GREEN GAS GRIDS

WP 2 / D 2.3
September 2013

BIOMETHANE GUIDE FOR DECISION MAKERS

Policy guide on biogas injection into the natural gas grid

INTELLIGENT ENERGY EUROPE

Authors
Sabine Strauch, Joachim Krassowski, Ankit Singhal

Contact
Fraunhofer UMSICHT
Research Group Biogas technology
Osterfelder Strasse 3
46047 Oberhausen, Germany
www.umsicht.fraunhofer.de

BIOMETHANE GUIDE FOR DECISION MAKERS

Policy guide on biogas injection into the natural gas grid

The Biomethane Guide for Decision Makers has been created within the project GreenGasGrids supported by the Intelligent Energy - Europe programme (contract number IEE/10/235/S12.591589).
www.greengasgrids.eu

THE GREENGASGRIDS PROJECT PARTNERS

German Energy Agency - dena (Germany)

Fraunhofer UMSICHT (Germany)

Austrian Energy Agency (Austria)

Energetski Institut Hrvoje Požar -EIHP (Croatia)

Agence de l'Environnement et de la Maîtrise de l'Energie - ADEME (France)

Renewable Energy Agency – REA (UK)

University Szdeged (Hungary)

European Biogas Association

Consorzio Italiano Biogas (Italy)

Agentschap NL (The Netherlands)

Krajowa Agencja Poszanowania Energii – KAPE (Poland)

Slovenská Inovacná Eneregetická Agentúra - SIEA (Slovakia)

Natural Gas Vehicle Association - NGVA

CONTENT OF THE SECTIONS

The Biomethane Guide for Decision Makers includes six sections, each providing an insight to strengthen the process of policy decision for biomethane development.

Introduction

Section I Biomethane as a high value renewable energy source
This section helps in generating the basic understanding of biomethane and discusses the underlying importance of biomethane as a renewable natural gas substitute. The section also describes the available potential in terms of production of biomethane and the extent of climate benefits which are derived from biomethane utilisation.

Section II Biomethane as an integrated energy solution
This section is intended for decision makers to become aware of the linkage between the key EU (European Union) level policy drivers and biomethane production and utilisation. It also highlights the role biomethane can play by integrating within the existing natural gas infrastructure and fulfilling the renewable energy targets.

Section III Best practice along the value chain
This section describes the value chain of biomethane to natural gas grid injection. It covers:
- Biogas production and feedstock
- Gas upgrading technology and emission control
- Grid injection, biomethane trade and utilisation

Section IV Support policies in Member States
This section provides information on the regulatory framework as established in EU countries. It further describes the financial instruments which are being encouraged within EU countries for the promotion of biomethane.

Section V Assess your biomethane strategy
This section describes a framework to create a strategy for biomethane development within your country or region. The framework is a set of questionnaire which acts as a guide to identify weak issues within biomethane development strategy. Identification leads to aligning the policies to address the weak issues and promote the growth of biomethane industry.

Summary

INTRODUCTION

Biomethane – the green natural gas substitute

Biomethane is methane sourced from renewable biomass such as organic waste, sewage, agricultural residues or energy crops. It can also be derived from woody biomass like forestry residues through production of synthetic gas. In each case it offers a climate friendly way of substituting fossil natural gas and is a flexible energy carrier for fuel, electricity and heat applications, moreover, material use for biomethane offers additional possibilities. Spacial separating the biogas production plant from its point of utilisation offers a lot more potential for increase the energy efficiency by serving heat sinks with thermal energy from cogeneration in a biomethane combined heat and power plant (CHP).

Countries like Sweden, The Netherlands, Germany and Switzerland already gained experience in integrating this environmentally friendly technology into its energy system. Throughout Europe there are in total more than 200 biomethane plants in operation (Table 1), a fact that clearly shows: gas upgrading technology is mature and proven, thus technology is no longer to be regarded as a restricting factor.

Biomethane offers tremendous potential when it is produced and injected into the natural gas grid. The existing natural gas infrastructure can be used for transporting the green gas to its final consumer, where due to its flexibility, biomethane can make a contribution to reducing greenhouse gases (GHG) in all three sectors - electricity, heat and transport.

Table 1: Number of biomethane production plants, biomethane to grid plants, plants producing biogas from organic sources (incl. landfill, sewage, biowaste and agricultural sector) in several European countries (source: Fraunhofer UMSICHT 2013)

Country	Biomethane plants	Biomethane plants feeding the grid	**Biogas plants total** (incl. LFG, sewage, agricult.)	Agricultural	Biowaste (incl. organic MSW)	Sewage	LFG
Austria	10	7	**503**	approx. 300	55	134	14
Croatia	-	-	**12**	9	-	2	1
France	3	1	**269**	40	98	60	71
Germany	107	105	**9.200**	approx. 7.400	100	1.700	
Hungary	1	-	**58**	36	-	14	8
Italy	-	2	**810**	498	32	60	220
Netherlands	21	21	**235**	98	21	75	41
Poland	-	-	**219**	30	2	approx. 200	
Slovakia	-	-	**57**	34	4	10	9
UK	2	2	**360**	60		100	> 200
Sweden	47	8	**229**	14	23	135	57
Switzerland	17	15	**600**	140		460	
TOTAL	**208**	**161**	**12.552**	**8.659**	**335**	**2.950**	**621**

The GreenGasGrids Project promotes the European biomethane market

The Biomethane Guide for Decision Makers is part of the initiatives within the Intelligent Energy for Europe (IEE) funded project GreenGasGrids. The three years project is running until June 2014 and includes a consortium consisting of 13 European partners, involving key stakeholders from biomethane, natural gas and renewable energy industries, as well as EU level and national level policy makers.

GreenGasGrids aims to promote a significant contribution of biomethane to the Renewable Energy Directive (RED) targets of 20 % renewable energy and 10 % renewable energy in transport in 2020 as well as the renewable energy targets set by individual EU Member States.

Aim of the Biomethane Guide for Decision Makers

The Biomethane Guide for Decision Makers is intended as a source of quick reference for municipal, regional and even national level decision makers and authorities with influence over policies. This guide describes the benefits offered by biomethane and the ongoing policy schemes in EU countries supporting the development of biomethane.

This guide also provides a framework to analyse the current state of biomethane development within your region and a devise and strategy to identify the weak areas within development of biomethane industry. The framework is meant to encourage a deeper understanding in biomethane production and utilisation and initiate a proactive role in aligning the policies for further development.

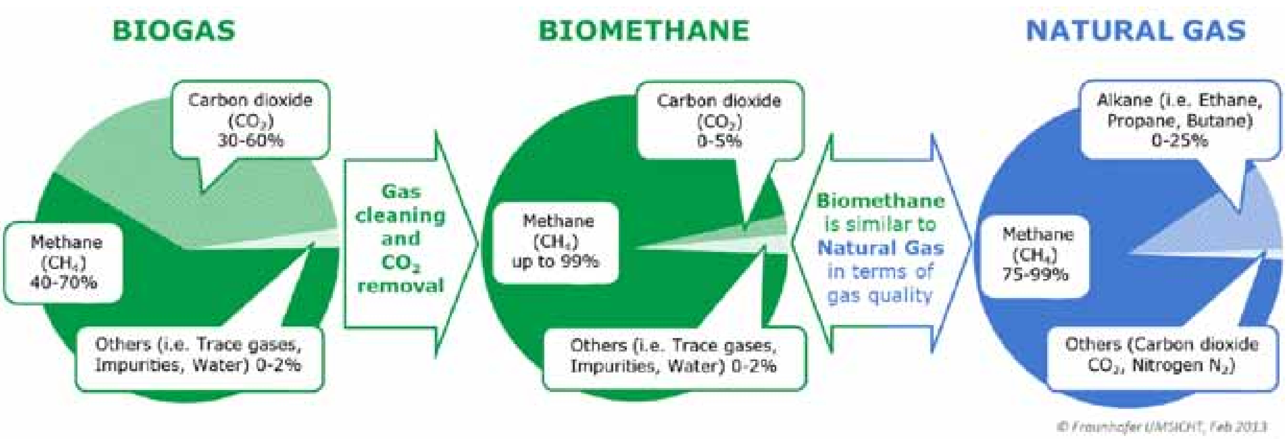
SECTION I BIOMETHANE AS A HIGH VALUE RENEWABLE ENERGY SOURCE

Biomethane is purified biogas

Biomethane is derived from biomass and has the major constituent in common with natural gas, which is methane. Intermixing with natural gas is possible in almost all proportions, thus biomethane is often referred to as a green natural gas substitute.

