LET'S GIVE FULL GAS !

THE ROLE OF GREEN GAS IN THE DUTCH ENERGY MANAGEMENT SYSTEM

NEW GAS PLATFORM

Creative Energy
Energy Transition

This report has been commissioned by the New Gas Platform,
Energy Transition.

Authors
Johan Wempe
Mathieu Dumont

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The New Gas Platform is one of the public-private teams currently focusing on Energy Transition in the Netherlands. The Platform works towards improving the sustainability of the gas chains, via four transition paths. One of these paths is known as Green Gas, which focuses on the use of gaseous energy carriers made from biomass. This publication is the result of discussions with, and contributions from, various stakeholders. The transition platforms known as Sustainability Mobility and Green Raw Materials also participate in the Green Gas Working Group.

The Green Gas Working Group was set up around the middle of 2006. In that same year a 'start document' was drawn up, which formed the starting point for this Outlook document. The following authors contributed to the start document:

- Jörg Gigler – Energy Valley
- Harold Boerrigter – ECN (now at Shell Global Solutions)
- Mirjam van Burgel – Gasunie Engineering & Technology
- Patrick Cnubben – Energy Valley
- Remco Hoogma – Sustainable Mobility Platform

This Outlook is partly used as input for the 'SNG in the natural gas infrastructure' transition path under the Green Raw Materials Platform, and supports the work of the 'Driving on natural gas and biogas' transition working group, which is part of the Sustainable Mobility Platform.

This document has been drawn up by the Green Gas Working Group, which consists of the following members:

Johan Wempe	**Chairman Green Gas Working Group, Saxion Hogescholen**
Mathieu Dumont	**Secretary, Green Gas Working Group, SenterNovem**
Menno Groeneveld	**Vice Chair, Green Gas Working Group, Gasunie**
Peter Besseling	**Ministry of Agriculture, Nature and Food Quality (Min. LNV)**
Marco Bosch	**Essent Retail**
Henk Brink	**NLTO**
Bas de Bruin	**Eneco**
Patrick Cnubben	**Energy Valley**
Joep Coenen	**Cogen Projects**
Bram van der Drift	**ECN**
Ronald Eenkhoorn	**Energy Valley**
Anouk Florentinus	**Ecofys**
Onno Florisson	**Gasunie**
Bram van der Ham	**Eneco Netwerk**
Esther Hardi	**Continuon**
Remco Hoogma	**Secretary, Sustainable Mobility Platform, Driving on natural gas and biogas working group, SenterNovem**
Joeri Jacobs	**Afvalzorg**
Klaas de Jong	**Energieprojecten.com**
Herman Klein Teeselink	**Host**
Klaas Kooistra	**BBO (Biogas Branche Organisatie), E-kwadraat**
Ton van Korven	**ZLTO**
Cees van Leeuwen	**MAN-Nederland**
Lodewijk Nell	**TNO**
Rob Nispeling	**Continuon**
Michael Sanders	**Essent Milieu**

Annemarie Schramm	Eneco
Henk Smit	Essent Netwerk
Peter Tromp	Gemeente Haarlem (Haarlem local authority)
Henk Verbeek	Rolande LNG
Hubert Veringa	Green Raw Materials Platform, ECN, Twente Technical University
Peter Verstegen	Nuon Retail

CONTENTS

SUMMARY

This document contains a description of the outlook developed within the Green Gas Working Group, and the steps that need to be taken, in the short term, in order to develop a Green Gas Market.

Green gas can make an important contribution to the government's climate policy. The Green Gas Working Group estimates that a net CO_2 return of 70% (over the entire chain) is certainly possible, compared to natural gas.

In the long term (from 2050 onwards) green gas produced from sustainable biomass could supply half of our natural gas requirements. The Green Gas Working Group feels that this sustainable replacement for natural gas can make a significant contribution to achieving the sustainability objectives set by the Dutch Government. The Green Gas Working Group therefore urges the accelerated development of green gas. 'The Netherlands is not just a gas country: but also a Green Gas country.'

Green gas generally refers to gas produced from biomass, which is then injected into the natural gas supply network. This is therefore gas that is released during fermentation of organic residues (including manure) from the agricultural sector, residues from the food and snack industry, plus residues from waste processing and water purification, as well as gas that is released during high-temperature gasification of biomass. Green gas is already being produced at several locations and is being injected into the natural gas distribution network. However, there are a number of obstacles that, according to the Green Gas Working Group, must be resolved in the short term via a good collaborative relationship between the various parties involved.

One important obstacle is the difference in cost price between natural gas and green gas. The subsidy scheme for sustainable energy announced by the Dutch Government (known as SDE), also covers the production of green gas. The Green Gas Working Group is therefore of the opinion that this is an important criterion in achieving the development of a Green Gas Market, and that the relevant stakeholders should get together soon, to use these opportunities and resolve these practical issues.

The Green Gas Working Group expects that the production of green gas will eventually be profitable without subsidies, provided that production is implemented on a reasonable scale.

However, producing green gas can result in a number of unintended social side effects. This document describes a number of criteria with which the socially responsible production of green gas must comply. These are criteria for the use of biomass that have been formulated by the Project Group for Sustainable Biomass Production, led by Mrs. Prof. J. Cramer (known as the Cramer Commission). These

criteria are detailed and further elaborated in this report with respect to manure fermentation. The criteria form a clear assessment framework for developing a Green Gas Market in a responsible manner. It continues to be important to monitor the social (side) effects and, where necessary, to adjust the production processes in order to comply with the aforementioned criteria. It is important to watch for undesired social side effects, particularly where the development of the Green Gas Market is encouraged via subsidy schemes.

The following focal points have been elaborated for the Green Gas Working Group, based on the insights gained and developments made over the past year.

In the short term (i.e. the next six months), the Green Gas Working Group will work towards:

1. a balanced scheme to encourage sustainable energy that creates a level playing field for green gas production;
2. projects that make it possible to drive on green gas (this can be in the very short term, with direct purchase of green gas for mobility applications in the proximity of a fermentation plant; eventually this will mean virtual fuel supply to a gas filling station);
3. projects (implemented via consortia) where green gas is injected into the gas supply network;
4. uniform criteria for injecting green gas into the entire gas network, as modifications to the Gas Act of 21 November 2006 only relate to injecting gas into the local and regional distribution networks;
5. developing a Green Gas Certificate;
6. cross-border cooperation of sectors, thus allowing innovations in the green gas chain and the profitable production of green gas;
7. complete recycling of the digestate, including its use as fertiliser;
8. initiating research into gasification of biomass via SNG (synthetic natural gas) production, thus allowing a considerable scaling up of green gas production;
9. initiating a discussion on the social effects of using organic material for energy applications.

1. OUTLOOK AND AMBITIONS

1.1 Net CO_2 return of 70%

Green gas can make a significant contribution to the government's climate policy. Replacing natural gas with green gas reduces CO_2 emissions. However, since energy is required to produce green gas, replacing natural gas with green gas cannot be calculated at the full 100% when calculating CO_2 reductions. The Green Gas Working Group sees a net CO_2 return of 70% as being feasible, by using a sensible choice of organic raw materials for fermentation or gasification, and through a sensible choice of production locations.

1.2 Green gas ambitions: 8-12% natural gas replacement in 2020, 15-20% in 2030 and 50% in 2050

Natural gas plays an important role in the national energy management system: 46% of our primary energy consumption (i.e. 1510 PJ) relies on natural gas. Applications include heat (70%), electricity (23%) and chemicals (7%). The Netherlands is one of the world's frontrunners when it comes to natural gas, with respect to trade, transport, applications and research. Natural gas is expected to continue to play a meaningful role in the future of our energy management system (see Appendix A).

If we wish to maintain the important role that gas plays in our own energy supplies, and the role of the Netherlands as 'gas distribution country', then we need to ensure a transition within the gas sector.

The New Gas Platform encourages two developments to support this transition: making fossil gas cleaner and more sustainable (via CO_2 capture, gas from biomass and hydrogen gas), and a more efficient use of natural gas (e.g. in the built environment and via micro-cogeneration).

From several viewpoints (security of supply, reducing the dependency on fossil fuels and protecting the climate) greening the natural gas supplies forms an interesting option, both geopolitically and economically. The current Cabinet's ambition is to increase the percentage of sustainable energy up to 20% in 2020. Considering the importance of natural gas as a primary energy source, certainly for supplying heat, this objective cannot be achieved without greening the natural gas in the distribution network. This 'greening' refers to the use of biomass (organically based material) to produce gaseous energy carriers such as biogas (via fermentation), SNG (via gasification) and hydrogen. All gas from a non-fossil origin can be classified as green gas. The CO_2 that is released when burning green gas is actually stored in the biological material. This is the difference between green gas and fossil-based natural gas.

The Clean and Efficient [28] project clearly focuses on developing the greening process of the natural gas supply network. This Outlook is a practical elaboration thereof.

A recent OECD report[1] [27] raises doubts about the CO_2 advantage of biofuels. This advantage could be almost completely cancelled out by the amount of energy required to produce biofuels. This criticism primarily concerns 1st-generation biofuels, such as bioethanol, where conversion still requires a lot of energy. These biofuels need to be developed further before they can contribute to CO_2 emission reduction. Green gas is, in fact, a 2nd-generation biofuel. The fermentation technology has been around since the 1970s, so the teething troubles have been overcome. Green gas based on this fermentation technology can make a (significant) contribution to CO_2 emission reduction. When determining the greenhouse gas emissions of green gas it is important to consider the entire chain, from production and energy conversion, as well as the sale of residues and transport of the biomass. A 70% emissions reduction, compared to natural gas, is possible by using organic residues and choosing sensible production locations, so that the organic residues do not need to be transported. A good monitoring system is required, which also looks at the displacement effects. It is also possible that the use of organic residues for fermentation or gasification may lead to the original application of the organic residues now being achieved in a more energy-intensive manner. The CO_2 return of fermented green gas will probably lead to this becoming an attractive biofuel that can be included under the framework of the compulsory blending requirements with which transport fuel manufacturers must comply .[2]

In theory, the composition of green gas is the same as natural gas. Therefore greening the natural gas allows almost all the existing advantages of natural gas to be used, such as the Netherlands' good trade and knowledge position, the infrastructure and applications. In addition, the Netherlands has a good starting position for playing a pioneering role on biomass issues, due to the infrastructure (harbours and hinterland), the highly developed agricultural sector, the knowledge gained, broad biomass applications in the energy sector, and the traditionally strong position on the world biomass market for animal fodder, raw materials etc. Combined with the country's good starting position on gas issues (one of the finest meshed gas networks in the world, plus experience of gas transport), this means that the Netherlands is in an excellent position to play a meaningful role in developing green gas.

Green gas can be used in the immediate vicinity of a fermentation plant, via a small network, in a residential area or by companies, or it can be supplied to a natural gas filling station for use in vehicles. A much larger sales market will be possible when green gas is injected into the existing natural gas supply network, thus blending green gas and natural gas. The sales market can be extensive when biomass is converted into SNG, although this requires injection into the high-pressure gas network. It is also important to monitor the social effects of large-scale gasification.

1 R. Doornbosch and R. Steenblik, Is the cure worse than the disease?, OECD, Paris Sept. 2007.

2 This is an EU requirement. Producers of transport fuels are currently blending 2% biofuel, which will be increased to 5.75% in 2010.

The use of biomass will need to comply with sustainability criteria, such as those recommended by the Cramer Commission [26].

As long as green gas is more expensive than natural gas, a blend of the two gases will also be more expensive. Just as with green electricity, a market solution would be to sell green gas on a virtual basis to clients who are prepared to pay a higher price (companies, government and consumers). This can be gas used for heating and cooking, as well as gas for mobility applications.

The New Gas Platform realises that the use of biomass will lead to various sectors (electricity, fuels, chemicals, food/snacks and agriculture) that are now functioning fairly independently, becoming more closely linked, and thus competing with each other.

An additional demand for biomass to produce gas can cause price rises for animal fodder and for agricultural products, and thus also for foods such as bread. This can have very serious consequences, particularly for developing countries. In its final recommendations, the Sustainable Biomass Production Project Group, led by Mrs. Prof. J. Cramer (Cramer Commission) [26], defined various sustainability criteria for energy conversion from biomass, which also include the greenhouse gas balance. The minimum criterion is that projects must achieve a net greenhouse gas emissions reduction of 50-70% over the entire production chain. Initial calculations clearly show that biogas produced via fermentation can meet this requirement [17 + 29], although previously mentioned possible displacement effects are not taken into consideration. In order to limit the aforementioned side effects, these elements are expressly elaborated under the framework for assessing sustainable biomass [26]. This framework applies to all forms of green gas. Additional criteria apply to green gas produced via fermentation, and particularly for cofermentation of manure. Together with the sustainability criteria defined by the Cramer Commission, these form the assessment framework for green gas, as described below.

The market for green gas can be created in a socially responsible manner, if the following criteria are met:

1. A net CO_2 reduction of 70% is achieved over the entire chain (from biomass production to final application).
2. Only organic residues are used, whereby the highest-value applications are continually sought, so that there is no competition with food production, local energy supplies, medicine production, and the manufacture of construction materials in developing countries.
3. There is no damage to protected areas or valuable ecosystems.
4. There are no possible negative effects on the regional and national economy.
5. There are no negative effects on the welfare of employees and the local population.
6. There are no possible negative effects on the local environment (e.g. extra emissions of ammonia, laughing gas, or NOx).

7. With cofermentation of manure, the minerals nitrate (N) and phosphor (P) are not extracted during the natural cycle, but are reused as fertiliser.
8. Subsidising green gas does not lead to full legitimisation, but does give a boost to the biotechnology industry.

It is a good idea to monitor the market that has developed for green gas, for these and other possible side effects (see Chapter 6).

The opportunities offered by green gas, even within the aforementioned conditions, are certainly impressive. In 2050 around half of our natural gas requirements can be met by green gas. According to the Green Gas Working Group it is therefore important that the energy transition also partially focuses on developing a greener gas supply network.

This report covers the possibilities for greening the gas production process by using green gas.

1.3 Green gas potential

According to the recommendations made by SenterNovem to the Ministry of Economic Affairs, the potential for using green gas via fermentation amounts to 2-3 billion m^3 natural gas equivalents [13][3]. This is the maximum potential based on domestic biomass, i.e. without using imports. Various estimates have been made of the potential for green gas, and these estimates differ somewhat. The diversity of these estimates depends on the development of the transition path. The short-term estimate (replacing 1-3% natural gas, based on domestic biomass) only results in limited debate. However, one of the related questions concerns the use of residues from the food and snack industry for energy purposes. The uncertainty in the medium-term and long-term estimates of this potential relate particularly to the following factors: the international availability of biomass and the speed with which gasification technology is developed. Very little of the biomass currently available is used for energy purposes. Where this does occur, almost all the biogas produced is (currently) used in cogeneration plants to produce electricity and heat. In most cases the heat produced is only partly used in an effective manner – injecting biogas into the natural gas supply network is therefore also the most sustainable option. However, before the biogas can be injected into the natural gas supply network, it must be upgraded to natural gas quality. The technologies to achieve this are already available [25]. The production and injection of green gas into the gas supply network will lead to a larger percentage of sustainable energy (more sustainable energy from the same amount of biomass) and thus to more efficient use of the available policy resources (more sustainable energy for the same budget). The publications included in the literature list [20 + 21] discuss the modifications required to the Gas Act to enable gas injection into the local and

3 Further research is required to determine the consequences of applying the aforementioned criteria to these estimates of green gas potential.

regional gas supply networks. As yet, no conditions have been defined for injecting gas into the high-pressure transport network. The best potential for green gas lies in injecting SNG gas from gasification. The expected large-scale use of these projects means it is necessary to inject SNG into the national transport network. Uniform conditions for doing so still need to be developed.

Giant steps forward can be taken if the transition is made to biomass gasification and generating green gas. Large-scale gasification of biomass requires biomass to be imported, or undertaking large-scale production elsewhere (e.g. in the Baltic States). There are sufficient possibilities regarding SNG to assume the use of residues. The criteria defined by the Cramer Commission concerned, among other things, using biomass to produce SNG. However, further research into this technology is required before SNG can play a serious role in the Dutch gas supply. Here too, the aforementioned organisational and social aspects should be included in the research.

