestion of organic waste fractions at considered scale, only green gas production at landfill sites or waste water treatment plants qualifies for SDE feed-in premium in 2008.
- Substantial cost reduction is possible through upscaling as well as by learning-by-doing.
- Green gas from both digestion processes and large-scale gasification of biomass is considered as a promising renewable option in the Netherlands with high potential.
- In order to promote green gas, many technical and organisational obstacles and barriers still have to be removed.

9 ACKNOWLEDGEMENTS

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The paper is part of dissemination activities of the REDUBAR Project, within which ECN is cooperating with a number of European partners. The main objectives of REDUBAR are to determine and remove the existing non-technological and administrative obstacles and barriers, and to propose legislative regulations for the injection of green gas into the natural gas grids and its distribution.

10 REFERENCES

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