Biogas, the pre-stage of biomethane, can be sourced from almost all kinds of organic matter. Wet organic matter with low lignocellulose content, e.g. organic waste, sewage sludge, manure, is appropriate for biogas production by anaerobic digestion. Anaerobic digestion is a naturally occurring process where bacteria act upon moist organic material and decompose it into biogas as well as the nutrient rich digestate. The biogas thus produced, is cleaned of its impurities and upgraded to increase the methane content. The upgrading and purification is carried out to match natural gas specifications.

Figure 1: Chemical compounds and approx. share of biogas, biomethane and natural gas



The Biomethane Guide for Decision Makers focuses on the above described gas derived from anaerobic digestion. Additionally other renewable methane gases are embraced by the term biomethane, e.g. Synthetic Natural Gas (SNG) derived from woody biomass, or methane built by hydrogen from electrolysis and carbon dioxide by biological methanation process, also called Biogenic Synthetic Gas (BioSNG).

These technologies are on the way and offer potential on the mid and long term. However, since they lack of large scale applications they will not be focal point of this document. Nevertheless further information on alternative ways of producing biomethane is summarized in a separate report available at the GreenGasGrids project webpage www.greengasgrids.eu.

Biogas potential in 2020 is 41.6 Mtoe – to be combined with high flexibility when taking the biomethane option.

Biomethane is cleaned, upgraded and conditioned biogas. To evaluate the existing potential for biogas, substrate streams from agriculture, from waste water treatment and organic biowaste have been estimated by different studies (Table 2). AEBIOM assumes 25 million hectares agricultural land in EU-27 being available for bioenergy production, 5 million of which for energy cropping for biogas production. Including other substrates from the agricultural sector such as manure (assumed percentage of use of 35 %) and straw (assumed percentage of use 5 %), the agricultural sector raises a biogas potential of about 32.8 Mtoe. Additionally, the waste sector comprising sewage, municipal and industrial biodegradable organic wastes, generates substrate flows that with the appropriate treatment processes result in a biogas potential of 8.8 Mtoe. In sum, a total biogas potential of up to 41.6 Mtoe (1,741 PJ) primary energy is assumed to exist.

Tabel 2: Biogas potential of EU-27 (source: based on AEBIOM 2009, IE Leipzig 2007)

Origin (according to template of NREAP)	Potential (109 m³ methane)	Assumed percentage of use until 2020	Primary energy (109 m³ methane)	Primary energy (Mtoe)
Agriculture	58,9		35,4	32,8
Agricultural crops directely provided for energy generation	27,2	100%	27,2	25,3
Agricultural by products / processed residues	31,7		8,2	7,6
o straw	10,0	5%	0,5	0,5
o manure	20,5	35%	7,2	6,7
o rest (Landscape management)	1,2	40%	0,5	0,4
Waste	19,0		9,5	8,8
Biodegradable fraction of municipal solid waste including biowaste (biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants) and landfill gas	10,0	40%	4,0	3,7
Biodegradable fraction of industrial waste (including paper, cardboard, pallets)	3,0	50%	1,5	1,4
Sewage sludge	6,0	66%	4,0	3,7
TOTAL	**77,9**		**44,8**	**41,6**

Assumptions and parameters	
Heating value biomethane (kWh/m³)	10,8
conversion factor Mtoe/TWh	0,0860

10.9 Mtoe (456 PJ) primary energy were produced from biogas (i.e. agricultural, sewage, landfill gas) in 2010. Biogas energy is mainly recovered in the form of electricity. However, the efficiency degree of this energy utilisation is always linked to the degree of utilisation of heat from cogeneration and therefore with the availability of a suitable heat sink. Since the most biogas plants are located in rural areas and lack of useful heat utilisation, at the majority of the existing biogas plants there is scope for optimisation and for an increase in energy efficiency.

Biomethane production is able to decouple biogas production from use and offer much more flexibility to make efficient use of the existing potential. Thus, it is assumed that at least a third of the above described biogas potential is more efficiently used when converted to biomethane. On that basis the total biomethane potential sums up about 14 Mtoe annually (582 TWh).

Biomethane applications reduce carbon emissions

Biomethane is a renewable gas and replaces fossil energy carriers in the fields of transport, electricity production and space heating. Therefore, it is able to make a significant contribution to climate protection and CO_2 emission reduction.

The extent of the CO_2 savings resulting from biomethane applications depends on three important factors:

- Kind and source of **feedstock**,
- **Mode of operation** of the biomethane plant and
- **Utilisation pathway** of the produced biomethane.

Manure and organic waste are the most climate friendly feedstock

Biogas generation from manure and dung causes the most significant GHG reduction. Besides the production of renewable energy, the GHG mitigation effect results from capturing climate harming gases such as methane, nitrous oxide which are prevented to emit into the atmosphere. Therefore, the anaerobic treatment of these kinds of agricultural residues should enjoy maximum political support. Another substrate with a low carbon footprint is organic waste. Most commonly municipal biowaste is treated in composting plants. Provided using state of the art technology, biogas production from organic waste offers a more beneficial GHG balance than composting.
Biomethane from energy crops is the cleaner solution compared to fossil fuels. Even growing energy crops for biomethane production involves effort and energy. However, if digestate is used for manuring, nutrients will be kept in the biological cycle – which saves emissions from an energy-intensive mineral fertiliser production.

Mode of operation: Energy efficiency and methane slip influence the Life Cycle Assessment (LCA)

The careful and wary mode of operating a biomethane production plant is a key factor in an emission saving biomethane production. Especially when using energy crops for gas production special attention should be drawn on minimizing methane emissions. Methane is both, an energy carrier and a GHG. Thus, for safety, ecological and economical reasons best practice plants prevent methane from being lost to the atmosphere and have an eye on gas leakage and flue gas treatment. Best practice plant operation can be supported by requirements that act as prerequisites for financial support, but also educational trainings for the local authorities.

The appropriate biomethane utilisation with most CO_2 saving – a question of national conditions.

For evaluating the climate effectiveness of biomethane it is a key question which energy carrier is replaced by the use of biomethane. It is crucial to analyse the national situation and use biomethane where it has the greatest benefit.

All countries face different conditions regarding the emissions from their national average electricity, fuel and heat mix. Nations whose electricity production is substantially based on black and brown coal achieve a great effect when replacing electricity with renewables. Biomethane used in a CHP delivers not only electricity - it also provides renewable heat.

SUMMARY SECTION I WHAT TO KEEP IN MIND

- Biomethane is cleaned, upgraded and conditioned biogas. Its main component is methane, which makes it a potential substitute for natural gas.
- Biogas can be obtained from all organic matter, being wet organic matter the most commonly used, processed by anaerobic digestion.
- Biomethane production separates biogas production from consumption. Using the well developed natural gas infrastructure, the gas can be transferred to where it is needed.
- Biomethane is a flexible energy carrier and can be used as electricity, heat and vehicle fuel. As one of the few storable renewable energies it is able to provide energy on demand.
- Biomethane's contribution to emission mitigation is dependent of national conditions (national emission factor for electricity, heat and fuel) and the chosen utilisation pathway.
- Manure, energy crops, sewage and municipal organic waste offer a biogas potential of 41.6 Mtoe, a third of which (14 Mtoe) are assumed to be available for biomethane production – to increase efficiency and flexibility.

Figure 2: Harvesting and silage making from energy crops

SECTION II BIOMETHANE - THE INTEGRATED ENERGY SOLUTION

Biomethane satisfies all three principles – security of supply, sustainability and competitiveness.