The New Gas Platform considers it technically feasible to replace 8-12% of the natural gas with green gas in 2020. This will be possible if most of the biogas potential from fermentation is used, and when one or two large-scale SNG projects are achieved. The New Gas Platform has also formulated the ambition to replace 15-20% of the natural gas with green gas in 2030. This is not an inflexible ambition, but a target: the extent is chosen to illustrate that green gas can make a real contribution. A 50% natural gas replacement has been chosen as a speculative target for the year 2050. However, the aforementioned sustainability criteria may make it necessary to lower these targets.

At this point in time it is difficult to predict the contribution that hydrogen can make to this potential. The question as to whether hydrogen should be used alongside green gas remains unanswered, due to the uncertainties that accompany the required system changes for hydrogen.

2. THE ROAD MAP

The transition path to greening the supply of natural gas (Figure 1) consists of three phases:

2.1 Short term: biogas route (approx. 1-3% natural gas replacement)

This transition path allows us to start now via the biological route: fermenting biomass into biogas (manure, GFT (compostable household waste), slaughterhouse waste, products/residues from the food/snack industry, etc.). This is a proven technology that is already being applied on a commercial basis. Typically, these are still small-scale projects using locally or regionally available biomass. Biogas can be applied directly (energy production, micro-cogeneration, as fuel for heating plants and processes) or upgraded to natural gas quality for injection into the gas supply network or used for mobility applications. The theoretical maximum potential for biogas in the Netherlands is estimated as 50-60 PJ, which is relatively small compared to natural gas consumption (approximately 1500 PJ per year). However, this route would be an excellent way of boosting the institutional framework for green gas and developing the market for this product. The biogas route is currently suffering primarily from the higher cost price of biogas (depending on raw materials used) compared to the price of natural gas (see Chapter 5), from institutional barriers (regulations, permits), technical and organisational barriers (quality problems when injecting into the gas supply network, reusing the minerals from the digestate and processing the digestate into fertiliser, support levels, developing market demand), as well as from the physical limitations of the natural gas supply network (capacity) for injecting green gas (see Chapter 6).

2.2 Medium term: SNG route (approx. 8-12% natural gas replacement in 2020)

Sustainable gasification of biomass and SNG production becomes interesting in the medium term. Gasification is a thermochemical process whereby biomass is converted (at high temperature) into synthetic gas that, after processing/ synthesising, eventually produces green gas. The scale size (from several dozen to hundreds of MWth) is characteristic of this process. Large-scale production of SNG also implies the import of biomass (residues).

In contrast to the biogas route, the maximum replacement of natural gas by SNG is 100% although, in practice, the percentage depends on the possibilities of obtaining sufficient sustainable biomass on the (global) market, and the competition with other applications, such as transport, electricity and materials. Large amounts of SNG could be transported via the national gas supply networks (regional or high-pressure, RTL/HTL), so that the gas can be used in an energy-efficient manner. Considering the wider variety of end-user applications, the higher pressures and the larger amounts injected, the criteria for injecting into the high-pressure supply network will be more stringent than those for local distribution networks.

A large-scale plant (around 3000 MW) in the USA has been producing SNG from coal for the past 20 years. At laboratory scale, experiments have shown that SNG (in the required composition) can be produced from biomass via gasification and methanisation processes. Further technology development is required to achieve an optimum conversion process (i.e. converting the energy in biomass as efficiently as possible into SNG with the required composition and characteristics). Aspects thereof include optimum gasification technology, suitability of gas cleaning, and the development of catalysts. Based on this development work, which is ongoing, over the next 5-10 years the conversion techniques are expected to be scaled up to achieve commercial production at a reasonable level. Further study is also required into the social aspects of using biomass.

2.3 Long term: scaling up to 50% natural gas replacement

After 2030 it may also be possible to produce hydrogen, and thus it may be possible to develop a hydrogen economy. However, due to the considerable uncertainty concerning the future expectations for hydrogen, this path is not elaborated here, but is simply included in order to provide a complete overview. See also the advisory report 'Waterstof – Brandstof voor Transities' (Hydrogen – Fuel for Transitions) published by the Hydrogen Working Group, which is part of the New Gas Platform. This report provides an integral outlook on using hydrogen as the basis for a clean and reliable energy supply.

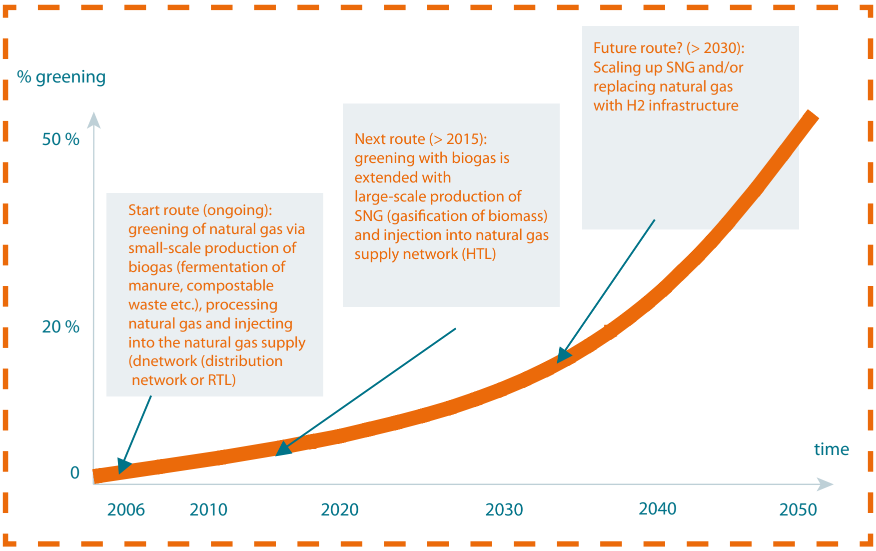


Figure 1: Transition route for the gradual greening of natural gas

3. DEVELOPING THE TRANSITION PATH

The Green Gas Working Group recognises the need for quickly developing a market for biogas, so that the first steps can be taken along the transition path to green gas. In the short term, injecting green gas into the natural gas supply network via cofermentation will prepare the way for producing green gas via the gasification route, which has the potential for far greater capacity. Biogas production also offers opportunities to integrate various sectors that have remained separated until now, particularly the energy and agriculture sectors. This concerns a real transition path, because the first steps along this path will soon become profitable. This will bring opportunities for creating an economic advantage, simply because the parties work together across national borders and sectors.

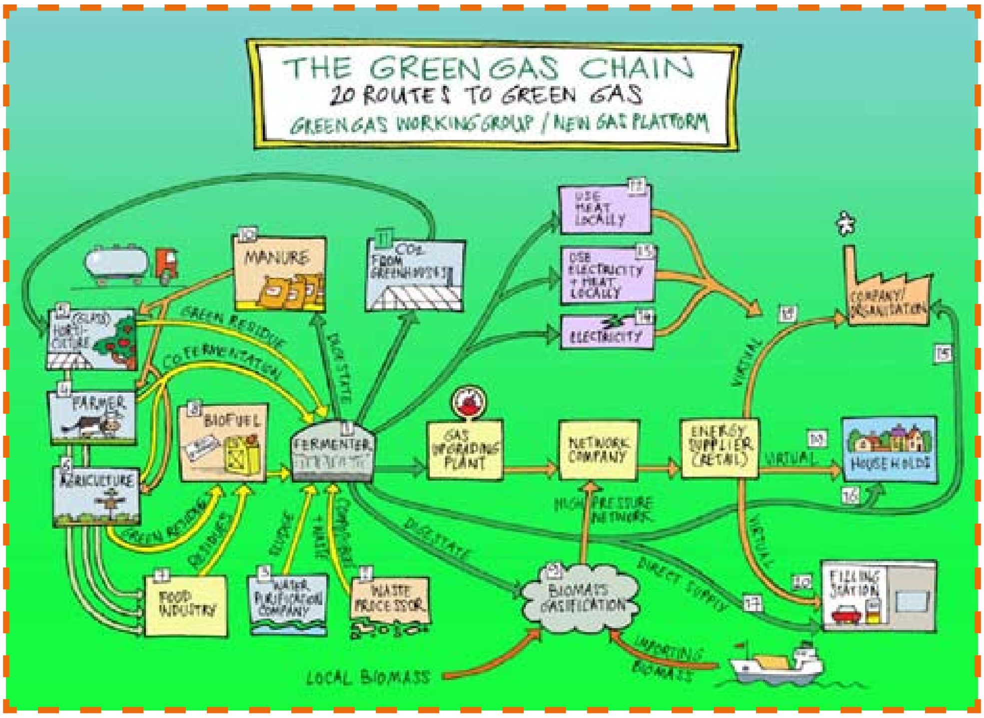
Many parties that possess a raw material for fermentation are interested in producing biogas. Where this raw material is available at little or no cost, biogas can be produced at a price that is comparable to natural gas. However, the development of a biogas market is obstructed here by organisational and institutional aspects. Priority should be given to the application that results in the greatest possible net CO_2 reduction.

An integral approach forms the core theme of a transition to green gas. Combining the (until now) individually operating sectors can achieve far better sustainability of production processes, as well as allowing scale advantages to be realised.

A real transition is only possible when there is the prospect of producing green gas profitably, without subsidies, in the long term (i.e. 5-10 years time). The green gas chain offers a large number of opportunities for producing green gas profitably. In general, there are four ways to reduce the cost price of green gas in the short term:

- The fermentation and reprocessing can become more efficient due to economies of scale. Production on a larger scale could reduce the cost price considerably. Fermentation could also be made more efficient if more residues were used as raw materials for cofermentation.
- The costs of raw materials for fermentation could be reduced by first using the high-value green materials in another way. It is better to first use the residue from the processing of sugar beet to produce biofuel. The residue can then be used as raw material in the fermentation process.
- The digestate contains valuable materials that can be used, for example, as fertiliser.
- The return on investment (on the gas produced) could be increased by selling green gas as a separate product with an added value. There are also new application possibilities for green gas, for example as a transport fuel.

The following diagram sketches a range of possibilities for making green gas more profitable, including the possible combinations of market segments that have, until now, remained separated.



Appendix L contains more details of this diagram, which also shows the integral embedding for developing green gas applications.

Routes 15-17 also sketch the possibilities for using biogas that has not been upgraded to natural gas quality, which can also be used locally via an energy conversion phase. Such applications include mobility applications, converting electricity and heat via a suitable cogeneration plant, as well as using it as fuel, for example in heating installations and processes.

4. AN APPROACH TO DEVELOPING A GREEN GAS MARKET

The approach taken by the Green Gas Working Group is that experiments should be initiated whereby upgraded biogas is injected into the gas supply network, particularly those experiments that study the various opportunities for producing biogas. It is assumed that biogas will, for the time being, only be injected into regional low-pressure and/or medium-pressure gas supply networks (RTL, between 100 mbar and 8 bar), behind a GOS (gas receiving unit). The long-term large-scale injection of SNG will probably need to be implemented via the national high-pressure transport network (HTL, 67 bar) due to the transport capacity required.

The Green Gas Working Group will shortly focus on developing green gas potential via fermentation. Projects are expected to be developed that vary in capacity from several dozen to several thousand m^3 of upgraded biogas per hour.

In parallel, the developments concerning gasification will be followed carefully, in connection with green gas production from SNG based on biomass. It is important that research be conducted into the large-scale production of SNG and the removal of production bottlenecks.

The most important opportunities and focal points for the Green Gas Working Group are:

- balanced financial measures (see Chapter 5);
- helping to find solutions for the focal points that deter green gas production and influence the injection of green gas into the (local) distribution network, plus those that help to utilise these opportunities (see Chapter 6);
- forming consortia to produce green gas (see Chapter 7);
- exchanging experience with respect to the production, distribution and sale of green gas (see Chapter 8);
- a research programme for the development and scaling up of SNG production (see Chapter 9).

The following chapters provide more information on these opportunities and focal points.

5. BALANCED FINANCIAL SUPPORT

It is clear that the green gas market will never get off the ground without some form of financial encouragement from the government. This does not, at least not initially, refer to investment subsidies, but a certain sales guarantee at a specific price for the green gas produced. Once there is a profitable market for green gas then investors will be prepared to make the required financial resources available.

Until recently biogas was primarily used to produce green electricity. The MEP scheme (electricity generation for environmental quality) only supports the generation of sustainable electricity. As yet, the production of green heat or green gas has not been (directly) encouraged and/or valued. If the heat released when generating electricity from biogas are not used, then considerable amounts of energy are lost. The development and installation of an exploitation allowance that is equivalent to the MEP, where the sustainable (energy) value of green gas is actually priced, will accelerate the successful introduction of green gas and considerably enlarge the production potential.

According to the Green Gas Working Group, a financial encouragement scheme should meet the following conditions:

- The scheme should ensure that the most efficient application (with respect to net CO_2 return) can be used for a specific situation (electricity plus heat, injecting upgraded biogas at natural gas quality into the regional gas distribution network, purely electricity, purely heat).
- The scheme should encourage innovation: the green gas chain offers plenty of opportunities for innovation, and thus possibilities to lower the cost price of green gas. If (part of) that advantage is passed on to the producers then this continues to encourage innovation.
- The scheme should allow a range of applications (raw materials; scale size; production, injection and distribution techniques; combinations with other innovations, such as using digestate as fertiliser). This also allows new forms of synergy to be found.
- Financing should offer long-term investment security.
- The scheme should discourage undesirable social side effects. This primarily refers to indirect encouragement of intensive cattle farming, particularly the relocation of the manure problem from the agricultural sector to the energy sector, and the care of animal welfare.
- The financial scheme should not cause any undesirable market disruptions.

The Dutch Cabinet has already indicated that it is working towards a subsidy scheme (SDE scheme, as follow-up to the MEP scheme), which should encourage all forms of sustainable energy generation in a balanced manner. This scheme aims to remove the financial gap from the various forms of sustainable energy production. In its January 2007 report to the Minister of Economic Affairs [13], SenterNovem calculated the production costs and financial gap in green gas production (in m³ natural gas equivalents) from various biomass flows for two scale sizes. The financial gap is calculated against a natural gas commodity price of 16 €ct/Nm³.

For calculations concerning SNG readers are referred to the ECN report dated November 2006 (ECN-E—06-018).

The Table shows that the cost price of green gas varies from 15 to 48€ct/Nm³, if fermentation of compostable waste is not included (due to the considerable technical challenges of process operation). The financial gap amounts to -1 to 32 €ct/Nm³. If this financial gap is recalculated for sustainable electricity, of which the MEP allowance in 2006 was 9.7 €ct/kWh for small-scale biomass, then the stimulation requirements for green gas are in the same order of magnitude as sustainable electricity. Even if calculations are based on ECN's new 2007 financial gap calculations for small-scale biomass of 6.2 €ct/kWh (a proposal, the policy decision has not yet been made), the magnitude remains the same.

Option	Scale[1]	Production costs Green Gas in 2006 (€ct/Nm³)	Financial gap (ORT) Compared to natural gas in 2006 (€ct/Nm³)	Financial gap [5](ORT) recalculated for sustainable electricity (€ct/kWh), 2006
1. Landfill gas	Large	17.7 – 19.6	1.7 – 3.6	0.5 – 1.1
2. RWZ[3]/AWZI[6]	Large	14.8 – 17.0	-1.2 – 1.0	-0.3 – 0.3
3. Compostable fermentation	Large	46.2 – 71.3	30.2 – 55.3	9.0 – 16.5
4. Cofermentation using residues[2]				
	Small	34.8 – 35.4	18.8 – 19.4	5.6 – 5.8
	Large	14.8 – 17.0	-1.2 – 1.0	-0.3 – 0.3
5. Cofermentation using energy crops (corn) [3]				
	Small	44.9 – 47.7	28.9 – 31.7	8,6 – 9,5
	Large	27.1	11.1	3.3 – 3.4
6. SNG via gasification				
	Decent-ralised	39.2 – 97.5	23.2 – 81.5	6.9 – 24.3
	Central [4]	29.5 – 48.5	13.5 – 32.5	4.0 – 9.7

1 Small = 100m³/h, large = 500-600 m³/h, decentralised = 1,000-10,000 m³/h, central = 10,000-100,000 m³/h.
2 No costs are calculated for purchasing and transporting residues. Considering the cost-price developments of biomass flows, it is reasonable to assume that such costs will need to be paid in the future.
3 The Green Gas Working Group assumes that only residues are used.
4 With imported biomass and SNG production for the high-pressure network (67 bar).
5 Converting ORT green gas based on producing 3.35 KWh of electricity from one Nm³ natural gas/green gas, based on a cogeneration-efficient electricity production from biogas of 35%.
6 Sewer/wastewater purification plants.