The European energy policy for 2020 is built on three core objectives namely security of energy supply, sustainability and competitiveness. The principles are understood as follows:

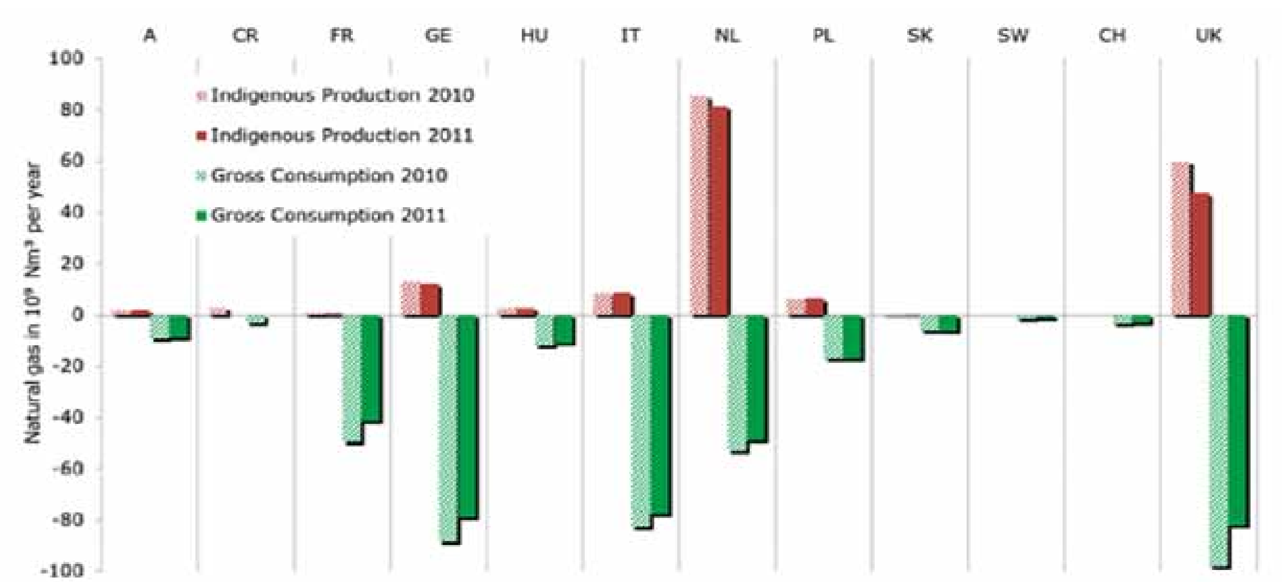
Security of energy supply - A strong need exists to minimize risk of exposure towards fossil fuel price volatility and ensure security of energy supply by diversifying the existing energy production sources.

Sustainability - The commitment towards sustainability calls for a reduction in greenhouse gas emissions, energy recovery from waste and increment in developing a healthier environment for future generations.

Competitiveness - Promotion of localized production of energy, and simulating technological innovation is the key to develop a competitive energy market and increased employment opportunities.

For a decision maker, it is crucial to understand how biomethane offers an integrated advantage and it is able to satisfy the referred policy goals.

Figure 3: Inland production and gross consumption of natural gas in different European countries
(source: IEA 2012)



Principle 1: Security of energy supply

Fossil energy reserves are limited. To a high percentage fossil gas and oil are imported from non-European countries and already today in most European countries gas consumption exceeds inland production (Figure 3). In contrast, substrates for biomethane production are renewable and homemade or are sources from domestic processes. When injected in natural gas infrastructure, biomethane can displace fossil fuel usage proportionate to its production and therefore, enhances the security of energy supply. Key policy driver linking biomethane to security of energy supply are represented in Table 3.

Table 3: Key policy drivers linking biomethane to the principle of security of energy supply

EU policy directive	Target of the directive and link to biomethane
Renewable Energy Directive (2009/28/EC) on share of RES in overall final energy consumption	aims to achieve 20 % share of the overall final energy consumption from renewable resources by 2020. The binding target is translated individually for each member and stated in the National Renewable Energy Action Plans (NREAP). The NREAP provides a detailed road map of achieving individual countries renewable energy generation targets by setting out sectorial technology mix in their long term energy strategy.
➔ **Biomethane can be a valuable part in this mix and is able to contribute to raising the renewable share of the final energy consumption in different utilisation pathways.**	
Renewable Energy Directive (2009/28/EC) on share of RES in transport	calls for a 10 % share of energy from renewable resources in each member state's energy consumption in transport. By definition the directive includes contribution from biofuels and biogas, as well as hydrogen and electricity from renewable resources. There are no individual targets but vast proportion is expected to be met by biofuels. Transport biofuels derived from waste, residues, non-food cellulose material and lingo-cellulose are counted double for satisfying biofuel obligation to meet the target.
➔ **Biomethane is a clean vehicle fuel and can help achieve the renewable fuels target in most efficient way. The transport sector is fastest growing sector in terms of emissions and biomethane is a means to lower vehicular emissions achieving sustainable transport.**	
Renewable Energy Directive (2009/28/EC) on regulatory conditions to establish grid connection	Member states shall ensure non discriminatory charging of transmission and distribution tariffs against gas from renewable resource. Where relevant, member states have the responsibility of assessing gas network infrastructure to facilitate the integration of gases from renewable resources and area also required to publish technical rules regarding conditions for establishing network conditions and connection tariffs.
➔ **Renewable gases such as biomethane are to grant non discriminatory access to the gas grid**	

Principle 2: Sustainability

Biomethane is derived from anaerobic digestion of organic waste, industrial waste as well as purposefully grown energy crops. It is a renewable fuel and can effectively contribute within climate change strategies of reducing emission. Production of biomethane via anaerobic digestion is also a key part of an integrated waste treatment process. It is an effective means to counter waste disposal, achieve landfill objectives coupled with production of energy. Key policy drivers, such as the Fuel Quality Directive (2009/30/EC), the Landfill Directive (99/31/EC) and Sustainability Criterion of the Renewable Energy Directive (2009/28/EC), link biomethane to the principle of sustainability (Table 4).

Table 4: Key EU policy drivers linking biomethane to the principle of sustainability

EU policy directive	Target of the directive and link to biomethane
Fuel Quality Directive (2009/30/EC)	aims to reduce the emissions from production and usage of fuels. The directive states from 1st of January 2011 onwards fuel suppliers must annually report a gradual reduction in GHG emission intensity by at least 6 % of average European GHG value of fossil based fuels for 2010.
➔ **Biogas produced from municipal organic waste, wet manure and dry manure; upgraded and blended with natural gas provides means to satisfy targets in Fuel Quality Directive.**	
Landfill Directive (99/31/EC)	mandates member states to ensure biodegradable municipal waste going to landfills to be reduced by 35 % of total amount produced in 1995, 15 years after it comes in force.
➔ **The avoidance of land filling of biodegradable component and satisfying the targets for the criteria makes a case for production of biomethane via anaerobic digestion.**	
Renewable Energy Directive (2009/28/EC) about the sustainability Criterion	sets criteria for biofuels and bio liquids for compliance to meet the obligatory targets. The GHG emission savings from the use of biofuels and bio liquids should be 35 % compared to fossil fuels and by January 2017 the target shall be increased to 50 % compliance value and further increment of 60 % is expected by January 2018.
➔ **Biomethane is able to fulfill the requested GHG emission reduction. Over the past recent years mechanisms have been developed to evaluate sustainability biomethane sourced from different feedstock.**	

Principle 3: Competiveness

Biomethane production generates high local added value. It is sourced from domestic biomass which is processed at local plants.
Despite its market price is higher compared to fossil natural gas, the increased local added value generated by biomethane production needs to be set off. Inland energy generation offers benefits such as

- Increased local added value,
- Support of the agricultural sector in the region,
- Generation of qualified jobs in planning, engineering, operating and maintaining of biogas and biomethane plants,
- Increased tax revenues in municipalities.

Figure 4: Effect of employment from biogas technology in Germany (source: Federal Environment Ministry Germany)

SUMMARY SECTION II WHAT TO KEEP IN MIND

- Biomethane integrates European Union energy policy goals:
  Sustainability of energy supply, security of energy supply and local competitiveness.

- High added value on local level.

- Biomethane can help achieve the renewable energy generation targets for production of heat and electricity. Biomethane usage in gas vehicles can balance the proportion of renewable fuels in transport.

- Anaerobic digestion and subsequent production of biomethane is an effective strategy to move towards targets of
  - Renewable Energy Directive (2009/28/EC)
  - Landfill Directive (1999/31/EC)
  - Fuel Quality Directive (2009/30/EC)

Figure 5: Biomethane production plant Könnern II, Germany

SECTION III BEST PRACTICE ALONG THE VALUE CHAIN

The dominant biogas production pathway is anaerobic digestion.

Anaerobic digestion is a complex biological process where organic material is converted into a gaseous mixture as well as residual digestate rich in nutrients. The organic substrate is pre-treated and cleaned and then undergoes decomposition in an oxygen free environment in digesters. The digestion takes place in a number of steps leading to the final production of methane, carbon dioxide and the residual digestate.

Organic waste and Manure are preferable substrates, purpose grown crops offer large potential

Biogas production through anaerobic digestion can utilise all kinds of organic material except lignocellulose (wood based) products.
A variety of feedstock is being used for biogas production. A broad categorisation can be made in terms of biomass from agriculture by-products and biomass from waste streams.

Table 5: Examples of biogas substrates

Agriculture based crops and by-products	• Farm manure and slurry • Agricultural by-products (i.e. sugar beet residue, spoiled corn, grass cut, cereals residue) • Purpose grown crops
Waste streams	• Sewage sludge and waste water treatment • Organic fraction of municipal solid waste • Residue from food industry (i.e. stillage, failed batches, vegetable trailings, potato peels, fruit pulp, brewer's grains, pomace, press cake) • Food waste and animal by-product from slaughterhouse

Farm manure and slurry occur as agricultural by product and are the traditional feedstock for biogas production. Using manure and slurry for biogas production mitigates GHG emissions and, moreover generates a suitable fertilizer, since after anaerobic treatment the nutrientscontained, e.g. nitrogen), are better accessible to plants after mineralisation. However, compared to other feedstocks such as biowaste or energy crops, these substrates contain comparably less energy due to a lower organic fraction. Thus, the required reactor volumes and consequently the specific investment costs per generated kilowatt hour for biogas from manure are higher than from energy rich substrates.

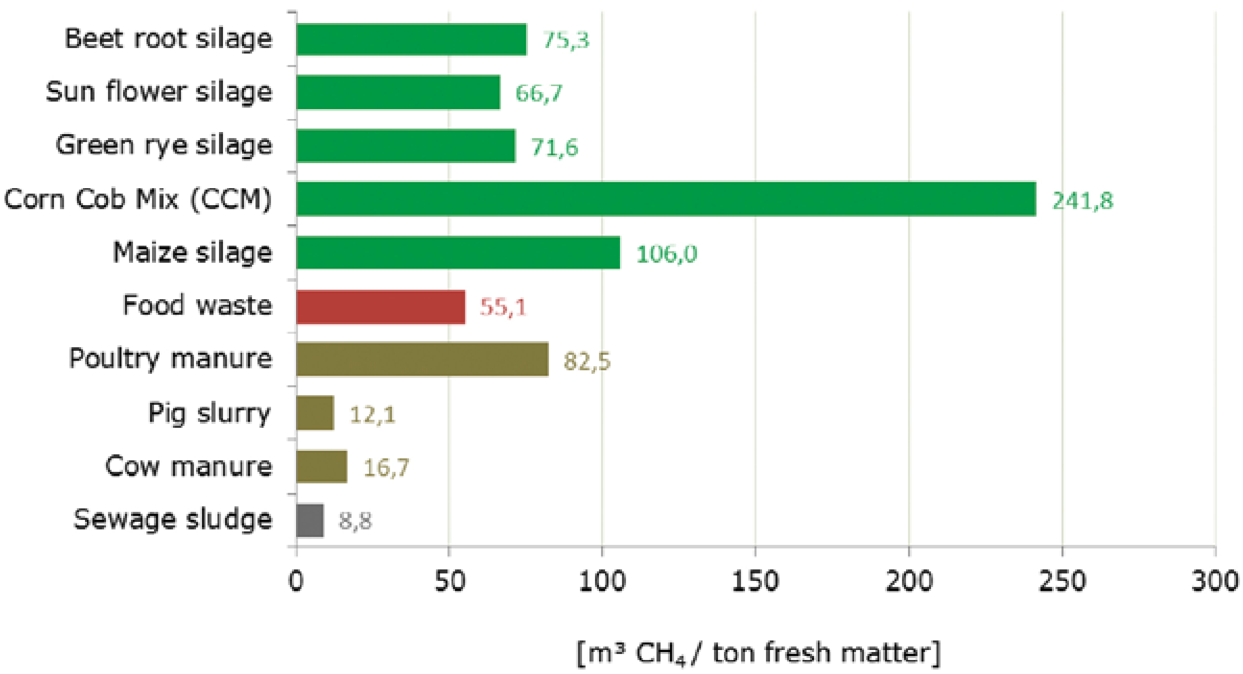
Purpose grown crops, also referred to as energy crops, can be specially cultivated for anaerobic digestion. Crops including maize, beet root, potatoes or grass silage are high yielding substrate that can be integrated in crop rotation practice as well. Blending energy crops with farm manure is a common practice to maximize yield and stabilize the process. The potential biogas yield from a single feedstock is shown in Figure 6. The choice of feedstock is based on gas yield data, annual availability as well as compliance to appropriate regulation. The range of gas yield available from the choice of feedstock is quite wide and multiple yields can be expected in cases of co-digestion.
When growing energy crops farmers benefit from an interesting additional segment and a second market for

their products. This market is able to compensate supply in years of rich harvest and creates demand for spoilt bulks. On the other hand, countries with high percentage of energy cropping experienced cases of competition for arable land which occurred primarily in regions with high livestock density. In order to avoid these conflicts, especially support measure for biogas production must pay attention to the specific regional conditions such as livestock density, dominant land use category and main crop.

Organic waste occur e.g. at food processing industry, as market wastes or from separated communal waste collection. An important step prior to the actual anaerobic treatment is substrate pre-treatment and removing contaminants such as plastics or packaging residues. Changing substrate load and the packaging remains require careful management and appropriate plant technology. Therefore, this process differs in plant design compared to digestion plant using agricultural substrates or sewage sludge.

Sewage sludge refers to the residual, high water containing remains from waste water treatment processes. Anaerobic digestion is an efficient technology for sludge treatment. Digestion decreases the sludge volume as well as volatility. The remaining digestate can be checked for toxicity and sent to landfill or used as landscaping purpose. Due to high water content the gas yield related to fresh matter seems to be low compared with gas yields derived from energy crops (Figure 6). Considering that waste water treatment capacities are expected to extended, sewage sludge bears considerable potential for biogas and biomethane production.

Figure 6: Methane yields from different biogas substrates related to fresh matter (sources: KTBL, Archea GmbH)



Gas upgrading and emission control

Raw biogas obtained from anaerobic digester, sewage treatment facilities or landfills are not suitable to be fed into the gas grid with its formative composition, since it is contaminated with impurities that may cause damage to downstream distribution and utilisation equipment. Hence raw biogas needs to be cleaned of its impurities and upgraded to match the combustion specifications of natural gas in the grid. The necessary process steps are in general removal of impurities, gas drying, removal of carbon dioxide while the order of the steps is linked to the applied CO_2 removal technology. Before gas injection it might be required to adjust the heating value. The chapter on grid injection will address these process steps more in detail.

Gas pretreatment: The treatment of biogas starts with a cleaning process that removes trace components harmful to the natural gas grid, appliances or end-users. Based on the substrate and technical design of the reactor, raw biogas may contain impurities that have a detrimental effect on end equipment. Table 6 provides an overview on the most important substances.

Raw biogas composition varies depending on the feedstock and digestion process. Each country has its own set of quality regulations for feed-in of gases in the public supply. When injecting the raw biogas in gas grid, cleaning and upgrading of raw biogas is performed to match the local specifications of natural gas. The technical standards are usually defined for unconventional gases including biomethane produced via gasification or via anaerobic digestion.

Table 6: Contains and contaminants of biogas, its sources and impacts on plant technology

Impurity	Source	Impact
CO2	Mineralisation of carbon from organic biomass (main component of biogas)	Reduces overall calorific value; promotes corrosion of metallic parts by formation of weak carbonic acid.
H2S	Proteins, manure, organic waste	Acts as corrosive in pipelines; causes SO2 emissions after combustion or H2S emissions in case of incomplete combustions; poisons the catalytic convertor.
H2O		A major contributor to corrosion in aggregates and pipelines by forming acid with other compounds; formation of condensation leading to the damage of instruments; freezing of accumulated water in high-pressure low temperature conditions.
NH3	Proteins	Leads to an increase in antiknock properties of engines; causes formation of NOx.
N2	Air input e.g. by desulphurization with air	Leads to an increase in antiknock properties of engines; leads to a reduction in calorific value as well.
Siloxanes	Cosmetics, antifoaming agents, washing agent, hydraulic fluent	They are mainly present in biogas formed out of landfill or sewage gas. These hydrocarbon acts as quartz of silica, grinding motor parts.
Terpene	Essential oils (e.g. from plants, fruits, cosmetics)	
Ester	Fruits, fruit aroma	
Dust		Damages vents and exhaust by clogging

CO_2 removal: The main process step in the biomethane production process is the removal of carbon dioxide. Currently there are several technologies in practice that are used to clean and upgrade biogas to reach the required specification for natural gas grid injection. A brief description of these techniques is given in Table 7.

Table 7: Processing principals for CO_2 removal from biogas

Basic Principal	Process technology	Process description
Absorption	High pressure water scrubbing	Water absorbs CO_2 under high pressure conditions. Regenerated on depressurizing
	Chemical scrubbing	Amine solution absorbs CO_2 regenerated on heating.
	Organic solvent scrubbing	Polyethylene Glycol absorbs CO_2 regenerated on heating or depressurizing.
Adsorption	Pressure swing adsorption (PSA)	Pressurized gas is led through an adsorber bed where the molecules adsorb with different strength at the adsorber. The separation effect is caused by the different strength of junction depending on the kind of gas.
Membrane	Membrane separation	Pressurized gas is passed through a membrane system, which has selective permeability for CO_2 respectively methane.
Cryogenic	Cryogenic separation	Biogas is cooled till CO_2 separates out as liquid form.