A calculation example of the stimulation requirements at project level

Let us assume a larger traditional cofermentation plant with cogeneration (option 5 in the previous Table), with an electrical capacity of 1.5 MWe and a biogas plant with biogas upgrading (capacity 500 Nm^3/h), thus allowing the following comparison to be made.

	Electricity production bio-cogeneration	Green gas project
Capacity	1.6 MW_e	500 Nm^3/h
Operating hours per year (full capacity)	8,000	8,000
Useful energy production	12,800,000 kWh (electrical)	31,264,000 kWh (total) at 80% efficiency energy conversion to green gas
Stimulation required	At € 0.097/kWh € 1,242 million/yr	At € 0.10/Nm^3: € 400,000/yr At € 0.20/Nm^3: € 800,000/yr At € 0.30/Nm^3: € 1,200,000/yr

The aforementioned calculations are based on a large number of assumptions. As the circumstances can vary so widely it is difficult to generalise about the cost price of injecting biogas into the natural gas supply network.

The FNLI (federation of packaged food producers) has developed a calculation model in cooperation with SenterNovem's MJA (long-term agreements) programme. Companies considering producing green gas can use this model to test the business-economic prospects based on their own specific corporate situation (see Appendix M).

Market disruptions

The Green Gas Working Group realises that some forms of use should be seen as undesirable. In theory, green raw materials should initially be used for high-value applications. Also, in theory, green gas production is presumably based on residues. It is important that subsidies watch for possible undesired market disruptions, such as the production of food crops and animal fodder out being manoeuvred of the market.

6. OPPORTUNITIES AND FOCAL POINTS

The following subjects need to be further detailed before green gas can be injected into the local natural gas supply network.

6.1 Cost price

This is covered in Chapter 5.

6.2 Technical opportunities and focal points

– **Quality**

On 21 November 2006 the Dte (Office of Energy Regulation) formulated additions to the gas network regulations [20, 21]. These include the criteria with which gas injected into the regional natural gas distribution network must comply and the measurement conditions that apply. These additions also stipulate that network managers may also set additional conditions. In the short term, maintaining these quality criteria offer sufficient support and clarity to develop a green gas route. The quality criteria maintained by the regional network managers are currently documented by Kiwa-Gastec and via the Green Gas Book [24]. The quality discussion with respect to biogas is still ongoing. This discussion will certainly include attention to the possible risks concerning the spreading of bacteria, moulds, viruses and trace elements. Over the next few years green gas injection into local and regional natural gas supply networks will probably develop via fermentation projects. Table 6 in Appendix G illustrates the legal quality criteria for injecting gas into the natural gas supply network.

Considering the responsibilities of network companies for gas transport and balancing of the natural gas network, further attention will need to be paid to the following subjects when implementing the green gas route. The following focal points will also be detailed in the Green Gas Book [24]:

How do you ensure that the caloric value is equal, or higher, than that of Slochteren gas? Monitoring and conversion systems for gas amounts and gas quality (including the Wobbe index) will need to be determined in any green gas certificate that is developed.

- How do you ensure that biogas does not contain any materials (trace elements, bacteria and moulds), burned or unburned, that could create unacceptable risks for human health, equipment, products and processes of those using the natural gas system (including pipes, compressors and underground storage)? An important bottleneck is that it is currently not yet known which criteria will be defined for substances that do not occur in natural gas but that could be present in biogas.
- How do you ensure that the pressure remains stable, and equal to the network to which the gas is being injected? Pressure fluctuations can lead to the end-user pressure dropping, causing equipment to fail. Sometimes, for example if the pilot light on an appliance goes out, this could lead to gas flowing freely

into the room as soon as the pressure returns to normal. This would result in dangerous situations.

The quality discussion concerning gas injection into the national gas transport network from large-scale SNG production is covered separately. The SNG production process is very different to fermentation, which results in a different composition to green gas.

- **Infrastructure required**
  The natural gas network has been designed for central injection. Decentralised injection of gas (particularly in local and regional natural gas networks) will highlight capacity limitations in the natural gas supply network. This will need to be anticipated when preparing for implementation. Project initiators will therefore also find it extremely important to contact the local network manager (as soon as possible), in order to gain insight into the various options for network injection.

  Apart from the transport capacity in the physical gas pipeline, the current allocation calculations also need to be revised: this should include the condition that injection should occur at one client and using one inspection profile. As a result of these two focal points, under the current circumstances, only a limited number of projects can be developed.

There are four options, but no clear priority for these options, as the one chosen will largely depend on the location:

- Set up an infrastructure to transport manure and organic residues over long distances, and wherever central and large-scale fermentation and injection take place.
- Develop a special local biogas network to which biogas producers and clients can be coupled.
- Decentralised fermentation and central injection (the biogas being transported via a special local biogas network, for central final processing/injection into the supply network at a central location).
- Decentralised fermentation and injection (possibly in the 100-mbar network).

It is not yet clear which is the most efficient way of injecting green gas into the gas supply network. Some market parties indicate that injecting into the 100-mbar network is possibly a more attractive option. This allows fermentation very close to the source of green raw materials, thus avoiding the need to transport the biomass. However, the gas would need to be upgraded to the required natural gas quality at every location, which would cause relatively high costs for small-scale projects. Another option is to transport the unprocessed biogas to a central point via a local biogas network, and then inject it into the traditional supply network at central points. However, this results in extra pipeline costs. Some form of centralisation would allow the medium-pressure network immediately behind a GOS (gas receiving unit) to be used, which is simpler for network management and easier to monitor the gas quality.

In conclusion, there is no standard solution, but a solution should be sought based on the specific project circumstances. This choice will largely be determined by the availability of biomass, the presence of natural gas pipelines and the sales options for digestate.

6.3 Institutional opportunities and focal points

- **Selling the digestate**
  The raw materials for fermentation (green residues, residual flows from the food industry, manure, compostable waste and other organic waste, sewage sludge) have a certain value, which should be utilised in the best possible manner. William McDonough and Michael Braungart, in their book 'Cradle to Cradle: Remaking the Way We Make Things' (2002) speak of 'from cradle to cradle' rather than 'from cradle to grave'. Thinking along these lines, the digestate should be reused, wherever possible, as a fertiliser. Digestate can currently be used as fertiliser under two circumstances:

  - as animal fertiliser, should the substrate composition in a fermenter consist of at least 50% animal manure. The disadvantage of the current fertiliser law is that all minerals in the digestate are indicated as being derived from animal manure. In practice, this limits the options for using digestate;
  - in other cases, under the BOOM legislation. The Besluit Overige Organische Meststoffen (BOOM / Decree for quality and use of other organic fertilisers) is currently being integrated into the modified Fertiliser Act, which contains a list of substances that fertilisers may contain. The Green Gas Working Group calls for harmonisation of the interpretation of these European regulations concerning fertiliser legislation. In some cases digestate is currently being transported to Germany.

At some point it may be possible to use the dry fraction of digestate as raw material for gasification (SNG). However, there is some concern regarding the reuse of phosphor, as it is possible that this mineral will be burned during high-temperature gasification. A criterion here is therefore to maintain the quality of the phosphor-retaining residue. The phosphor should be available as fertiliser.

- **Developing a system for trading green gas**
  In order to develop a market for green gas, it needs to be sold in a virtual way, the same as green electricity. Under the current situation, the company injecting green gas needs to have both a virtual buyer for the green gas and a physical client in the local supply network into which the green gas is being injected.

A certification system needs to be set up as a basic criterion for the virtual supply of green gas. A Green Gas Certificate would thus be available for injecting a certain amount of green gas into the conventional supply network. The green gas client purchases a certain amount of gas from the network, plus the certificate. When implementing a certification system for green gas, the production and sale of green gas are uncoupled. This removes a huge barrier to the introduction of green gas. Other advantages of a certification system include:

- the possibility of coupling directly to the national monitoring of sustainable energy;
- introducing transparency in issuing and redeeming certificates, thus preventing sustainable energy and possible stimulation measures being counted twice (see Appendix J).

- **Fermenting manure as agricultural activity**

Under the framework of assisting cofermentation, at the beginning of 2005 Infomil developed an assessment framework for issuing permits for cofermentation plants. However, in practice, it is still difficult to develop projects with a processing capacity of over 36,000 tons per year. A certain business scale is necessary in order to run a project profitably, particularly in cattle-intensive areas where farmers often want to combine cofermentation with a form of manure processing. In practice, it appears that zoning plans are not aligned and that new discussions continue to be initiated as to whether fermentation is, or is not, considered an agricultural activity. Based on a decision by the Council of State (22 August 2007), a manure fertilisation plant is not considered an agricultural activity [30]. This indicates that there is a great need for more manageable definitions.

- **Uniform conditions for injecting into the gas supply network**

The additions to the Gas Act dated 21 November 2006 [20 + 21] only concern injecting gas into local and regional gas distribution networks. However, a national transport network is required to inject large-scale production of green gas. Uniform conditions for this have yet to be developed.

6.4 Organisational opportunities and focal points

- **Cooperation between the various parties involved**

In order to utilise the opportunities offered by green gas, harmonisation and cooperation between the various stakeholders will need to be achieved. Aspects requiring cooperation include for following.

- Setting up a certification system for green gas.
- Making uniform agreements concerning the quality of the green gas injected into the supply network. This includes managing risks and preventing the shifting of those risks. It is currently unclear which party in the chain is responsible when a client complains that the gas supplied does not meet the applicable quality criteria.
- Distributing the advantage: one party has more advantage than another.

A better distribution of the advantage gained from producing and injecting biogas ensures that all links in the chain have a more equal interest in producing and injecting green gas. Methods of equalising this need to be developed. The answer to such questions can be found in the setting up of consortia that include green gas producers, consumers, as well as the digestate, network and trading companies.

- Attention should also be paid to the costs involved in injecting green gas into the regional supply network. The supervisory body, the DTe, should also be involved.

It is possible that the clustering of powers, for example by forming cooperatives of green gas producers, could encourage the fast development of the green gas market.

- **Social discussions**

  Although green gas has a number of social advantages, it also generates a number of (potential) social discussions.

  - People living in the surrounding areas can object to the transport of biomass. This primarily concerns semi-centralised large-scale fermentation.
  - There may be some fear of pollution (odour and the view), primarily with large-scale central fermentation.
  - The environmental movement may object to green gas production being based on cofermentation, using manure from current cattle farms. There is then a chance that the CO_2 impact and the environmental pollution caused by the cattle farms are no longer accounted for as manure.
  - Objections may be made to the cultivation of energy crops[4]. This can influence the price of food and animal-fodder crops. It can also lead to land being used elsewhere in order to cultivate these products. Setting priorities (the highest value application first) should be part of the sustainability criteria for green gas.
  - Life-Cycle Analysis, as generally implemented today, takes little or no account of the carbon balance of the soil. This should also be included in the analysis.
  - There is some concern about the consequences for developing countries of large-scale green gas production via the SNG route. Producing SNG will require large quantities of imported biomass. The sustainability criteria set by the Cramer Commission (see Chapter 1) aim to prevent these undesirable side effects. It is important that these aspects are actively pursued in a social discussion concerning the effects of using biomass and the fermentation of organic residues.

The criteria developed by the Cramer Commission and the Green Gas Working Group form a valuable assessment framework. This will be evaluated and modified (where necessary) based on the monitoring of the effects of introducing green gas and the social discussions that result.

4 The Green Gas Working Group assumes residues.

7. FORMING CONSORTIA

The development of a green gas market requires cooperation between a considerable number of stakeholders from sectors where, until now, there have been little or no cooperative agreements: the agricultural sector, waste processors, water boards, food/snack industry, wood and paper processing industry, mobility sector, housing associations, and the energy sector. Cooperation is also required between the potential producers of green gas, network companies, filling stations and potential consumers of green gas (such as sustainable procurement companies, governments, and the energy retail companies that offer green gas to their consumers).
This means not only cooperating to realise a common interest, but intensive forms of cooperation to equalise the advantage among stakeholders.

The Green Gas Working Group is of the opinion that forming local consortia with the stakeholders involved is a crucial step in developing a green gas market. Cooperation is therefore sought between organisations from the agricultural sector (ZLTO, a southern agricultural and horticultural organisation), the packaged food industry (FNLI), the Green Raw Materials Platform, and the Driving on Natural Gas and Biogas Working Group.

In forming consortia, the Green Gas Working Group will work together with the Driving on Natural Gas and Biogas Working Group, which has already developed a market for green gas as a transport fuel. The first project in this respect is known as the Coalition Driving on Biogas, which has a fleet of buses in Zeeland running on green gas, and plans to open eight public green gas filling stations in Gelderland. The second project is called Driving on Compostable Waste and is operated by the waste processing company ROVA in Zwolle, which will run refuse collection vehicles on green gas. Both projects were initiated using a UKR (unique opportunities scheme) subsidy. Initiatives to promote the use of green gas are also being operated in areas such as Haarlem, The Hague, Brabant and Friesland.

Provincial governments and (larger) local authorities can also play an important role in developing (local) consortia: as facilitator, as a purchaser of green gas, and in spatial planning.

8. SWAPPING EXPERIENCE

At the end of 2006 the company BioGast Sustainable Energy took the initiative to work together with other stakeholders and draw up a Green Gas Book (GGB) [24]. This is a manifest on how to implement the transition to green gas. Experiences, knowledge and skills – partially built up by the green gas demonstration plant in Beverwijk – are clustered and expanded into publicly applicable tools and methods. The GGB programme was implemented in 2007 by a number of partners: energy companies, the national gas sector, governments, NGOs and organisations with high ambitions with respect to corporate social responsibilities. The input by the various partners consists of know-how, manpower and financing. Project leadership and editing is carried out by BioGast Sustainable Energy. The Green Gas Working Group and the GGB partners will coordinate the contents on a regular basis.

In addition, the Energy Valley Foundation has set up a green gas programme to form a complete green gas chain (from production and upgrading through to final consumption) and to search for potential product-market combinations (mobility, high-efficiency boilers, industry etc.). This programme focuses both on biogas production (particularly market introduction) and the SNG route (particularly technology development and demonstration).

The Green Gas Working Group also foresees activities such as the formulation of consortia to cluster potential initiators and local governments.

9. RESEARCH INTO SNG

In terms of volume, SNG from biomass has a greater longer-term potential than green gas from fermentation. SNG production is also complementary to biogas produced via fermentation, as SNG is produced from woody biomass and thus does not compete with the wet residues that are suitable for fermentation. In contrast to the fermentation route, the development of SNG projects will primarily occur due to the expected scale size. These projects will thus also be realised in the vicinity of a high-pressure distribution network, and be situated in logistically advantageous locations, such as harbour areas, partly in connection with the transportation of the required biomass.

A demonstration project has been started in the Austrian town of Güssing. Another project (in Swedish Göteborg) has started at a (minimum) practical scale of 100 MW, which is expected to go into production in 2012. The approach in both these towns is based on a short-term horizon, using a combination of existing techniques to demonstrate the working principle. When setting up these projects, concessions were consciously made with respect to the efficiency of the total concept, as these pilot projects will be used to further develop a 2nd-generation SNG plant. The timeframe here is 5-10 years. With respect to the Dutch situation, this 2nd-generation SNG plant is a logical and necessary follow-up to the production of green gas. E.ON Sweden foresees this development path resulting in several SNG plants being built before 2020.

- A number of demonstration projects will start over the next few years, and these will conduct specific research. The subjects relevant for these projects include:
- the optimum gasification technology;
- the most suitable gas cleaning technology;
- selection of catalysts and conditions;
- the conditions under which injection into the (high-pressure) gas distribution network is possible (i.e. quality criteria);
- the social effects of large-scale SNG production (including the consequences for other sectors, such as the food industry, but also the consequences for developing countries);
- fundamental research to benefit the development of 2nd-generation SNG.

LET'S GIVE FULL GAS !

THE ROLE OF GREEN GAS IN THE DUTCH ENERGY SYSTEM

Appendices

APPENDIX A NATURAL GAS IN OUR CURRENT ENERGY SUPPLY

Natural gas is an important energy source within the Netherlands' energy supply, with 46% of the (primary) energy consumption. The most important natural gas application is heat production (70%). In the medium term natural gas will play an increasingly more important global role due to the lower CO_2 emissions when generating electricity (compared to coal) and the larger stocks available (compared to oil). Domestic production of natural gas has reached its peak and, over the next few years, the Netherlands will also become more dependent on imports of natural gas.