The energy demand for CO_2 removal differs and is dependent on process conditions such as

- Process conditions such as ambient temperature,
- Condition of the raw biogas e.g. methane content, contaminants,
- Requirements for product gas (biomethane) methane content in the biogas.

However, all technologies bear their own strengths and weaknesses. A well engineered site specific solution takes advantage of the strengths and engineers an energy efficient plant.

- **Example 1:** A heat requiring process e.g. an amine scrubber is suitable for a plant site where a cheap heat source is available, e.g. cogenerated heat from a CHP. If such a heat source heat is not available and has to be generated e.g. by burning wood pellets, costs are added and the overall efficiency of the technological process is slightly lowered.

- **Example 2:** Some biogas upgrading technologies operate at over pressure and produce compressed biomethane, e.g. membrane technology operating at up to 16 bars provides biomethane at almost the same pressure level. Feeding this compressed gas into a gas grid with similar pressure level, compression energy can be saved. If the gas is fed into a grid section at a much lower pressure level, the technology's advantage will remain unused.

Well implemented political measuressupport efficient plant engineering and provide incentives for all involved actors, most commonly biomethane plant operator and gas grid operator.

Emission control is necessary for safety, economic and first of all for ecologic reasons.

Methane emissions are often a result of failures in construction works or of poor plant operation. Gas losses may cause

- **Deterioration of the GHG balance**, since methane has a global warming potential of 25 compared to CO_2,
- **Odour problems** and resulting conflicts with residents,
- **Decline in revenues** from gas sale,
- **Safety** problems (danger of explosion and poisoning)

and therefore are to be prevented by appropriate measures. Regular checks with sniffer or with special gas cameras conducted by trained staff as well as appropriate plant engineering and well chosen operating parameters must become a matter of course.

Besides leakages at gas pipes or gas storage tanks, the lean gas stream of the CO_2 removal plant may be a source for methane emissions. Only amine scrubbing plants reach concentrations lower than 0.1 %. Here a post treatment of the lean gas can be waived. Other upgrading technologies operate with residual methane contents in the lean gas stream in the range of 0.6 % to up to 8 % related to raw gas concentration, depending on type of technology, plant set up and mode of operation. For these cases lean gas treatment is advised. Proven technologies for air purification are already used in other applications. For lean gas treatment at biogas upgrading plants good experiences were made with using for example:

- Thermal air combustion,
- Catalytic air combustion,
- Flameless oxidation (FLOX).

The German regulation limits methane emissions from upgrading plant's lean gas down to 0.2% related to raw gas. The financial support is linked to this minimum limit. Germany's biogas production relies strongly on purpose grown crops.

Grid injection, trade, utilisation

The biomethane plant is connected to the natural gas grid by a gas pipeline of several meters to kilometers depending on the distance between the biomethane plant and the choosen grid connection point. A facility of major importance is the grid connection station which completes several tasks:

- Measuring gas quality and flow are measured by calibrates instruments,
- Adjusting the heating value e.g. by adding propane, butane or air,
- Compressing biomethane to the required pressure level.

To ensure a safe and smooth operation of gas grid and connected gas utilisation equipment, biomethane has to meet **gas quality standards**. The requirements differ between the countries and even between single grid sections within one country. Apart from methane number, wobbe index and heating value also the minimum limits for various trace gases vary. Reasons are different natural gas qualities and their origin; however, also particular characteristics of some national grid like type of material used are given reasons. Several gas standards offer the possibility to feed biomethane off spec gas, meaning gas that does not fully comply with the limits, as long as the resulting gas quality is in line with the requirements. This praxis offers an economic option when feeding high calorific gas grids at high volume flow.

In 2011, the European Committee decided to give a mandate to a new CEN technical group (CEN TC 408) to develop a **common standard for biomethane** which is currently under development. The scope of CEN TC 408 encompasses both biomethane and natural gas as fuels and biomethane for injection into natural gas grids.

Biomethane injection is possible at any pressure level of the natural gas grid.

The natural gas grid contains different sections that are operated at different pressure levels and suit different purpose. The grid parts can be divided into

- Interregional transportation grid (usually > 16 bar),
- Regional transportation grid (about 4-16 bar),
- Distribution network (usually < 4 bar),

while the pressure ranges differ between the various countries. Naturally both options, injecting in the high pressure grid as well injection in the low pressure grid, bear pros and cons. At lower pressure levels, injection requires less effort for gas compressing and therefore less energy and costs are to be spent. On the other hand, these grids may be limited in its take-up capacity. In times of low gas consumption in the connected supply area this might become an issue. Grids at higher pressure levels transfer most commonly high gas volumes and therefore are less limited in gas take up capacity.
This advantage has to be paid. Energy demand for compression increases with required pressure level and is linked with costs.

Both investment and operation costs for grid connection need to be considered when developing financial support mechanisms for biomethane injection. Grid operator and biomethane producer should look for the most suitable and most efficient grid connection point in terms of

- Distance between biomethane plant and grid connection point (length of connection pipe),
- Injected pressure level,
- Design and equipment of the gas connection station.

Transparency for all administration steps is an important issue. Documents for planning grid connection such as

- Maps of transportation and distribution gas grid
- Draft agreement for grid access
- Requirements for gas quality

should be easily accessible for all involved stakeholders.

Biomethane trade takes primarily place within a nation's border. Cross-border trade is able to balance the markets and increase flexibility.

Biomethane transport makes use of the natural gas infrastructure and thus underlies partly the rules of national gas trade. This requires calibrated metering, energy balancing.

Biomethane is a green gas and distinguishes from natural gas by an important feature: it is renewable and has the green feature. To keep track of this valuable characteristic after having been mixed with fossil natural gas, a tracking mechanism is needed. Mass or energy balances serve reliable and complete retracing of biomethane from its production site to the final consumer. They can serve various purposes

- Providing proof of the green feature,
- Keeping track of the parameters related to the gas production that relevant for financial support (kind of substrates used, plant size, certificate for complying with emission limits, energy efficiency of the plant etc.),
- Avoiding doubled sale.

Therefore, several countries already established its national tracking system, the biogas register (Table 8).

Table 8: Tracking mechanisms for biomethane in different countries

Country	Name of mechanism	Institution in charge	Status
Austria	Biomethane Register Austria	AGCS	In operation since May 2012
Denmark		Energinet	In operation
France	GoO register	Gaz réseau distribution France (GrDF)	Under development
Germany	German Biogas Register	German Energy Agency (dena)	In operation since 2011
The Netherlands		Vertogas	In operation since July 2009
Poland	Register of energy companies producing agricultural biogas	Agricultural Market Agency	
Sweden		Energigas Sverige	In operation
Switzerland		Federation of Swiss Gas Industry	
UK	Green Gas Certificate Scheme	Renewable Energy Association REA	In operation

Biomethane trade predominantly takes place in the country of its production. There are only a few examples of physical cross border biomethane trade, e.g. from Germany to Sweden, and to The Netherlands as well as from the UK to The Netherlands. If the market is not balanced, meaning demand exceeds supply or vice versa, cross border trade is able to increase flexibility and transfer biomethane where it is needed. Barriers are often created by the different national regulatory frameworks, but they can be removed by harmonising the national tracking systems which means that two different biogas registers are able to exchange biomethane amounts from the country of production to the country of final consumption.

German Biogas Register and Dutch Register of Vertogas harmonised their systems in order to be able to exchange biomethane amounts between the two countries.

European Committee's aim to strengthen the EU internal energy market is an objective that goes in line with the principle of competitiveness. Establishing a European biomethane market brings Europe a further step into the right direction.

Various choices for biomethane applications – for electricity or heat generation on demand or for vehicle fuel or material use

Electricity generation: Biomethane is used for electricity production in gas engines, such as biogas. Electricity is fed into the public electricity grid while the cogenerated thermal energy is used for heating or drying applications. The energy efficiency of the overall process increases with the degree of heat utilisation. Separating the biogas production site from the final place of consumption via biomethane production, much more heat sinks become available. In order to justify the energetic effort for biogas upgrading process and grid injection, biomethane must be used in cogeneration in CHP and minimum limits for heat utilisation should be defined.

In energy systems with a major share from fluctuating energy sources such as wind and solar, storable energy carriers are becoming more and more important. Biomethane is storable and uses the public gas grid as energy storage. This allows the biomethane CHP operator to generate green electricity on demand.