A.1 Current use of natural gas in the Netherlands

The Netherlands consumes almost 3,300 PJ of primary energy to produce electricity, heat, transport fuels and other products and chemicals. Table 1 shows the way in which the various primary energy sources are split over the various products [1]. Natural gas therefore represents 46% of the national (primary) energy consumption. Applications using natural gas include chemicals (7%), generating electricity (23%) and, by far the largest application, generating heat (70%). Outside industrial uses, almost all heat is produced via natural gas (96%), with oil only being used in cogeneration (combined heat and power) plants. When natural gas is used for heating outside industrial applications, 40% is used for households (over 400 PJ).

Consumption [PJ]	Coal	Oil	Natural gas	Electricity	Other	Total
Electricity	200	10	350	70 [5]	230	860
Transport (fuels)	0	480	0	10	0	490
Products and chemicals	70	370	100	30	0	570
Heat	40	240	1,060	0	20	1,360
Total	310	1,100	1,510	110	250	3,280

Table 1. Primary energy consumption (in PJ) in NL for various products

A.2 Expected natural gas developments

In its World Energy Outlook 2005 [2], the International Energy Agency (IEA) predicts that, worldwide, the absolute use of natural gas will increase more than any other type of primary energy source. The global demand for natural gas will increase fairly dramatically, at 2% per year up to the year 2030. This is a relative drop in growth compared to the period 1980-2004 (2.6%). However, it remains a considerable increase in gas consumption. In 2030 the total worldwide gas consumption will be almost double. In addition, policies are being prepared to become less dependent on oil imports, by replacing 10% of the oil with natural gas.

5 Electricity from electricity concerns import.

The most important motivators for the increasing use of natural gas in the energy supply are the climate problem and, to a lesser extent, the economy: gas-fired power plants are less expensive than coal-fired plants. As part of a global agreement, the EU Member States have committed themselves, under the Kyoto Protocol, to reduce all greenhouse gas emissions (with CO_2 as the most important component). The measures taken to realise the aforementioned objectives generally fall into two categories: using more renewable energy, and replacing ‘heavier’ fuels with ‘lighter’ alternatives, for example by using natural gas rather than ‘heavier’ fuels such as coal and oil. Out of all the fossil fuels used today, the extraction and use of natural gas, per unit of energy, has by far the least effect on the environment. In comparison: natural gas generates (per kWh) half the CO_2 of coal; for the other greenhouse gases this is even less.

With respect to the last point above, the electricity sector in particular is still flexible when it comes to the choice of fuel. The EU electricity sector is responsible for one-third of the total CO_2 emissions. The EU is currently generating only 16% of its electricity from natural gas, with coal and nuclear energy accounting for the majority. In the Netherlands, gas accounts for the majority (over 50%), but a considerable amount of electricity is also generated from coal (almost 30%).

In theory, gas reserves around the world are still sufficient to meet this growing demand for natural gas. The EU currently meets around 60% of its gas requirements from its own stocks. This is primarily due to the production in the Netherlands and the UK, where almost half the current EU gas demand is supplied. Although the limited amount of own energy supplies within the EU is generally seen as a problem, the situation regarding natural gas is better than that of oil and coal.

However, the total Dutch gas supply has reached its peak and will shortly start to fall. This means that the increasing demand for natural gas and the reduced stocks will result in additional import dependency for the EU, to approximately 70% around the year 2020. In order to meet the required security of supply, more and more gas will need to be imported from regions such as Russia, Africa and the Middle East. Some of this required gas stock will need to be transported over long distances in liquid form (LNG). This is risky, particularly due to the ever-increasing price of oil and the dependency on politically less stable countries, as shown at the beginning of 2006 when Russia decided to turn off gas supplies to the Ukraine, with far-reaching consequences for various countries in Europe. In addition, the search for more and cleaner fuels will increasingly turn towards sustainable fuels, such as gas produced from biomass [3].

APPENDIX B DEFINITIONS OF GREEN GAS + UNITS

Gas type	Description
Natural gas	- extracted from natural gas fields, contains mostly CH_4 - composition varies, Gasunie ensures constant quality
Biogas	- produced via fermentation, contains mostly CH_4 and CO_2
Landfill gas	- a product from landfill waste sites, composition comparable to biogas
SNG	- 'Synthetic Natural Gas', contains mostly CH_4 produced via gasification, followed by methanisation main origin: coal and biomass
SNG	- sometimes the term SNG is used as an acronym for Substitute Natural Gas; the meaning is broader than that described above, and refers to all gas with which fossil natural gas can be replaced. This gas can thus also be derived from fermentation or gasification processes.
Bio-SNG	- SNG from biomass
Green Gas	- collective term for reprocessed bio-SNG as reprocessed biogas or landfill gas. suitable and (per specification) used to replace natural gas.
Syngas	- synthetic gas: H_2 and CO (as well as CO_2 and H_2O) from fossil origin - produced via gasification or reforming of coal, oil residues or natural gas
Biosyngas	- biomass origin; chemically equal to syngas produced via high temperature (>1200°C) or catalytic gasification
Product gas	- produced via high-temperature (<1000°C) gasification contains H_2, CO, CH_4, CxHy including tar (and CO_2 and H_2O)

Table 2. Definitions for gas

Units:

1 kWh: 3.6 MJ

1 Nm^3: 1 natural gas equivalent = 35.17 MJ

1 MJ: 106 J

1 GJ: 109 J

1 PJ: 1015 J

APPENDIX C PRODUCING GREEN GAS VIA FERMENTATION: BIOGAS ROUTE

Biogas is released during the fermentation process. Biogas can be upgraded to natural gas quality (i.e. green gas). After processing, the green gas has the same specifications as Groningen natural gas, and can be injected into the regional natural gas supply network.

C.1 Biogas production

Biogas is produced by subjecting wet organic material (sealed against the air) to anaerobic bacteria for at least one week. These micro-organisms partially break down the biomass and convert this into biogas, which consists of around 55-65% methane (CH_4) and 35-45% CO_2. Biogas also contains low concentrations of pollutants. In practice, animal manure is often fermented together with other agricultural residues, organic waste or energy crops (known as cofermentation). The advantages here include the higher biogas efficiency per ton of raw materials, and the better characteristics of the unfermented segment (the fermentate) for use as agricultural fertiliser.

Fermentation is a proven technology. A lot of fermentation plants have been built, particularly in Denmark, Germany and Sweden, with capacity varying from 10,000 tons of biomass/year to around 150,000 tons/year (for clusters of farms). In the Netherlands these plants tend to be capable of processing 2000-4000 tons/year (for a single farm) up to around 36,000 tons/year (above this level applicants are eligible for MER subsidy). The large-scale processing of residual products, for example from the food industry and/or agricultural sector, also allow biogas and green gas to be produced on an industrial scale.

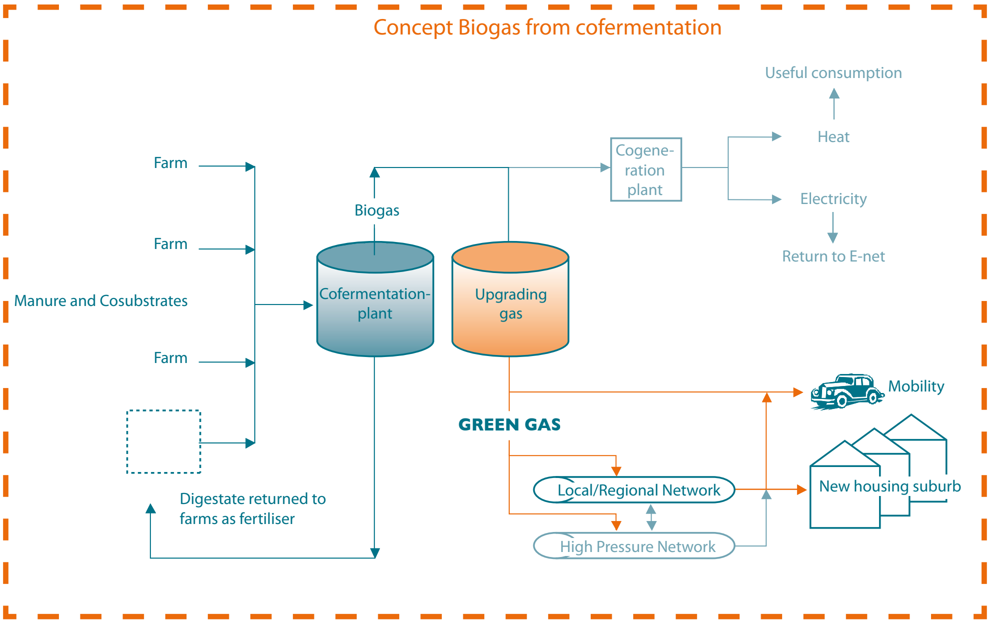
Biogas production

Until now the biogas produced has been almost entirely converted (via cogeneration) into ‘green electricity’ (approximately 35% efficiency) and heat (around 60% efficiency). Of the heat produced, around 35% is used to heat the plant itself. The remainder cannot always be used locally and is often released into the air, thus resulting in the energetic return falling from 90% to 65% [12].

Upgrading biogas to green gas

Following the example of Denmark and Germany, producers are increasingly looking at cooperative forms of cofermentation. However, this brings considerable challenges in terms of permits and logistics, but this type of cooperation would allow large-scale biogas production of over 1,000 m^3/u per location. This scale makes it attractive to consider using biogas in the gas transport or distribution network. However, the biogas produced would need to be purified to natural gas quality – the so-called Green Gas. The advantage here is that the biogas/green gas has a higher energetic efficiency for the end-user, the heat produced can be utilised more usefully, transport losses of (natural) gas are lower than that of electricity, and the gas supply network allows buffering. Injecting green gas into the natural gas supply network is the same as injecting natural gas. With respect to applications, every application using natural gas is also eligible for green gas.

The following diagram illustrates the application options for green gas produced from biogas.



As previously mentioned, biogas contains some CO_2. For high-cal gas the Gasunie uses N_2 in the mixing stations to bring the blend down to 'Slochteren' (low-cal) specifications. However, this is unnecessary for the scale at which biogas is upgraded, and in fact is economically totally unfeasible. 'Green gas', when upgraded from biogas to natural gas quality ('low-cal / Slochteren quality') is generally not brought up to Wobbe specifications by first removing all CO_2 and then extracting N_2 from the air and adding this to the blend. In the upgrading plant, the gas blend CH_4/CO_2 is 'thickened' up to a CH_4 concentration that matches the caloric value and Wobbe range, conform the 'Slochteren' / low-cal specification, and then (after monitoring/analysis) is supplied to the low-pressure gas network. The CO_2 concentrations in 'green gas' must be greater than these concentrations in fossil-based natural gas.

C.2 Demonstration route: green gas from biogas

Various project initiatives are working towards the engineering and investment plans for producing biogas and green gas that can then be injected into the regional natural gas supply network.

The list below shows the steps to be followed.

- Engineering and investment plans, and initiation of the construction process.
- Completion of the necessary permit process.
- Building the fermentation plants.
- Starting up the cofermentation plants.
- Starting up the gas upgrade plants.
- Producing green gas and injecting this into the regional natural gas supply network.

The production of green gas from biogas is an essential technological step to gain experience in the way green gas behaves in the gas infrastructure.
Experience gained with green gas made from biogas can contribute to the 'simplified' integration of large-scale SNG production from gasification processes.

APPENDIX D PRODUCING GREEN GAS VIA GASIFICATION: SNG ROUTE

SNG (Synthetic Natural Gas) is produced via gasification and catalytic conversion of the gasification gas in methane. After reprocessing, SNG has the same specifications as Groningen natural gas, and can be injected into the HTL network. SNG can be made from biomass at around 70% efficiency.

D.1 SNG production

SNG is produced by converting biomass (via gasification) into a methane-rich product gas and, after cleaning, converting the CO and H_2 into CH_4. The raw SNG then needs to be reprocessed into green gas, by removing the CO_2 and water. Figure 3 shows this in detail.

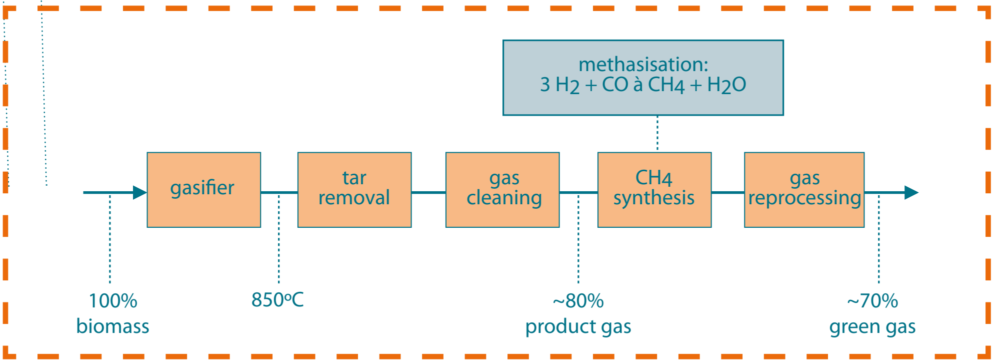


Figure 3. Diagram of an optimum SNG production system

The system is based on a biomass gasifier that works best at a higher pressure and which produces a nitrogen-free product gas. For high efficiency conversion of biomass to SNG the gasifier should preferably produce a gas with a high initial concentration of CH_4. Typically, the gasifier works at 850°C. The gas contains organic pollutants (the so-called 'tars') and inorganic pollutants, such as sulphur and HCI (hydrochloric acid). The tars should be removed, for example via the OLGA process, and can be recycled to the gasifier where they are converted into product gas components. The sulphur, chlorine and other pollutants are then removed during gas cleaning. The CO and H_2 in the gas are converted into CH_4 during the synthesis phase. The raw SNG contains almost equal parts of CH_4, CO_2 and water. During the reprocessing, the CO_2 and water are removed, then this pure green gas is compressed to the pressure required by the natural gas supply network. Not all the CO_2 is removed because a few percent of CO_2 is necessary in order to comply with the required Wobbe index.

Components	Concentration (vol%)
CO	~0
H_2	~0
CO_2	5.2
H_2O	~0
CH_4	94.1
N_2	0.7

Table 3. **Typical composition of reprocessed SNG**

The energetic efficiency of producing SNG from biomass is around 70%. In addition, an extra net 5-8% electricity is produced from the heat that is released during the process [4]. Table 3 shows a typical composition of reprocessed SNG. It is unclear whether, in the future, low concentrations of H_2 and CO will be acceptable. These components must be completely removed in order to meet the current criteria for the high-pressure distribution network, but if (in the future) a few percent of H_2 is allowed, similar to the low-pressure distribution network, this would reduce the process costs and increase the efficiency. Experience gained in using SNG with low concentrations of H_2 in the HTL network is relevant for the long-term ambition of blending hydrogen with natural gas.

D.2 SNG development route

Gasification technology is clearly still in the R&D phase, and it will be some time yet before it becomes a 'proven technology'. Before large-scale production of SNG can be implemented, another development route must also be followed. The integral system, from biomass to SNG, was demonstrated by ECN in 2006. The optimum course, aimed at fast implementation, consists of the following phases and their estimated timeframes.

1. Slipstream demonstration. Construction of a 10 MWth demonstration plant where, initially, 90% of the gas will be used to generate electricity, and 10% for SNG synthesis (see Figure 4). The plant will produce enough green gas to run a corporation's or bus company's fleet of vehicles.
2. Pilot. Construction of a pilot green gas installation at ECN, and implementation of a test programme aimed at supporting slipstream demonstration (phase 1) and design of a full-stream demonstration (phase 3).
3. Full-stream demonstration. The entire gas flow from the existing 10 MWth plant is used for green gas production. Expected to commence around 2009.
4. Large-scale demonstration. Construction of scaled-up unit from 50 to 200 MWth biomass input.
5. Commercial implementation, to start around 2015. Construction of large-scale commercial plants with SNG production capacity of 500 to 1000 MW.

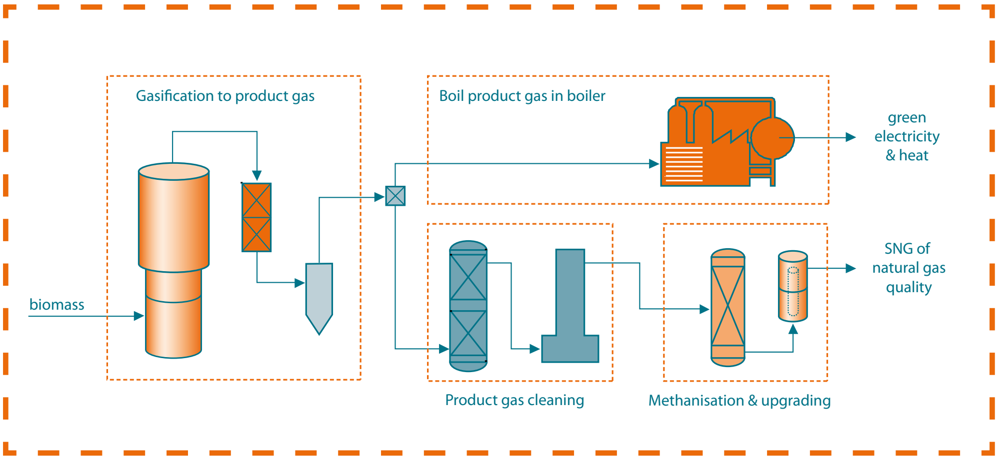


Figure 4. **Diagram of a slipstream demonstration plant (phase 1)**

It is clear that SNG will not play a role in the production of green gas until around the year 2015, in addition to the (then) existing biogas production capacity. SNG technology can be implemented on a commercial basis towards the end of the second decade. The proposed implementation path is ambitious, and considerable support will be required from the government (for permits, financial security etc.) in order to achieve this timeframe.

The greening of natural gas can also be achieved by blending (sustainable) hydrogen. The EET (economy, ecology and technology) project known as 'Greening Gas' (V2G, www.vg2.nl) and the project NATURALHY (EU's 6th Framework Programme) study the possibilities of using the natural gas supply network as a means of transporting hydrogen. The amount of hydrogen in the mixture is limited, due to the danger of damaging materials (pipelines, coupling fixtures) as well as the criteria concerning the quality of natural gas (particularly the Wobbe-index). No conclusions have been made, as yet, although it is clear that restrictions are highest for the HTL (blending just a few percent).

Initially, the Netherlands will primarily produce hydrogen by reforming natural gas and coal (Clean Fossils), but after 2030 it will also be possible to produce hydrogen directly from the syngas resulting from a biomass gasifier.

The Hydrogen Working Group (part of the New Gas Platform), in its report 'Waterstof – Brandstof voor transitie' (Hydrogen – fuel for transition), publishes its outlook on the role that hydrogen can play in the Dutch energy supply.

APPENDIX E AVAILABILITY OF BIOMASS AND LOGISTICS

In order to realise the ambitions for green gas (15-20% in 2030), around 300 PJ of green gas needs to be produced each year. Biogas (60 PJ) is produced from nationally available wet biomass residues. However there is not enough domestic biomass available to produce 240 PJ of SNG, and thus around 20 millions of biomass (that meets previously formulated sustainability criteria) must be imported each year. The international biomass trading market will need to be developed over the next few years. The biomass logistics for the Netherlands fit into the existing practice of transferring coal, animal fodder, wood and pulp. In the long term, gas production could also take place elsewhere (Eastern Europe) and then be transported via gas pipelines.

E.1 Availability of biomass

The Netherlands has several ambitions for using biomass for a wide range of applications: electricity (and heat), transport fuels, raw materials, chemicals and green gas. All these routes complement each other, and together they lead to biomass contributing to the Dutch energy supply, i.e. 20-40% in 2030, or replacing 600-1200 PJ of primary energy. Some 300 PJ of green gas needs to be produced annually if the green gas target (20% in 2030) is to be achieved. However, the Netherlands has insufficient amounts of biomass available to meet this huge demand, and will therefore need to rely on large-scale imports of biomass.

Biogas production primarily requires relatively wet biomass residues. Considering the scale of biogas plants (local/regional), the domestic residues that are available will presumably be used for this purpose. In 2004 Ecofys made an inventory showing that, technically, up to around 44-51 PJ (approximately 2.5 billion m^3) of biogas could be produced – after reprocessing/upgrading this is equal to 1.5 billion m^3 of green natural gas.

In addition to the ambitions expressed by the Netherlands, the (high) targets in other countries (European and global) should also be taken into consideration. This means that, over the coming decades, the enormous demand for biomass will result in a large biomass trading market being developed. An important question here is: will there be enough sustainable biomass available around the world for energy applications?

Two scenarios have been used to forecast the future developments in global energy consumption and the amount of biomass that will be available for energy applications, without competing with its use for food and materials. Figure 5 shows the developments in global energy consumption and the availability of biomass. It is fair to say that, for both cases in the long term, around 60% of the global energy consumption can be achieved using biomass.

In March 2006 the European Energy Agency (EEA) reported indicative figures showing that there was sufficient biomass material available within the EU-25 countries to supply 300 Mtoe (oil equivalent) in 2030, under sustainable conditions, in agreement with a target of around 25% biomass replacement of primary energy in the EU-25 countries.

The criterion for achieving biomass use on this scale is that a global biomass trading system and logistics infrastructure are established. Even more important is the fact that, within this system, guarantees are given (certification, monitoring checks etc.) that the biomass was produced in a sustainable manner.

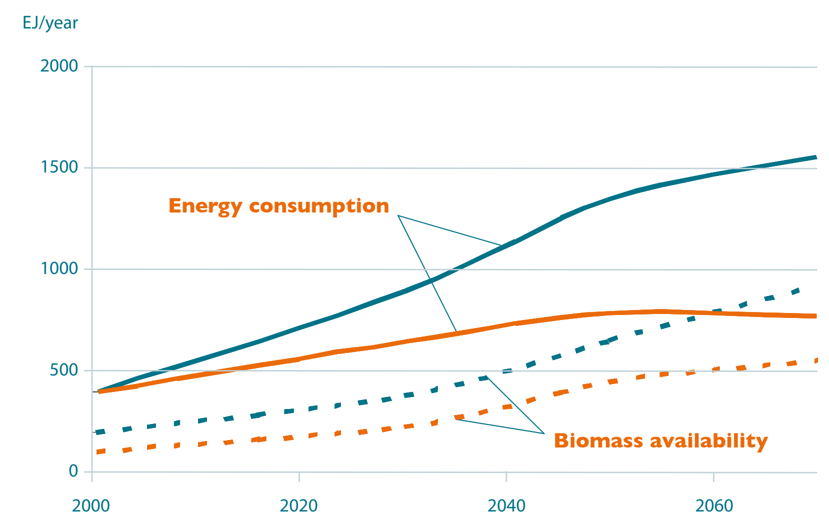


Figure 5. Two scenarios for the long-term development of global energy consumption and the availability of biomass for energy applications

The price of biomass depends on the cost-supply curve, which is in the form of an s-curve. Biomass is available at various quality levels; the better the quality, the higher the price. The number of alternative biomass applications will also increase as the quality increases. In the end, the biomass market (currently being developed), the economic legislation (supply and demand) and the supply contracts (time period and amounts) will determine the price to be paid for biomass.

The availability of biomass is thus fraught with uncertainties. Information from various corners indicates that there will be more than enough biomass available. Whether or not the Netherlands will be able to procure this will eventually depend on the country's position on the international biomass market.

E.2 Biomass logistics

In order to produce 240 PJ of SNG, around 20 million tons of biomass will need to be imported each year. This is undoubtedly a huge amount.

Import and export via sea transport (2004)			Transfer [millions of tons per year]			
Harbour	Position	%	Total	Coal	Crude oil and oil products	Minerals and ores
Netherlands	-	100	464	47	161	71
Rotterdam	1	76	352	25	136	50
Amsterdam	2	11	50	13	16	6.4
Ijmuiden	3	4	18	5.8	0.3	9.0
Delfzijl and Eemshaven	7	0.5	2.3	0.008	0.013	1.2

Table 4. **Transfer of selected materials through several Dutch harbours [6]**

There is currently no established logistics infrastructure, although the Netherlands has plenty of experience in other areas, such as importing coal and animal fodder. In order to determine whether or not these logistics could be realised in the future, it is necessary to look at the existing import and transfer practices in the Netherlands. Table 4 shows the transfer of several selected products in the Netherlands via the top three harbours plus the harbour at Delfzijl. An amount of 20 million tons corresponds to around 4% of the current transfer in the Netherlands, and less than the amount that is transferred annually via Rotterdam alone. The import of biomass is thus comparable to coal imports. As a reference, Table 5 shows an overview of selected organic material transferred via the Netherlands. The current transfer of wood and pulp is around half that of the intended biomass import for SNG production. Here too, existing experience with biomass transfer is within the proportions required for SNG production.

Organic materials (2000) [kton/year]	Import	Export	Transfer
Wood and pulp	7,010	3,462	10,472
Oil seed	7,133	1,845	8,978
Meat, fish and dairy products	2,995	5,028	8,023
Grains	6,413	630	7,043
Sugar and cacao	1,926	1,856	3,782

Table 5. **Import and export of selected organic (biomass) materials in the Netherlands [7]**

SNG will have to be produced from imported biomass. It seems logical that this will be clean woody biomass from production forests. Studies into large-scale production of synthetic transport fuels from imported biomass have researched the optimum import route [8]. The most important conclusions that apply to biomass import are as follows:

- Transport and transfer costs make up a significant part of the total production costs of the fuel, certainly if the biomass costs are relatively small at the biomass source.

- Transport and transfer costs can be significantly reduced if the biomass is sealed beforehand, for example by making wood pellets, pyrolysis slurry or torrefied (roasted) wood. Woodchips are the least attractive option, considering the transport costs, the risk from heat and biological degradation.
- The investments required to pre-treat and seal the material are more than compensated by the lower transport costs.
- Pre-treatment of biomass (via torrefaction) results not only in transport advantages, but also other advantages regarding higher gasification efficiency and reduced intermediate storage charges.

In the case of SNG there are also other supply options available. In addition to importing biomass and producing SNG in the Netherlands, it is also possible to produce SNG in the country of biomass origin, and then transport the SNG to the Netherlands in the form of CNG (compressed natural gas), LNG (liquefied natural gas) or via a pipeline. Recent studies by ECN show that, over shorter distances (up to around 3500 km) it is better to transport the gas via pipelines. However, transporting the biomass to a Dutch SNG production plant, or transporting the bio-LNG is an even better choice.

APPENDIX F ENVIRONMENTAL ASPECTS

It is not clear how the use of biomass in the green gas chain 'scores' (in terms of eco-efficiency) compared to other biomass applications. However, it is clear that the use of biomass scores better than the equivalent fossil-based route.

In January 2006 Ecofys implemented a quick scan into the optimum use of biomass for energy purposes [9]. This quick scan resulted in 50 relevant studies that have been implemented over the past 5-10 years, 20 of which were studied in more detail. The most important conclusion was that it is not possible to say, from an environmental point of view, which is the best use of biomass, because no single study includes all possible options. The starting points and implementation methods used in the studies were so varied that direct comparison was simply not possible. Finally, no single study was found that determined the environmental performance of SNG production. Therefore, the question as to which purpose (electricity, heat, transport, raw materials, chemicals etc.) enables the best use of biomass will, for the time being, remain unanswered from a scientific point of view. Under the framework of the Transition Action Plan drawn up by the Energy Transition Task Force, ECN calculated how much CO_2 could be reduced by using SNG rather than natural gas. The result, extrapolated from 400 PJ (22 Mton of CO_2 reduction) to the target of 20% natural gas replacement (240 PJ) is a reduction of around 14 Mton CO_2.

The Ecofys study concluded that biomass routes are generally better than the alternative fossil-based routes, from an environmental point of view. For biogas, the study concluded that the combined production of heat and electricity from manure is very interesting, from an environmental point of view, particularly due to the effective manner of preventing direct methane emissions from manure.

A study carried out by Alterra specifically looked at the sustainability of cofermentation from animal manure [17]. A system was established for assessing the sustainability of cofermentation, including the various aspects of the technique that determine sustainability, particularly the greenhouse gas balance in the entire chain, from the cultivation of energy crops through to applying the digestate. The study was set up from the 'traditional' use of the biogas produced in a cogeneration plant.

In addition, CML in Leiden [29] is currently working on a CO_2 tool, under the framework of sustainability assessment of bioenergy conversion routes that consider the entire chain.

APPENDIX G INJECTING GREEN GAS INTO THE NATURAL GAS NETWORK

The advantage of injecting green gas into the natural gas network is that the gas can be used in an energy-efficient way for the same sales market as natural gas. Small amounts of green gas from biogas are already being injected into the distribution network. However, large amounts of green gas from SNG will need to use the national natural gas network (RTL/HTL).

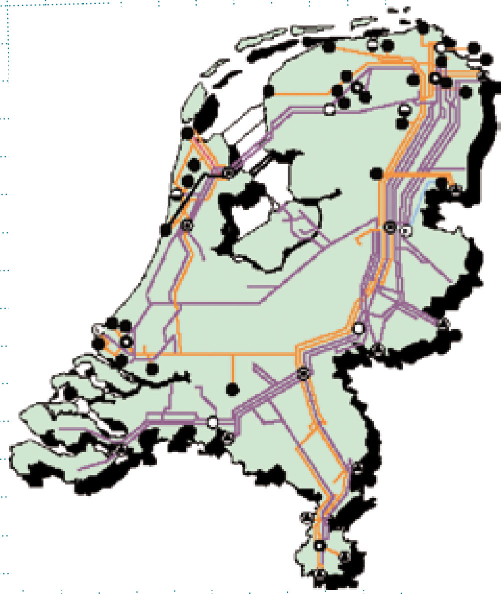
G.1 Injecting green gas into the natural gas supply network

The advantages of biogas and SNG and their huge potential mean it is worthwhile considering converting these gases to natural gas quality (green gas) and distributing this via the natural gas supply network. The advantage of injecting green gas into the natural gas network is that the gas can be used in a very energy-efficient way for the same sales market as natural gas. The Netherlands has one of the most fine-meshed gas networks in the world, and has considerable knowledge and experience of gas transport. Initially the natural gas can be used as energy carrier for new gases made from biomass, whereby the natural gas forms a bridge to sustainable gas.

Integrating biogas into the local low-pressure distribution network is already occurring at a number of locations around the world, including four landfill gas projects in the Netherlands. However, injecting biogas into the natural gas high-pressure main transport network is not a simple matter. In addition to economic and technical obstacles, there are still many uncertainties as to the possible consequences for the integrity of the natural gas network, the use of biogas as raw material, the functioning of end-user equipment, as well as the safety and health of consumers. Since the pressure and injected amounts of green gas are much greater, and there is a much wider variety of end-user applications compared to local distribution networks, quality criteria for green gas will be much more stringent. It is therefore not surprising that, as yet, biogas is not being injected into high-pressure transport networks anywhere around the world.

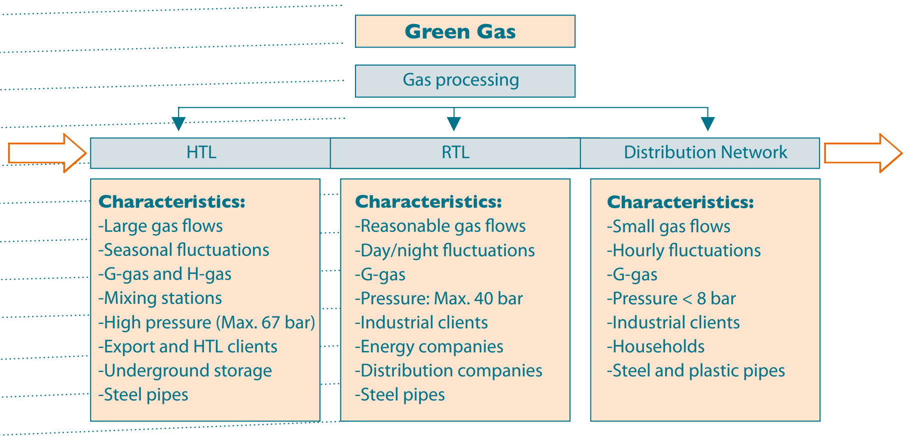
G.2 Where can green gas be used in the natural gas network?

The Netherlands has a very extensive infrastructure for the transport, storage and distribution of a whole range of natural gas applications. There are two domestic transport networks: for H-gas (high-caloric) and for G-gas (Groningen, low-caloric) – both networks are managed by Gasunie. The mixing stations form the connections between these two networks. The Gasunie transport networks for G-gas and H-gas are split into a main transport network (HTL-67 bar) and a regional transport network (RTL-40 bar). This regional transport network is in turn connected to another distribution network that is managed by the energy companies. This local distribution network operates at 8 bar and is fed from the RTL via a gas receiving station. Several large industries and export pipelines are directly coupled to the HTL/RTL, but most connections occur via the distribution network and its various sub-networks.