Heat generation: In the same way as natural gas, biomethane can be used for household applications such as cooking and heating. Compared with other renewable heat sources biomethane is one of the more costly fuels, however, it offers to operate an existing natural gas heating system with green energy. If a country is weighing to give priority to this biomethane utilisation pathway, contribution of other renewable heat sources need to be taken into consideration and support mechanisms need to be arranged accordingly.

Vehicle fuel: Biomethane can fuel CNG and LNG vehicles and thus is able to green both public and private transport. CNG and biomethane complement one another in the transportation sector. Both share the CNG infrastructure of fuel stops and gas grids and serve CNG cars. Moreover, biomethane is able to green CNG traffic while fossil CNG provides quantity.

The stage of development regarding CNG fuelled mobility in European countries varies. Number of CNG service stations and CNG vehicles registered are indicating to which extent gas fuelled mobility has already taken market share. If biomethane is planned to play a major role in the transport sector, the development status of CNG infrastructure becomes a significant issue. To successfully introduce biomethane as a vehicle fuel, an established CNG infrastructure must exist or, in case of long term planning, must be supported and promoted in parallel.

Check out for more information on natural gas mobility the Webpage of NGVA at www.ngvaeurope.eu

Material use: Natural gas is used as a reactive carbon source in chemical processes e.g. for fertilizer production (Haber Bosch process) and iron-ore reduction processes. Furthermore, natural gas is expected to gain increasing importance as resource for the chemical industry, especially for the production of short chain olefins. However, in view of the fact that fossil resources are on decline, the chemical industry is aware that its raw material base needs to be widen. Apart from the expiring fossil oil and gas, the industry starts now looking at biomass as renewable resource. Biomethane can replace fossil natural gas as a resource for the production of base chemicals via intermediates like synthesis gas or methanol.

SUMMARY SECTION III WHAT TO KEEP IN MIND

- Waste and manure are preferable substrates, while purpose grown crops offer large potential. Financial support for biogas from energy crops has to be developed in accordance with regional and agricultural conditions in order to avoid conflicts and undesirable developments.

- Biogas upgrading means gas pre-treatment (gas drying, removal of contaminants) and CO_2 removal. For all steps proven technology is available.

- Site specific engineering is essential to ensure the most efficient technical solution - and to maintain the public acceptance for this technology. Policy support should address all involved stakeholders and set incentives for building an energy efficient plant.

- Biomethane offers various utilisation pathways such as
  - Vehicle fuel
  - Electricity generation
  - Heat generation
  - Material use

- In energy systems with high percentage of fluctuating energy carriers (wind, solar) storable and flexible energy carriers are required to ensure stable grid operation. Biomethane CHP can deliver green electricity generation on demand.

Figure 7: Biomethane piping and measurement equipment in the grid connection station

SECTION IV SUPPORT POLICIES AND MEASURES

Various support measures are applied in biomethane forerunner countries.

Biomethane capacity development is not only a result of the political will targeting the inclusion of biomethane as a renewable fuel with prime importance in energy mix. The capacity is equally affected with reliable and long lasting financial support mechanisms and investment subsidies since under the current market conditions biomethane can not compete against natural gas in sales price.

There exists sufficient variation in support policies within nations driving biomethane demand. These support schemes mainly fall under measures such as feed-in tariffs (FIT), investment aids, quota systems or beneficial tax policies (Table 9). The success of all measures depends in the goodness of fit between sharing of project risks and revenues to ensure a balanced promotion of biomethane. Furthermore, programs for closely related fields such as promotion of natural gas applications in CHP or fuel applications must be coordinated with biomethane supporting measures to avoid competitive situations. Obviously in a quota system for renewable electricity it is unlikely that biomethane will prevail over other green electricity sources like wind and solar, if biomethane's particular talents, namely flexibility and its storage properties, do not pay.

Biomethane projects need long realisation times – and therefore need stable support conditions and long term policies

RES projects with long project development and implementation times face a risk in changing legal framework and in decreasing revenue streams. Especially for these kinds of projects a reliable and long term policy is important. Biomethane projects need several months, and in some cases up to few years, until the plants start its operating mode. The German example shows that even in countries with an established legal framework for biomethane the time period between planning stage and plant commissioning on average is around 32 months – while the procedure to negotiate and realise the grid connection takes the longest time period.

Table 9: Overview on different support measures for biomethane

Support measures at the production side
Direct investment support, e.g. in form of • Grants for plant construction, • Interest reduced loan.
Cost sharing for grid connection
Standardisation of licensing procedures for plant construction
Non discriminatory / priority access for renewable gas to the public grid
Transparency in terms of technical requirements for gas feed-in
... at the consumption side
Feed in tariffs, e.g. for • Renewable gas, • Renewable electricity from CHP.
Obligatory quota e.g. for the consumption of • Renewable fuel, • Renewable heat, • Renewable electricity.
Investment support, e.g. for • CHP-systems, • CNG cars, • Bus and vehicle fleets.
Beneficial tax policy featuring tax releave, exemption or refund, e.g. in terms of • Energy tax, • Fuel tax, • Electricity tax, • Income tax.
Revenues from emission trade

Apart from financial support additional measures addressing financing, licensing and legal aspects are essential for reducing project risks.

During planning stage the licensing procedure bears the risk to project delay. Clear licensing procedures are the key for a realisation according to time schedule. Guidelines for local authorities may help facilitating the permitting process and reduce the project risk at that stage.
The grid connection often turns out to be the bottle neck of a biomethane project. Therefore, rulings on network connection process need to name clear rights and responsibilities for all involved partners. A supervising authority (e. g. a governmental energy agency) can help to ensure a fair and effective negotiation and implementation of the grid connection.

The first step into this new technology is setting up a demonstration plant. Biomethane plants in pilot scale scientificly accompanied by appropriate R&D programs help to gain experiences, to identify technical and administrative barriers and to set a proper basis for industrial stage projects. Demonstration plants face a lot of barriers being a first of a kind in the country like unproven legal framework, inexperienced local authorities and gas grid operators, poor established service network for upgrading technology provider. Further information on Best practice approach to implementing a biomethane demonstration project is summarized in a separate report available at the GreenGasGrids project webpage www.greengasgrids.eu.

Examples from the GreenGasGrids member countries

Several countries already established support mechanisms for biomethane. Having a closer look at the strategies of these countries it becomes obvious that the applied mechanisms differ and come into action at various points of the biomethane value chain. In the following, an overview is given on the major support mechanisms of three biomethane forerunner countries i. e. Sweden, Germany, The Netherlands. The United Kingdom presents a country that just started its biomethane carreer and is included as an additional example. The measures of each country are shown along the biomethane value chain, starting from substrates and bioggas production up to grid injection and final utilisation in fuel, electricity, heat sector respectively for material use.

The Swedish example shows a promotion system that supported target orientated biomethane production via investment programs for municipalities and farmers and in parallel, created a demand for biomethane by promoting green transportation (Figure 7).

Just like Sweden also the UK goes for a two stage scheme and provides investment support on the one hand to directly support plant construction, and on the other hand established with the Renewable heat incentive (RHI) the instrument that is mainly driving the UK biomethane market. Besides the RHI biomethane receives support from other measures affecting the utilisation side of the value chain (Figure 8).

Germany sets their focal point at the end of the value chain and integrated biomethane support into the existing biogas feed in tariffs for electricity and the biofuel quota. Since grid connection has been identified to be a critical issue, the German ordinance on gas grid connection strengthens the position of the biomethane producer with several measures and provides priority access and transport for biomethane (Figure 9).

The Dutch support scheme approaches both biomethane production using its main support scheme called SDE+, and offers support for biomethane utilisation in the transport sector. The SDE+ scheme provides a feed-in subsidy covering the difference between production costs and energy price. (Figure 10). It operates on a first come first served basis within each categories eligibility criteria’s whereby projects applying for support in low cost category will be served first. In 2012 for biomethane there are five categories ranging from 0.483 €/Nm^3 to 1.035 €/Nm^3.