As injection occurs further upstream (HTL/RTL), as more green gas can be blended at each injection point because there are greater gas flows. However, the pressure of the gas to be blended must also be high, which means high safety-technical criteria, extra compression energy, and this can thus also be cost-prohibitive. Gas conversion facilities (mixing stations) should have pressure-technical advantages, and there is experience available within the Netherlands, but the gas flows at residential or suburb level can be too low to make a project financially feasible. Specifically, this means that the injection capacity must be harmonised according to the minimum amount purchased on that network. This minimum is usually measured on a summer's night, when all gas heating etc. is switched off.

The following sketch shows an overview of gas injection into the various types of gas networks.



Another aspect of blending that can play a role concerns the consequences of adding more green gas injection locations to the same pipeline in the regional gas distribution network. If green gas is blended up to the maximum then no more green gas can be injected into the same network. A separate regulation is required. A possible solution is the compulsory contracting of a certain gas volume and gas quality [11].

G.3 Green gas specifications

It is not yet clear what the quality criteria for green gas should be for the HTL network, although this has already been defined for the distribution network: Connection and Transport Conditions [20]. Although biogas and SNG contain the same main components as natural gas, methane and carbon dioxide, the exact percentages of these components differ from natural gas, particularly the presence of trace elements. The acceptable limits of some trace elements, such as water and hydrogen sulphide (H_2S) are already known. However, for many trace elements that do not occur in natural gas, e.g. micro-organisms in biogas, hydrogen gas in SNG, ammonia, chlorides and siloxanes, it is not yet known what effect these will have on the integrity of the transport and distribution networks, when using green gas as a raw material, on the way end-user appliances function, and how the safety and health of consumers will be effected. Since the safety cannot therefore be guaranteed, green gas cannot, as yet, be injected into the natural gas supply network. Since the composition of biogas can vary widely, making an overview of these trace elements and the effects thereof is a very time-consuming affair.

With respect to the main components of green gas, the quality criteria for these are well known, and correspond to the admission criteria for natural gas (see Table 6). The criteria for G-gas and H-gas are shown in the Entry and Exit criteria on the Gastransport Services website (www.gastransportservices.nl). The G-gas criteria are shown in the following table. When looking at these criteria, it is primarily the removal of water, CO_2 and H_2S that are important. The Wobbe-index is mostly important for combustion characteristics, a factor indicating the amount of energy that can be added to a burner. Within the Netherlands, the amount of flexibility allowed in the Wobbe-index (known as the Wobbe-range), is extremely small, and therefore stringent criteria are required for the gas mixture. The Wobbe-range is much broader in surrounding countries.

Quality component	Conform Gastec advice	
	Limit	**Unit**
Caloric top value	31.6 – 38.7	MJ/Nm^3
Wobbe-index	43.46 – 44.41	MJ/Nm^3
Water dewpoint	-10 (8 bar)	OC
Temperature of gas to be injected	0-20	OC
Sulphur (total)	45	mg/Nm^3
Inorganic bound sulphur (H_2S)	5	mg/Nm^3
Mercaptans	10	mg/Nm^3
Odorant level (THT)	>10, norm 18<40	mg/Nm^3
Ammonia	3	mg/Nm^3
Chlorine-retaining compounds	50	mg/Nm^3
Fluor-retaining compounds	25	mg/Nm^3
Hydrogen chloride (HCL)	1	ppm
Hydrogen cyanide (HCN)	10	ppm
Carbon monoxide (CO)	1	Mol%
Carbon dioxide in dry gas networks (CO&)	6	Mol%
BTX (benzene, toluene, xylene)	500	ppm
Aromatic hydrocarbons	1	Mol%
Oxygen in dry gas networks	0.5 (3)	Mol%
Hydrogen	12	$Vol\%/Nm^3$
Methane level	>80	-
Substance	Technically free	-
Siloxanes	5	ppm
Odour level (odorised biogas)	sufficient	-

Table 6. **Criteria for natural gas, G-gas [20]**

Table 7 shows the most important gas composition bottlenecks currently known for injecting green gas into the regional gas distribution network.

	Bottleneck	Actions
Biogas	- Organic Chlorine and the formation of dioxines during burning - Organically active material and corrosion and danger to the end-user[3] - Possible risks: bacteria, fungus and pathogens, partially unknown - Siloxanes and the production of silica during burning - CO, poly-aromatic hydrocarbons, ammonia, fluorides	- Permanent monitoring, good purification, exclusion of high-concentration sources - Good purification/upgrading claims to prevent this
SNG	- Presence of CO and H_2 - Presence of Cl and NH_3	- CO and H_2 are converted when reprocessing SNG Admitting a few percent H_2 can improve production efficiency. There are no specifications for Cl and NH_3. These have yet to be defined. - Complying with specifications will not be a problem because the methanisation catalyst is far more critical than the (expected) SNG specification (just as with sulphur specifications).

Table 7. **Bottlenecks in gas composition**

There is also some discussion over maintaining criteria for injecting green gas into the local supply networks. It has been suggested, conform current practice, that network managers should set the CO_2 criteria for injecting into low-pressure networks somewhat broader than those shown in Tables 6 and 7. The argument behind this is that, in practice, very dry gas is supplied. CO_2 corrosion occurs in metal pipes under the simultaneous influence of CO_2 and water. It is also questionable whether the CO_2 criteria should be generically applied, or whether network companies should at least use a wider bandwidth, without adding N_2, for CO_2-retaining gas when injecting ‘green gas’ from biogas into low-pressure networks. In any case, if plastic pipes are used in these networks then corrosion is not a problem, and this is almost always true of networks with a pressure of 4 bar or lower.

APPENDIX H EXAMPLE PROJECTS

The number of biogas projects in the Netherlands is increasing fast, and there are already over 20 projects being implemented in this country. Germany already has several thousand installations. The production of SNG from biomass is still in the R&D phase, therefore there are few specific projects.

H.1 Biogas projects

The examples described here are simply used to illustrate the situation. The overview is not complete.

BONGO project

The link between various green gas initiatives will be made via the European BONGO (Biogas and Others in Natural Gas Operations) project. This will become the project that will prepare the gas industry for green gas. Since transport is a cross-border sector, and a European cooperation ensures maximum benefit for everyone by exchanging each other's knowledge and experience, a European approach has been chosen. A proposal is currently being prepared to serve as a subsidy application in Brussels. BONGO will be implemented under the GERG (European gas research group) flag, and will be supervised by Gasunie Engineering and Technology. Together with gas transport and distribution companies, research institutes, universities and biogas producers, risks will be analysed and lessons learned from existing biogas-injection initiatives, particularly in countries such as Sweden and Switzerland, and quality criteria will be defined under which green gas can be injected into the natural gas supply network, with acceptable consequences for the safety and integrity of the network and its end-users. This will build a bridge between small-scale biogas injection into local networks and large-scale implementation of all types of green gas in the gas infrastructure.

Biogas in Midden-Drenthe and biogas in the Westerkwartier

The project Biogas in Midden-Drenthe focuses on a core coalition between three farmers located in and around Midden-Drenthe. This research project studies the possibilities of a small-scale collective cofermentation plant. Typical biogas production amounts to around 3 million m^3 per year.

A local cofermentation cooperative has been established in Zuidhorn local authority (Vereniging Collectieve Co-vergisting Westerkwartier), consisting of 21 cattle farmers and 10 arable farmers. This group has also studied the possibilities of starting up a central collective biogas plant. Typical biogas production would be around 8 million m^3 per year. The biogas produced can be used in a number of ways.

These projects also focus on the business-economic aspects, such as various application options, for example upgrading to natural gas quality (for eventual injection into the HTL), use as a transport fuel, or transporting the biogas to a location where this can be used at a higher efficiency level. The backup option is to convert the biogas (using cogeneration) into electricity and heat.

Alternatieve Verwerking Slachtbijproducten (AVS)
The AVS demonstration project (alternative processing of slaughterhouse by-products) uses anaerobic fermentation to convert slaughterhouse by-products into sustainable energy. The methane-rich biogas (70%) produced can be effectively converted into green gas via an upgrading process. If this project is successful this could lead to full-scale processing plants for relevant industries. This will substantially reduce energy costs and sales costs for slaughterhouse by-products and residues.

The CROB (Coalitie Rijden Op Biogas / Coalition Driving on Biogas) project, in collaboration with the provinces of Zeeland and Gelderland, with support from the Ministry of Economic Affairs' UKR (unique opportunities scheme), which is implemented by SenterNovem

1. In 2008 Zeeuws Vlaanderen will have 26 public transport buses running on natural gas; in 2009 these will switch over to upgraded biogas.
2. There are seven public transport buses from Veolia that are currently running on natural gas along the Valleilijn route (Ede – Wageningen) that, in 2009, will switch over to upgraded biogas. Gelderland province has also taken the initiative to run 20 extra public transport buses on upgraded biogas. Gelderland also hopes to use UKR subsidy to purchase 80 corporate vehicles that run on biogas, and also realise six biogas filling stations throughout the province.

H.2 SNG projects

Dakota 'Great Plains' SNG plant
A coal-fired SNG plant has been running in Great Plains (Dakota, USA) since 1984, producing around 100 PJ SNG per year, and isolating chemicals for cleaning the gasification gas. The plant was built as a result of American policy in the 1980s to reduce the country's dependence on oil. More plants were planned, but this policy changed and all SNG developments ceased as a new President came to power. Motivated by the current problems concerning the security of supply, the US is once again considering boosting coal-SNG options. Various new projects for Dakota-like plants are currently in the feasibility phase[6].

PSI: research and demonstration
The Paul Scherer Institute (PSI) in Switzerland is conducting a research programme into SNG production from biomass. PSI is working jointly with a Swiss equipment manufacturer. The PSI technology is based on a commercial (nickel) catalyst that is used in a single-step fluidised bed methanisation reactor. Product gas from

6 Product gas from coal gasification differs from that derived from biomass gasification, whereby existing technologies for producing coal-SNG can only partially be applied when producing bio-SNG.

gasification is converted into raw SNG, with a ratio of around 1:1 CH_4 and CO_2, and several percent (2-5%) hydrogen. The gas no longer contains (aromatic) hydrocarbons, NH_3 and CO [10].

After laboratory-scale research, the RENEW (Renewable Energy Networks for Energy Welfare) project was set up in 2005 under the EU's 6th Framework Programme; this is a collaborative project with Vienna Technical University (TUV) and Repotec, which owns a biomass cogeneration gasification plant in Güssing (Austria). In Güssing a slipstream of cleaned product gas is further cleaned of all sulphur and chlorine, and then used for SNG synthesis (10 mn^3/h; 2-3 bar). The system works well, but after around 200 hours the catalyst loses all power for accumulated pollutants. A solution to this problem has not yet been found [10].

The parties are busy scaling up the SNG section to 1 MWth as part of a demonstration project under the EU's 6th Framework Programme. This pilot SNG section will be tested first in Güssing, where the SNG will be returned to the gas engine. Later in this project the SNG section will be installed behind the new (yet to be built) 8 MWth cogeneration plant in Oberwart (Austria). This plant is a copy of the Güssing plant, although in Oberwart the SNG will be injected into the gas supply network. The catalyst problems are not considered to form a huge obstacle, as the catalyst is not expensive.

ECN development and demonstration

ECN has implemented various SNG research projects since the year 2000. Since 2004, under the framework of a SenterNovem project, the company has worked together with Gasunie on experimental research into the development of an integral system of gasification, gas cleaning and methanisation to produce SNG from biomass at high efficiency levels. At the end of 2004 ECN became the first organisation in the world to produce bio-SNG from a slipstream of product gas. A follow-up project was started at the beginning of 2006, funded by a subsidy from SenterNovem.

In 2006 ECN tested an integral laboratory-scale system whereby the complete flow of cleaned gasification gas was converted into SNG. The development of this system focuses on producing SNG from biomass at 70% efficiency. Important characteristics of the ECN system are:

1. Compact indirect gasification for high-efficiency manufacture of a product gas with a high initial methane level (typically 15%);
2. Very deep cleaning of organic components (particularly tar) with OLGA tar-removal technology;
3. Multi-step catalytic conversion and methanisation to avoid catalyst-deactivation through pollutants. The system is preferably similar to existing (and/or previously developed) systems to produce SNG from coal.

The 1 MW pilot Milena gasifier, part of the1 MW pilot SNG line, will be built at ECN at the end of 2007.

Under the EU's 7th Framework Programme, a project proposal has been submitted by PSI, Göteborg Energi and several other important stakeholders to study the problems of sulphur and specific (aromatic) hydrocarbons when methanising the product gas from the gasifier.

Göteborg Energi initiative

In Rya (Sweden, near Göteborg) a 600 MWth cogeneration combustion plant was built in 2006, to produce 294 MW of heat and 261 MW of electricity at an overall efficiency of 92%. The plant is owned by the energy company Göteborg Energi. The plant is driven by natural gas and, with the current price developments of natural gas, the efficiency of the plant is 'alarmingly' low. Well before the official opening of the plant, Göteborg Energi is already looking at replacing a significant percentage of the natural gas with SNG. This would reduce the use of natural gas, while also increasing the accessibility of the plant because SNG can be supplied as a transport fuel whenever the heating demand is low (e.g. during the summer months).

E.ON Sweden initiative

Similar to the Göteborg Energi project, E.ON Sweden is also focusing on its first demonstration bio-SNG plant. The company hopes to have several SNG plants in operation before 2020.

Various SNG initiatives

SNG is a subject that has recently received more attention in the biomass world, although previous years have seen most attention being spent on the production of liquid transport fuels. This is probably due to the fact that SNG is a much easier product to manufacturer using existing low-temperature gasification technologies. SNG production is far simpler, cheaper and thus more efficient at smaller scales than alternatives such as Fischer-Tropsch diesel production. Organisations that have undertaken studies into bio-SNG include VTT (Finland, TPS (Sweden), Aston University (UK) and Foster Wheeler (Sweden).

Green gas projects in the Netherlands				
Project name	**Location**	**Conversion**	**Category**	**Application**
Biogas reprocessing plant Wijster	Wijster	Fermentation	Upgrading landfill gas	Injection to gas network
Biogas reprocessing plant Collendoorn	Collendoorn	Fermentation	Upgrading landfill gas	Injection to gas network
Biogas reprocessing plant Nuenen	Nuenen	Fermentation	Upgrading landfill gas	Injection to gas network
Biogas reprocessing plant Spinder	Tilburg	Fermentation	Upgrading landfill gas	Injection to gas network
Biogas reprocessing plant Beverwijk	Beverwijk	Fermentation	Upgrading landfill gas	Injection to gas network
Natural gas buses for Haarlem and IJmond	Haarlem		Natural gas	Driving on natural gas
Ecopark De Wierde	Oudehaske	Fermentation	Upgrading landfill gas	Injection to gas network
Developing CFB (circ. fluidised bed)	Hengelo	Gasification	Biomass gasification + cleaning system	
CFB gasifier	The Hague	Gasification	Biomass gasification + cleaning system	
Cooperation Biogas in Midden-Drenthe	Midden-Drenthe	Fermentation	Cofermentation follow by biogas upgrade	Injection to gas network
Ver. Collectieve Covergisting Westerkwartier	Zuidhorn	Fermentation	Cofermentation followed by biogas upgrade	Injection to gas network
Manure fertilisation initiatives (approx. 50)	Noord-Nederland	Fermentation	Flowing of biogas	Cogeneration
Alternative processing slaughterhouse byproducts	Kornhorn	Fermentation	Fermentation of poultry slaughterhouse byproducts	Cogeneration or upgrade
Bareau	Groningen	Fermentation	Cofermentation or mono-fermentation	Biogas production under high pressure

Green gas projects in Europe				
Project name	**Location**	**Conversion**	**Category**	**Application**
Metan	Reykjavik, Iceland	Fermentation	Upgrading landfill gas	Driving on bio-SNG/ inject- ion to gas network
Malmo	Malmo, Sweden			Driving on biogas/natural gas
Boras	Boras, Sweden	Fermentation	Upgrading landfill gas and slaughterhouse waste	Driving on bio-SNG
Bioenergy village Juhnde	Juhnde, Germany	Fermentation	Biomass and manure	Cogeneration, injection to gas network
Biogas Vast	Göteborg, Sweden	Fermentation	Upgrading landfill gas	Driving on biogas
Kompogas Zürich 'Salat im Tank'	Zürich, Switzerland	Fermentation	Organic waste	Driving on biogas/ injection to gas network
Biogas Motor Interbrew	Leuven, Belgium	Fermentation	Sludge	Cogeneration, own use
Biogas for buses in Linkoping	Linkoping, Sweden	Fermentation	Organic waste	Driving on biogas, train on biogas (Amanda)
Biogas motor Stevan	Lendelede, Belgium	Fermentation	Landfill waste	
Biogas motors Pellenburg	Leuven, Belgium	Fermentation	Landfill waste	
Wood gasifier Güssing	Güssing, Austria	Gasification	Wood gasifier	Cogeneration
Växjö Värnamo Biomass Gasification Centre (VVBGC)	Värnamo, Sweden	Gasification	Biomass gasifier	Includes driving on bio-SNG
Eskilstuna Energi and Miljo	Eskiltuna, Sweden	Fermentation	Wastewater purification, sludge fermentation	Driving on biogas

Storstockholms Localtrafic	Stockholm	Fermentation	Wastewater purification, sludge fermentation	Driving on biogas
Agrotpi gas project	Grythe (Vasteras)	Fermentation	Household refuse, catering waste, fat-separation waste	Driving on natural gas
Fixed bed gasifier	Moldavia	Gasification	Biogas gasifier + gas cleaner	Duel-fuel diesel Diesel engine

Green gas projects around the world				
Project name	**Location**	**Conversion**	**Category**	**Application**
Antioch Community High School	Illinois, USA	Fermentation	Upgrading landfill gas	Cogeneratoin
SNG plant	Great Plains, (Dakota, USA)	Gasification	Coal gasification	

Table 8. Non-exclusive overview of projects in the Netherlands, Europe and elsewhere

APPENDIX I GREEN GAS POTENTIAL

The stated ambition of the Green Gas Working Group are: to increase from 8% to 12% green gas in 2020, from 15% to 20% in 2030, and up to 50% in 2050. These targets will be realised in three consecutive paths, i.e.:

1. Green gas from fermentation projects;
2. Green gas via the SNG route, via gasification of biomass;
3. Injecting hydrogen into the natural gas supply network.