Figure 8: The Swedish support measures shown along the biomethane value chain

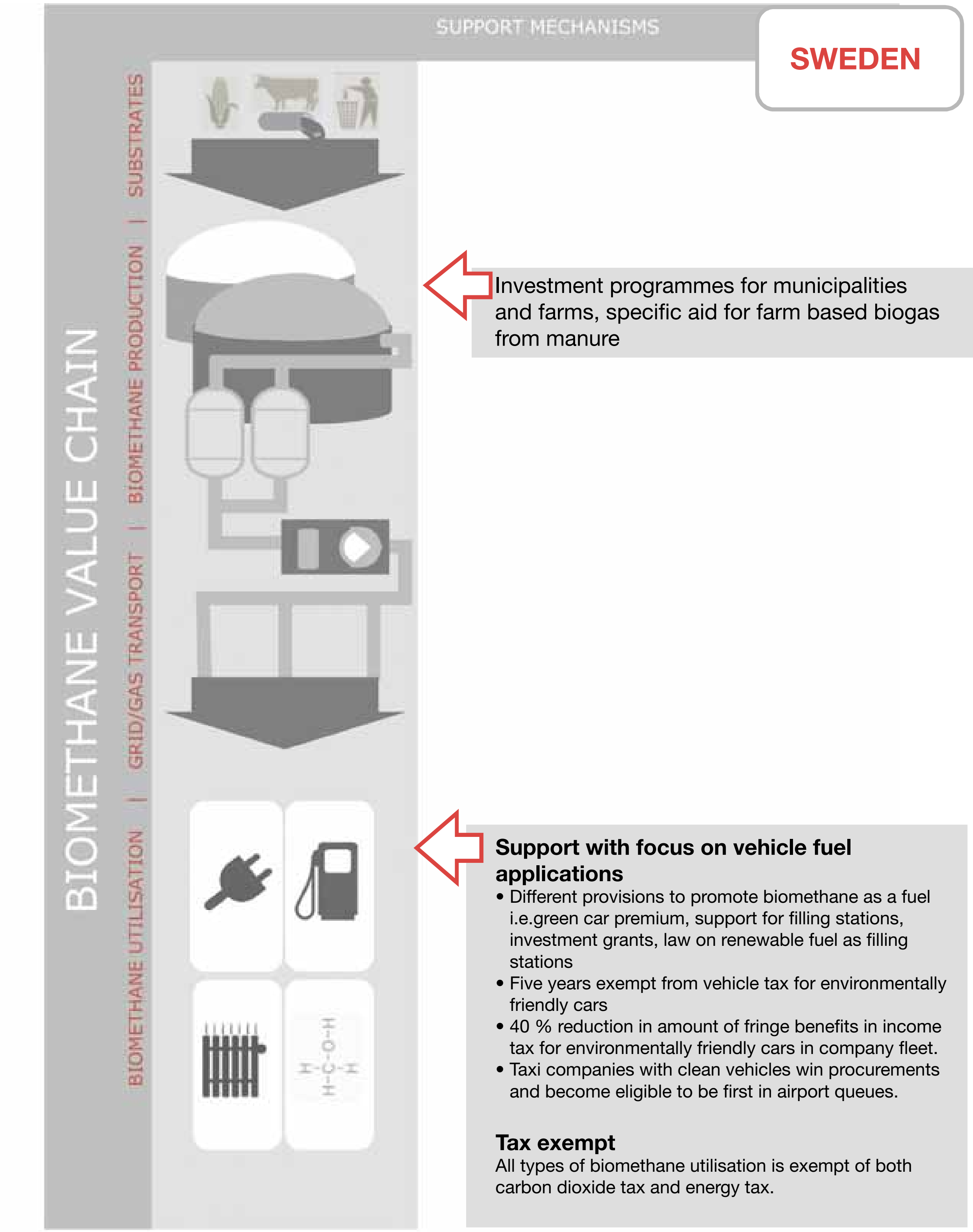
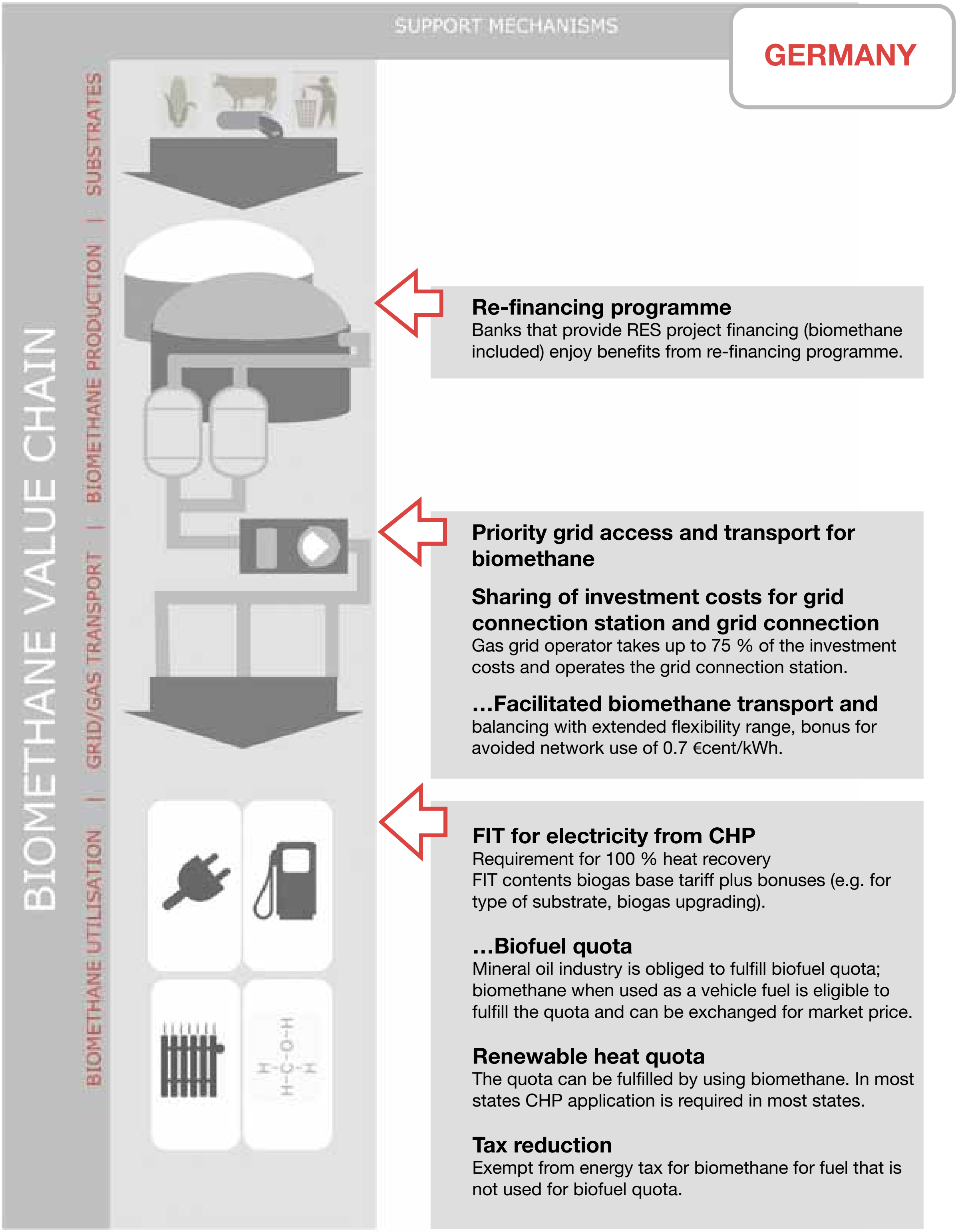


Figure 9: The German support measures shown along the biomethane value chain



Re-financing programme
Banks that provide RES project financing (biomethane included) enjoy benefits from re-financing programme.

Priority grid access and transport for biomethane

Sharing of investment costs for grid connection station and grid connection
Gas grid operator takes up to 75 % of the investment costs and operates the grid connection station.

...Facilitated biomethane transport and
balancing with extended flexibility range, bonus for avoided network use of 0.7 €cent/kWh.

FIT for electricity from CHP
Requirement for 100 % heat recovery
FIT contents biogas base tariff plus bonuses (e.g. for type of substrate, biogas upgrading).

...Biofuel quota
Mineral oil industry is obliged to fulfill biofuel quota; biomethane when used as a vehicle fuel is eligible to fulfill the quota and can be exchanged for market price.

Renewable heat quota
The quota can be fulfilled by using biomethane. In most states CHP application is required in most states.

Tax reduction
Exempt from energy tax for biomethane for fuel that is not used for biofuel quota.