This is shown in Figure 1.

Alongside these projects, various studies also focus on the potential for greening the gas supplies. Estimates of this potential vary widely depending on the various studies. The numbers mentioned largely depend on the starting points taken with respect to available biomass and technology development (particularly for SNG), but certainly also include the stimulation frameworks and general developments in the energy market as a whole.

The following provides a brief overview of the findings from the various reports that have been published on this subject.

The potential for green gas in the Netherlands is estimated at 10% of the current natural gas consumption [13, 19]. This sketches a development route of upgrading biogas from fermentation plants (in the short term) and producing SNG from biomass (medium term). This potential could be realised from biomass generated in the Netherlands. A greater potential could be achieved if imported biomass were also used (see Appendix K).

Germany has a potential of 30%, calculated for replacing natural gas in the natural gas supply network with upgraded biogas [14]. Considering the importance of this potential, preparations are currently being made for a GEG (Gas Einspeise Gesetz). The first projects for upgrading biogas and injecting this back into the public supply network are still being developed in Germany.

A study into potential natural gas replacement for Europe as a whole (including Russia, Ukraine and White Russia) calculates this potential to be 550 billion m^3. This would entail completely replacing all natural gas consumption throughout Europe with green gas [15]. This calculation only looked at the availability of biomass, including woody biomass in the area around the European gas distribution network. The study did not consider the financial feasibility, or the competition from biomass flows for other applications.

APPENDIX J GREEN GAS CERTIFICATION

If green natural gas is to be injected into a natural gas distribution network then certification of this sustainable source will certainly be necessary. The gas molecules from a sustainable source can no longer be separated from those derived from a non-sustainable source. It is thus impossible to determine who uses biogas, and who can thus claim its green value.

Where the green gas produced is not used directly (and usefully), and is not injected into a pipeline network, certification is not immediately necessary. The user can determine whether or not green gas from a biogas plant is 'consumed', and can thus immediately claim this green value. To improve transparency, the green gas, or green gas component (i.e. the amount of biogas at natural-gas quality) should also be certified. Green gas certification is therefore not necessary in all cases, but always requires transparency in the consumption of the green value in the energy market.

Certification determines the amount of green gas that is injected into the pipeline networks, as well as the specific characteristics for this amount of gas. This includes production data and dates when certificates were issued, but also the origin of the biomass, the technology used, efficiency levels, or even the CO2 balance, where required, etc.

It is important that the green value of biogas be identified, as it is this that makes biogas different, and desired, in the energy policy. It is precisely this desire that also gives the green value its financial value. This might be a subsidy or extra price that the consumer is prepared to pay, and can thus reclaim (for whatever reason or application) – using biogas to generate electricity, using upgraded biogas (i.e. green gas) in households or companies, using green gas as a transport fuel, or using green gas in the chemical industry. Certification of green gas needs to be implemented, both in the free market and as encouragement by the government, perhaps in combination with monitoring of the eventual sustainability targets. Only certification can provide the necessary market flexibility to use the green gas where it will result in the best green value, with or without subsidy. Only then can the huge potential for green gas (over 1500 million m^3 natural gas equivalents) in the Netherlands be realised.

In setting up a certification scheme a lot can be learned from other sectors, particularly certification of sustainable sources in the electricity sector. Important elements in a certification scheme are as follows:

- A clear definition of the life cycle of the certificate, from issue, transfer to others, through to redemption (cancelling the certificate).
- A clear role for the issuing body, with clear rules for participation in the certification scheme. Important tasks for the issuing body are the management (or subcontracting) of a central digital register of all certificates, and

determining the consequences for their ownership.

- The question of how suppliers and clients can contact each other, and the way in which price transparency can be achieved, is a separate issue. Initiatives by market players, possibly facilitated by the government, are required and will undoubtedly be forthcoming.
- A balanced accurate measurement system at ports of entry, including cooperation with EDBs (Economic Development Boards).

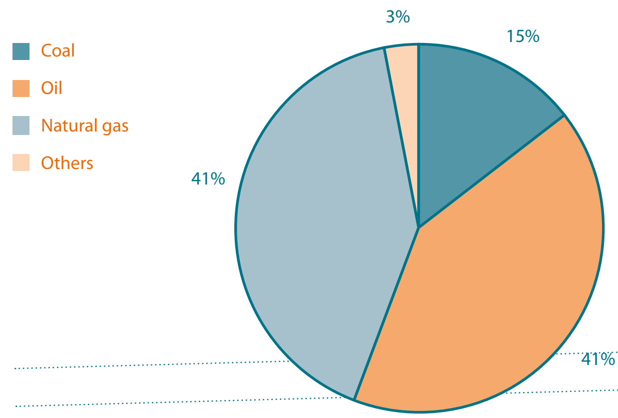
Eventually a market for certificates will be created with supply/demand and a market price. The fact that the certificate is given a price tag will encourage biogas, because an extra source of income will be created just for biogas. The government plays a very important role in formulating this market (or the demand) for certificates. There are many policy instruments available to the government as it seeks to encourage the demand for certificates. These include making it compulsory, providing a subsidy or even arranging a compulsory purchase scheme for green gas certificates. This would stimulate green gas production, as separate from the application, which fits into the energy transition paths such as those for Green Raw Materials and New Gas. Encouragement currently lays primarily with the end-user applications, in particular a subsidy for producing green electricity and the compulsory blending of biofuels.

Implementation of a green gas certification scheme can be achieved via two routes. The initiative can be taken by the market parties, who appoint a particular body to issue certificates, and which starts setting up such a certificate system to benefit the voluntary market. The government can also take the initiative and appoint a particular body to issue certificates. The latter will probably require more time, because the necessary legislation will need to be drafted and approved. A combination would seem to be the best approach, provided that the private initiative occurs in close consultation with the government.

APPENDIX K THE IMPORTANCE OF SNG (SYNTHETIC NATURAL GAS) FROM BIOMASS (GREEN GAS VIA GASIFICATION), ECN

K.1 The importance of SNG from biomass

Natural gas supplies around 50% of the primary energy in the Netherlands. Heat production, which accounts for 40% of our energy consumption, is almost entirely dependent on natural gas. In turn, natural gas is responsible for around 40% of the total CO_2 emissions in the Netherlands. This contribution is equal to that of oil, and almost three times greater than coal (see Figure below). If CO_2 emissions are to be reduced, it is essential to focus on SNG.



The EU targets set at the beginning of 2007 propose that in 2020 Europe should have:

- CO_2 emission reductions of 20%
- 20% of the energy should be sustainable energy.

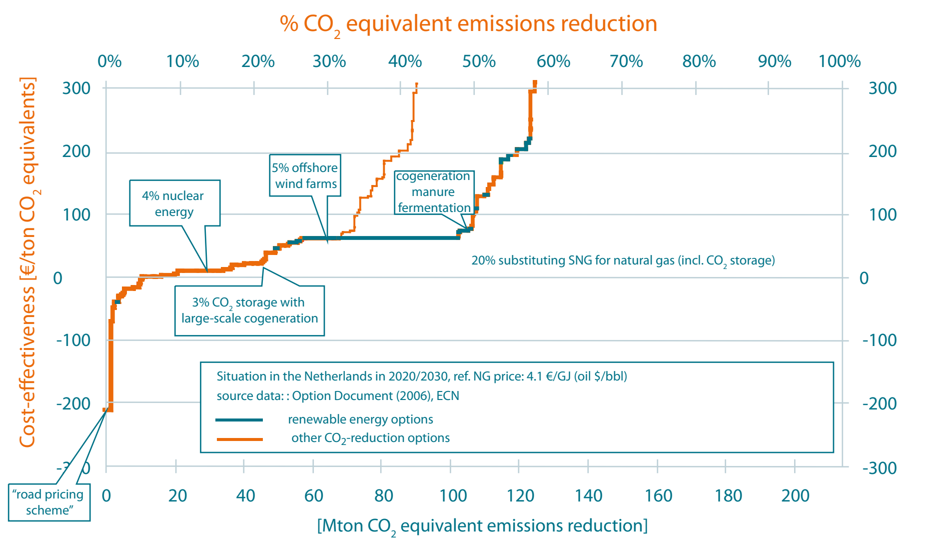
This means an actual reduction of 30% for industrialised nations. In the longer term, CO_2 emission reductions of 60-80% are required in 2050. The UK has already anticipated this by setting a legal requirement for 50% CO_2 emission reduction in 2050.

K.2 Potential for SNG from biomass

The calculations concerning the potential for SNG are based on existing cost-effectiveness curves for reducing CO_2 emissions used by ECN's Policy Studies

Department in the National Options Document[7]. SNG, along with other options such as sustainable H_2 production, is not elaborated further due to the limited timeframe (2010-2020). The curve shows that all measures costing less than 150 €/ton will collectively only achieve a 35% reduction in CO_2 equivalent emissions. These measures also include social and politically sensitive issues, such as constructing new nuclear energy plants and implementing road-pricing schemes.

The data concerning SNG has been added to the cost-effectiveness curve drawn up by ECN's Policy Studies Department. The following Figure shows the original and the result if 20% of the natural gas is replaced with SNG. The scale has been increased to the actual total amount of CO_2 and other greenhouse gases emitted in the Netherlands (215 Mton CO_2 equivalents). Substituting 20% is in line with the target set by the New Gas transition path for 2030. The SNG contribution results in a horizontal plateau that can be continued to the right, depending on the substitution level (even up to 170 Mton for complete substitution of natural gas[8]).



In practice this image will change because the choice often needs to be made between various technologies (*either* this *or* that). For example, replacing 100% of the coal-fired power plants with natural gas plants *and* CO_2 capture from coal-fired plants cannot work together. This does not apply to SNG because most technologies for CO_2 reduction are not relevant for the natural gas segment of the primary energy consumption. Using SNG as transport biofuel can even increase the potential for SNG.

7 Daniëls, B.W.; Farla, J.C.M.: Option Document energy and emission 2010/2020. ECN-C--05-105 / MNP 773001038, March 2006 (www.ecn.nl/docs/library/report/2005/c05105.pdf).

8 This contribution is double the CO_2 emissions from combustion of natural gas, because as by-product from SNG the net CO_2 can be removed from the atmosphere.

The cost-effectiveness largely depends on the assumptions made: what will green gas (SNG) cost, and what will happen to the price of natural gas? The National Options Document assumes that natural gas will cost 4.1 €/GJ. We assume that SNG will cost 10.5 €/GJ[9]. The price difference amounts to 115 € per ton avoided CO_2 when substituting fossil-based natural gas. This can fall to 60 €/ton by taking a simple extra step. When producing SNG, the same volume of CO_2 is separated as avoided by replacing natural gas with SNG. Storing this CO_2 leads to the direct removal of this CO_2 from the atmosphere. This storage can be compared to storing CO_2 during refining, the costs of which are estimated at 9 €/ton. In total the price per ton of CO_2 falls by a factor of two, and doubles the potential for CO_2 reduction. Substituting 20% of the natural gas with SNG brings the potential to 35 Mton CO_2 reduction.

K.3 Alternatives for CO_2 emissions reduction

The following Table shows a number of alternatives for reducing CO_2 emissions. Replacing 20% of the natural gas with SNG is based on the target set by the New Gas transition path for 2030[10].

Technology	Costs	Potential
– SNG production at 20% substitution of natural gas (without CO_2 storage):	115 €/ton	17 Mton
– SNG production at 20% substitution of natural gas (with CO_2 storage):	60 €/ton	35 Mton
– Green gas from landfill gas:	-42 €/ton	0.3 Mton
– Constructing new nuclear power:	8 €/ton	9 Mton
– CO_2 capture and storage:	56 €/ton	9 Mton
– Offshore wind farms:	61 €/ton	10 Mton
– Using 1st-generation biofuels for transport:	194 €/ton	5 Mton
– Green gas from cofermentation of manure (and biomass):	236 €/ton	2 Mton

The costs shown and the potential for other options are taken directly from the National Options Document. This concerns only technical potential that can be realised up to the year 2020. No account is taken of the various problems that could occur when implementing the measures, whereby effects could be less and costs could be higher. There are also a number of measures that are attractive based on the national costs, but bring too much risk or are too expensive to the particular sector, such as removing existing (not yet depreciated) installations. Implementing new CO_2-reducing technologies can thus lead to the direct waste of capital.

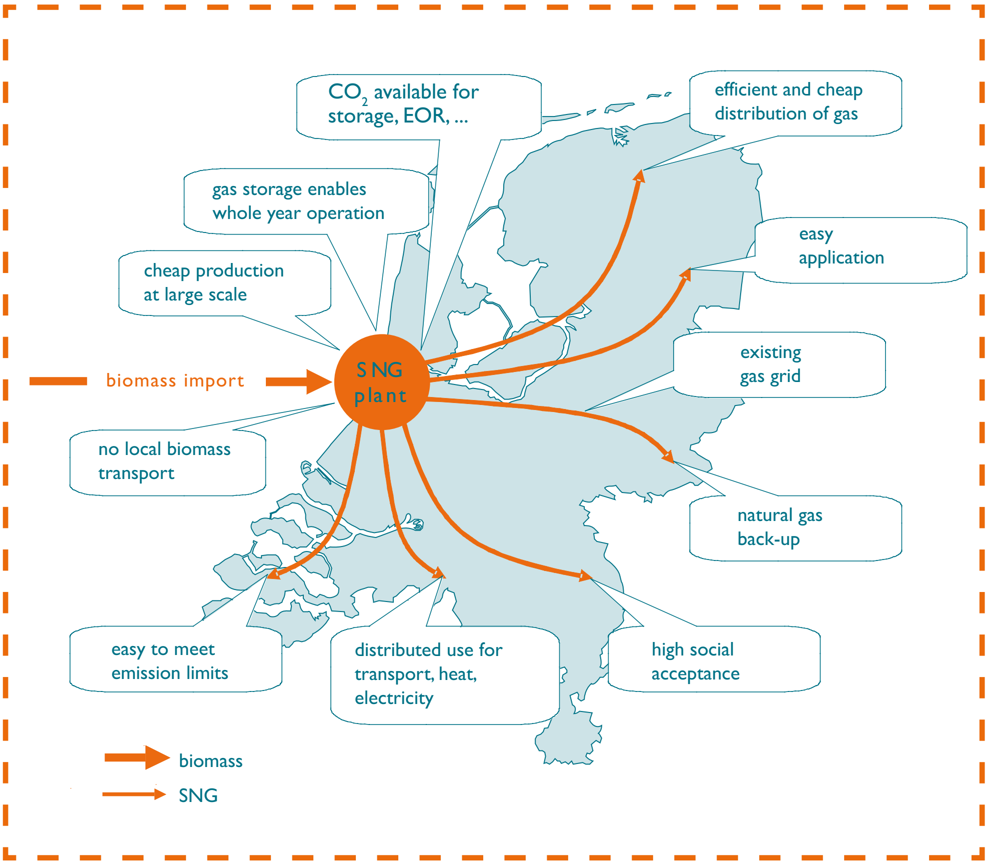
Replacing natural gas with green gas does not encounter this problem, because the primary energy carrier is replaced and not the existing conversion technology or

9 This estimate is based on statistics and procedures in the National Options document.

10 Gigler, J. et al:Vol gas vooruit! De rol van groen gas in de Nederlandse energiehuishouding. Draft initial report for the Green Gas Working Group and the New Gas Platform, 7 December 2006.

infrastructure[11]. Replacing natural gas with green gas also has the advantage that an alternative primary energy carrier (biomass) can be used to compensate for the depleting national (and European) stocks of natural gas. Over the next few years Europe will need to rely more on gas stocks from countries outside Europe. The Netherlands can therefore become an important logistics hub for northwest Europe, the so-called 'gas hub'[12], for processing gas flows from the various input directions, also including green natural gas.