Figure 10: The Dutch support measures shown along the biomethane value chain

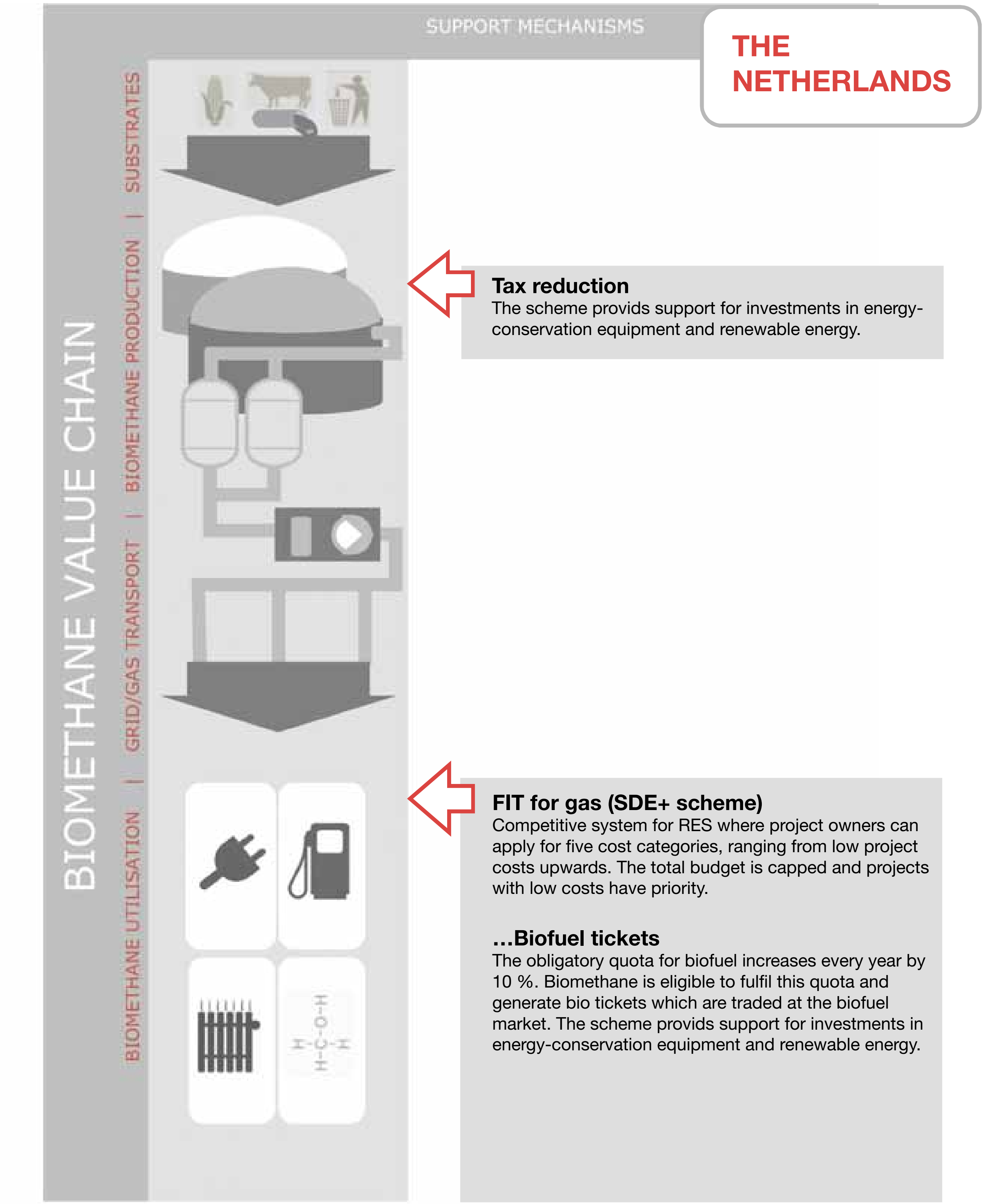


Figure 11: The UK support measures shown along the biomethane value chain

THE UNITED KINGDOM

Investment support to directly facilitate the construction of new AD plants (fund £10 million)

The AD Loan Fund provides loan for a minimum of £50,000 and a maximum of £1 million for a maximum term of five years.

Renewable Heat Incentive (RHI) provides FIT for gas. RHI is paid as a premium on top of the natural gas price for injection in natural gas grid. Premium guaranteed for 20 years, increasing with inflation.

...FIT for electricity from biogas or biomethane are paid on top of electricity price, grandfathered for 20 years.

...Levy Exemption Certificates (LECs) can be issued for CHP generation from biomethane can generate CHP.

...Renewable Transport Fuel Certificates whereby biomethane adhered to sustainability and Biomethane production from waste earns double certificates.

SUMMARY SECTION IV WHAT TO KEEP IN MIND

- Biomethane relies on support schemes since under the current market conditions biomethane can not compete against natural gas in sales price.

- Biomethane forerunner countries use divers support schemes for biomethane, most prominent
  - Feed-in tariffs for gas or electricity
  - Biofuel quota or certificate systems
  - Beneficial tax policy
  - Investment aid for biomethane production plant

- A pure quota system for green electricity does not pay biomethane’s distinguished features and the resulting advantages for the energy system.

- Biomethane projects have long development periods and therefore are reliant on long-term policies offering stable conditions and grandfathering.

- Apart from financial support additional measures addressing financing, licensing and legal aspects are essential for reducing project risks.

SECTION V IDEAS TO ASSESS YOUR NATIONAL BIOMETHANE STRATEGY

In this section a framework is described that shall help decision makers to assess their national biomethane market. The framework is a set of questionnaire which acts as a guide to identify weak issues within biomethane development strategy. Identification leads to aligning the policies to address the weak issues and promote the growth of biomethane industry.

Assessment of the system functions will lead to the emergence of a functional pattern that highlights the strength and weaknesses of current biomethane strategy. In order to facilitate this understanding, the system functions are characterised by a series of questions.

The set of system functions are:

How strong is the presence of actors in thebiomethane industry?

- Is the number of actors in the value chain sufficient?
- Is the trend of growth of the actors in the value chain inclining or levelling?
- Is lack of actor in certain category forming a barrier for the development of a Biomethane to Grid Technological Innovation System (BTG TIS)?

What is the status of knowledge development and diffusion?

- How broad is the scope of research activities? Does it generate sufficient technical, operational and market-oriented experience concerning the categories of the value chain?
- Is sufficient number of pilot trials conducted?
- How many or how frequently are conferences and workshops being conducted?
- What is the participation level of the actors within the conferences and workshops?

Does the biomethane industry hold growth potential?

- Is the substrate potential of biogas / biomethane generation studied within the countries context?
- Is such a study available to the actors in the value chain?
- Do national targets for biomethane generation exist?
- Is there a national target or recommendation to substitute a percentage of natural gas with biomethane?
- What are the governmental policies in support of biomethane generation and grid injection (environmental or energy security or waste management)?
- Are the regulations for gas quality requirements for grid injection clearly specified?
- Is the procedural requirement to establish a grid connection established and clearly documented?
- Existence of any national targets for vehicle fuel substitution with renewable fuel?
- Are there any restrictions on usage of substrate?
- Is there a national policy regulating the purchase of biogas in gas grids?

What is the status of the market formation?

- Does a niche market application for biomethane exist, or is it being promoted?
- Do financial incentives for biomethane generation and grid injection exist?
- How reliable and extensive is natural gas infrastructure?
- What is the role of natural gas in current energy mix?
- What is the demand pattern for heat and CHP applications?
- Can biomethane drive a proportion of heat and electricity demand?
- How extensive is the CNG / LNG filling station infrastructure?
- Do CNG / LNG vehicles form a growing segment or niche segment?

Is the technology accepted by adopters?

- Is permitting or legal procedure with regional offices causing a barrier?
- What are the activities of lobbying group or promoting organisations?
- Is there an issue of public acceptance against biogas plant construction? Is such an issue being addressed?
- Is more mobilisation of resources needed to promote the biomethane industry?
- Are there any indirect schemes, schemes promoting end use of biomethane e.g. tax benefits on vehicles, investment subsidies etc.?
- Is sufficient skilled human resource available?
- What is the status of government funding of projects in this sector?
- What is the status of access to financing options?

ABBREVIATIONS

AD	Anaerobic Digestion
AEBIOM	European Biomass Association
BioSNG	Bio Synthetic Natural Gas
BTG TIS	Biomethane to grid grid – Technological Innovation System
CH4	Methane
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO_2	Carbon dioxide
EC	European Committee
EU	European Union
FIT	Feed-in tariff
FLOX	Flameless oxidation
GHG	Green house gas
GWh	Gigawatt hour
IEA	International Energy Agency
IEE	Intelligent Energy for Europe
KTBL	Kuratorium für Technik und Bauwesen in der Landwirtschaft
LCA	Life Cycle Assessement
LEC	Levy Exempt Certificate
LFG	Landfill gas
LNG	Liquefied Natural Gas
Mtoe	Megatons oil equivanent
NREAP	National Renewable Action Plan
PJ	Petajoule
R&D	Research and Development
RED	Renewable Energy Directive
RES	Renewable energy sources
RHI	Renewable Heat Incentive
SDE+	Stimuleringsregeling Duurzame Energieproductie
SNG	Synthetic Natural Gas
TWh	Terawatt hour
UK	United Kingdom
WP	Work package

TABLE OF FIGURES

GREEN GAS GRIDS