K.4 Advantages of large-scale central SNG production



11 Derijcke, E.; Uitzinger, J.: Wat vinden Nederlanders van warmte uit biomassa? (What do the Dutch think about heat from biomass?) IVAM 0610O, February 2006 (www.ivam.uva.nl/rapportenpdf/samenvatting_NL.project113pdf.pdf).

12 Dam, E.: De betekenis van de gasrotonde: (inter)nationaal en regionaal. Gasunie, 21 February 2006 for the Energy Valley Winter Session (www.energyvalley.nl/uploads/gasrotonde.pdf).

Conclusions

1. We need to focus on natural gas substitution in order to achieve significant savings in CO_2 emissions, such as previously proposed in the new EU targets defined at the beginning of 2007.
2. SNG production, as a technology, can only become completely competitive with other CO_2 emission reduction technologies if CO_2 storage is included.
3. SNG production with CO_2 storage is more than just being CO_2-neutral, it removes CO_2 from the atmosphere.
4. SNG has by far the greatest potential because it focuses on the natural gas market.
5. SNG offers an alternative, compared to imported LNG and natural gas, to compensate for depleting national (and European) natural gas stocks.
6. SNG does not result in a direct waste of capital because it focuses on replacing a primary energy carrier.

We are currently working on a short and simple presentation that makes a clear and unambiguous statement: SNG offers a business opportunity with which Dutch stakeholders can take a strong position, both nationally and internationally.
In anticipation of this short presentation, which we hope to have ready for you soon, this Appendix should provide you with all the latest information on SNG.

This Appendix was written by: Hubert Veringa, Robin Zwart, Luc Rabou, Bram van der Drift (ECN)

APPENDIX L 20 ROUTES TO GREEN GAS

Green gas is a sustainable form of energy, derived by fermenting biological residues (manure, green raw materials, waste, compostable waste, etc.) or high-temperature gasification of dry biomass (wood). The former method concerns 'biogas', and the latter creates SNG (Synthetic Natural Gas), which is the second form of green gas.

The CO_2 that is released during combustion of green gas is stored in the biological material, and is the reason why green gas is known as a CO_2-neutral fuel. This is where green gas differs from fossil-based natural gas.

Green gas is an attractive form of energy because it can be injected back into the gas distribution network, and can also be blended with natural gas. In addition to the Slochteren Gas and gas from small fields, green gas fields can also be developed.

L.1 Integral approach

The Figure below shows the production of green gas in the gas production and sales chain.

This also includes all the diagonal links. Ecological advantages can often be achieved by closing the cycles. A start has often been made to improve the cost-effectiveness of green gas production. The diagram provides an overview of all types of diagonal links and cycles that bear a relationship to the production and application of green gas.

L.2 The importance of reducing production costs

Green gas is socially very desirable. However, the production costs of green gas are still above those of natural gas. This will not make it any easier to develop a green gas market. There are several possibilities to reduce the cost price of green gas. The following section indicates the opportunities for achieving this. In general, there are five ways to reduce the price of green gas:

- Make the process more efficient.
- Reduce the costs of the raw materials for fermentation.
- The digestate (the residue that remains after fermentation) can be used to better economic advantage.
- Increase the amount of gas produced.
- Market the coproducts (CO_2, chemicals).

L.3 Improving efficiency

The fermenter is at the centre of the entire process (1) as this is where the fermentation gas is released after heating the wet biological material. At some point in the future, the gasification plant (9) will be added. Here the dry biomass is converted into gas (SNG) at high temperatures. This can become the most important source of green gas.

The Figure ('The green gas chains') shows the application possibilities of green gas and the relationships between the various chains.

The reprocessing/upgrading plant is particularly important for supplying the green gas to customers via the (virtual) network. The following shows the opportunities for improving the efficiency of these reprocessing plants.

Opportunity 1
When green gas is produced on a large scale this will bring scale advantages. It will therefore be possible to select the optimum production scale.

Opportunity 2
Large numbers of fermentation and reprocessing plants will also be produced. Large-scale production can reduce the cost price of biogas plants by around 25%. This is an opportunity to make green gas profitable. This percentage is even higher for SNG plants.

L.4 Reducing the cost price of raw materials for green gas

Links in the diagram show which fermentation raw materials can be used. The following raw materials are already being used: compostable waste (green household refuse) and grey waste (primarily from households) (2):

- Sewer purification sludge (3);
- Industrial waste (7), particularly from the food industry, but also from the paper industry;
- Manure from farmers (4), fermenting manure in combination with green residues (known as cofermentation);
- Organic waste from horticultural companies (5);
- Green residues from the agricultural sector (6).

Opportunity 3
Using the cheapest possible raw materials for fermentation will reduce the cost price of green gas.

Initially using green materials for other applications, and the remainder for fermentation can reduce the cost price of the fermentable raw materials. This can be achieved, for example, by first using the green raw materials/residues from the agricultural sector and the food industry to produce biodiesel or bioethanol. The residues can then be used for fermentation. This is known as 'biorefining'.

Opportunity 4
Using organic residues first for higher-value applications can reduce the costs of raw materials for the fermenter.

However, there is also some risk attached. If energy prices rise, food production will compete with land use for energy purposes. This question is particularly urgent for the developing countries.

L.5 Using the by-products of green gas

The residues released during fermentation can be used to greater economic advantage. Eventually, the digestate (dry fraction) can be used as input for biomass gasification (9).
The digestate (wet fraction) can also be used as fertiliser (10), thus closing the cycle. This alternative fertiliser can be used by cattle farmers, arable farmers or horticulturalists. An additional advantage is that less natural gas is required to produce the fertiliser. Manufacturing artificial fertilisers takes a lot of natural gas. Replacing artificial fertiliser with the digestate leads thus to a double reduction of CO_2.
It is also possible to use the CO_2 released during fermentation in horticultural greenhouses. For the horticulturalists this means that the plants in the greenhouses can grow at a low temperature, which leads to energy savings. This use of CO_2 also applies to SNG, as well as to chemicals such as benzene, toluene, ethene etc.

Opportunity 5

Using the digestate as input for high-temperature gasification allows the cost price of green gas to be reduced. The phosphor in the digestate will probably need to be removed beforehand. In any case, a suitable technology should be used to ensure that the valuable phosphor is retained for use as fertiliser.

Opportunity 6

Using the digestate to produce fertiliser. Contracts could be made with the companies supplying raw materials for fermentation with respect to the sale of fertiliser.

Opportunity 7

The CO_2 that is released during fermentation can be used in the horticultural sector, but (on a larger scale) also for EOR (enhanced oil recovery) or underground CO_2 storage.

L.6 Increasing the amount of green gas produced

Green gas can be used in several ways. At the moment green gas is generally converted into electricity and heat. Local use forms the most attractive option (13), as there is no need to upgrade the gas to natural gas quality. The green gas can be used directly in a (micro) cogeneration plant to produce electricity. The heat is thus also used locally. In many cases the heat is not used and thus the green gas is use solely to produce electricity (14). This route was attractive because, until recently, green electricity was subsidised via the MEP scheme. Where the heat from electricity generation is not used, it is preferable to upgrade the gas to natural gas quality and inject it back into the local supply network. This is also more attractive than just producing heat (12).

Opportunity 8

By using green gas in a micro-cogeneration plant, the heat that is released during electricity generation is used efficiently and the energy value of the green gas is used optimally.

The green gas can be used in the area immediately surrounding the fermentation plant via a small network. It can therefore be used in a residential area (16) or by one/several companies (15). A special form of direct use for green gas produced by the fermentation plant is for transport purposes (17). It is therefore possible to also produce green gas from a waste-processing plant, so that the household refuse collection vehicles can tank up on green gas at their local filling station.

Opportunity 9

Using green gas in a local residential area, at one or more companies/organisations (an industrial estate, or hospital) or at a local filling station is attractive because less stringent criteria are applied when upgrading green gas to natural gas quality, and the costs of the gas network can be prevented.

A real sales market will be possible when green gas is injected into the ordinary natural gas supply network. The green gas is then blended with natural gas. It is thus impossible to determine who uses the green gas molecules. Green gas customers receive supplies in a virtual manner. The green gas is injected into a local network. This same network must contain a physical client; the virtual clients will usually be located elsewhere.

An important point in supplying virtual green gas and injecting green gas into a local network concerns the quality criteria with which the green gas must comply. This means the right caloric value, pressure and the prevention of chemical and bacteriological gas pollution.

Virtual green gas customers include companies and organisations, households and filling stations. Consumers, companies and government bodies that specifically purchase green gas are prepared to pay a slightly higher price. This may be either for using gas for transport purposes, or as gas for heating/cooking. Government bodies will focus on sustainable procurement in 2010, which will considerably encourage the development of a green gas market. With respect to mobile applications, the 2% green gas blending commitment applies. Stakeholders concerned with this commitment should work together with those that sell green gas to motorists via the filling stations. It is important for all these green gas applications that the virtual purchasers of green gas are convinced that green gas is really being purchased.

Opportunity 10

With respect to mobile applications, it is important that green gas should count towards the (2% and increasing) biofuel blending requirement. Companies that are required to blend sustainable fuels can purchase green gas for this purpose. This will create a demand for green gas and give it, as fuel, extra value.

Opportunity 11

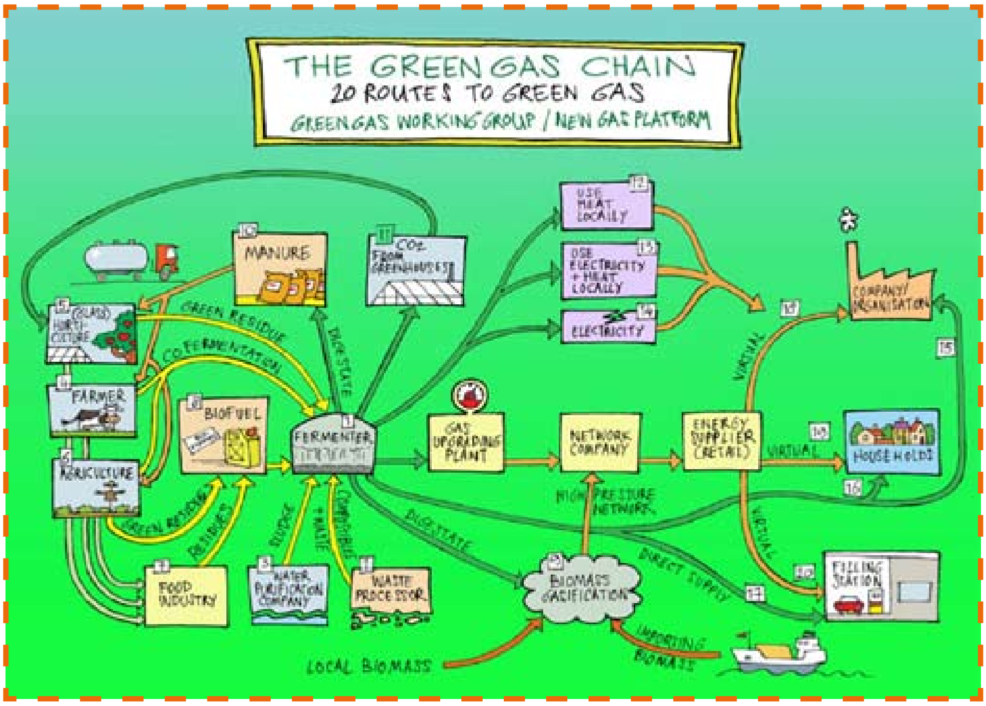
Green gas is a valuable commodity for sustainable procurement by government bodies and sustainable companies. This leads to a market demand for green gas, which will have a positive effect on price development.

Opportunity 12

Sustainable consumers are prepared to pay a slightly higher price for green gas. Selling green gas alongside green electricity on the consumer market could result in a higher price being charged.

Opportunity 13

Companies that are obliged (under the Kyoto Protocol) to reduce emissions of CO_2 and other gases could switch over to biogas. Since this is a short-cycle CO_2 emission it could legitimately be recognised as CO_2 credit. Using biogas rather than a fossil-based fuel can be seen as a tradable credit, which gives it a value for the user. This makes the purchase of CO_2 more attractive. In this case, companies could take advantage of this fact. The CO_2 emissions trading route also has room for emission advantages in the production chain to be valued, rather than focusing exclusively on emissions reduction as a result of replacing fossil fuels. Taking a more integral environmental approach in the chain could, for example, mean emission advantages of non-CO_2 greenhouse gases also being included, such as CH_4 (from manure) and N2O (from fertilising).



Green gas transition: 20 routes to green gas

Routes 15-17 also sketch possibilities for the direct use of biogas that has not been upgraded to natural gas quality. This biogas can still be used locally via an energy conversion step. This could be a conversion to electricity and heat via a suitable cogeneration plant, or use as a fuel, for example, in heating equipment and processes.

APPENDIX M FNLI STUDY: USING RESIDUES FROM THE FOOD INDUSTRY FOR FERMENTATION

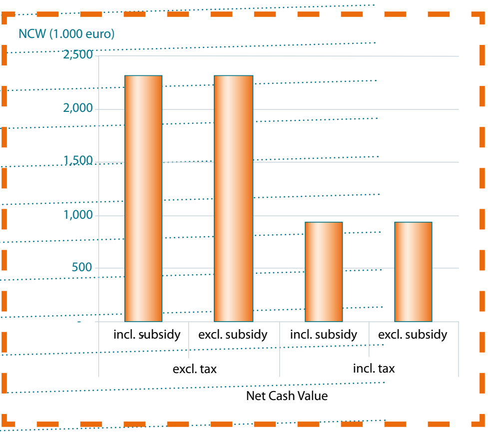
The food industry offers a considerable potential for energy production via fermentation and residues. In order to survey these possibilities, the FNLI and the MJA (long-term agreements) programme (implemented on behalf of the Ministry of Agriculture, Nature and Food Quality) run by SenterNovem implemented a project to develop a business-case model for investing in equipment where biomass is converted into biogases. These biogases either drive a cogeneration plant or can be used directly as an alternative for natural gas. The model can be used to:

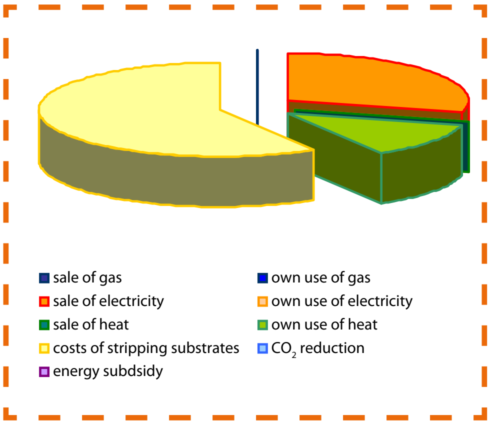
- identify the conditions necessary to make a fermentation plant profitable;
- analyse the feasibility of specific fermentation plants.

The model can calculate the effects of a wide range of scenarios and circumstances, and is meant as a tool during internal and external consultations. This tool focuses particularly on quickly determining the financial feasibility of projects. The model is implemented as an Excel spreadsheet, with accompanying user manual.

For further information, please contact Ms. E. Hoog Antink, of SenterNovem's MJA programme.

The results are usually clear and illustrated in the form of graphs. The following example provides a cockpit view.





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Energy Transition
New Gas Platform
P.O.Box 8242
NL - 3503 RE Utrecht
e nieuwgas@senternovem.nl

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