AEBIOM

EUROPEAN BIOMASS ASSOCIATION

A Biogas Road Map for Europe

Content

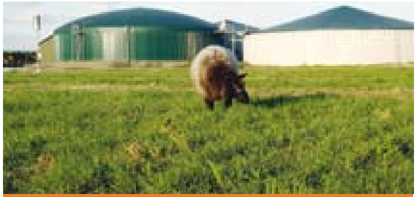
Why biogas?

Versatile energy carrier

Source: Göteborg ENergi AB

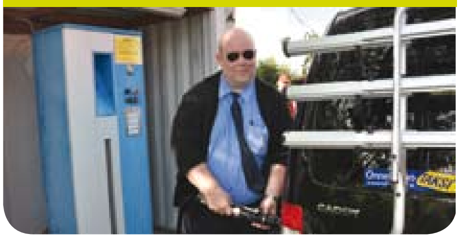
Great potential for use of various waste streams

Source: EnviTec



An appropriate technology to exploit energy potential from wet organic waste

Decreased dependency on natural gas imports to Europe



Source: Aebiom

Sustainable raw material for chemicals

Source: Nahtec

Alternative vehicle fuel

Source: Aebiom

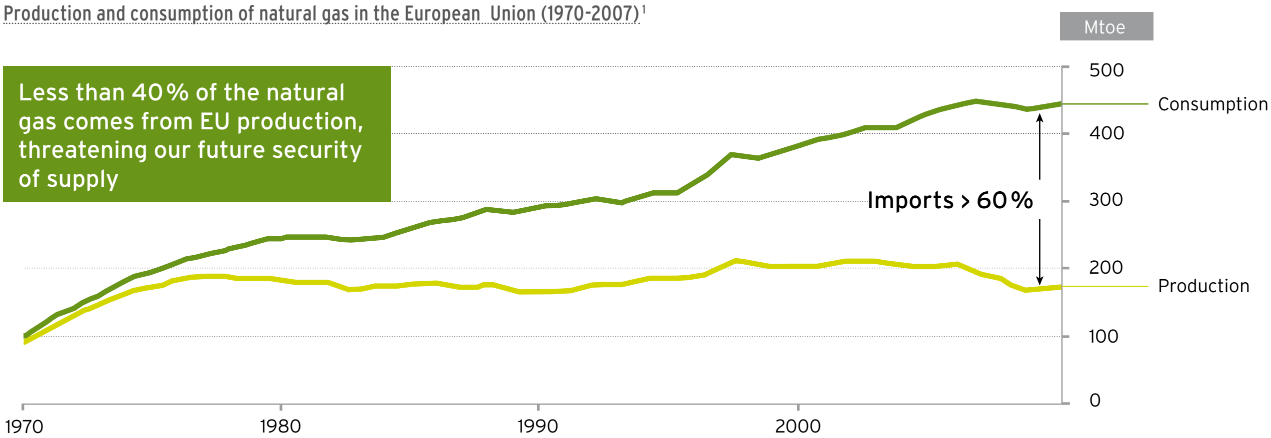
Source: Thöni

Injection into the natural gas grid

Production of electricity and heat

Production and consumption of natural gas in the European Union (1970-2007)[1]

Less than 40 % of the natural gas comes from EU production, threatening our future security of supply



[1] BP Statistical World Review 2009

1 Introduction

Biomass currently accounts for 2/3 of renewable energy in Europe and bioenergy will play a key role in achieving the ambitious targets approved by the renewable energy directive. 20% of the final energy consumption have to be provided by renewable sources by 2020. A great target compared to the share of 8,5% we have today. According to a study of the European Environmental Agency[2] the potential from agricultural is still largely unexploited and this sector is expected to have the highest growth rates in the coming years.

Within the bioenergy sector the increased use of biogas opens up new fields of applications where biomass has not played a major role so far. High tech process energy for industries, effective small scale power generation and transportation fuels. Biogas cogeneration plants have reached a parity of heat and electricity output (one kW electric for every kW thermal) through technological advances in recent years.

Europe's dependence on fossil fuel imports should further encourage the energy market and politicians to invest in a renewable alternative and create market incentives for biogas. Biogas is the versatile, sustainable energy carrier Europe is looking for.

Energy diversity brings stability. The use of manure and other organic waste should be a priority for biogas production. A large share of energy crops could be converted into biogas, but also used in different technologies, depending on needs in the particular country/region. "Such a diverse and wide ranging approach to power will bring greater economic security and stability to our environmental and energy future than our current one-size-fits-all approach" *(Logan, 2006)*.

The use of agricultural material such as manure, slurry and other animal and organic waste for biogas production has, in view of the high greenhouse gas emission savings potential, significant environmental advantages in terms of heat and power production and its use as biofuel. Biogas installations can, as a result of their decentralised nature and the regional investment structure, contribute significantly to sustainable development in rural areas and offer farmers new income opportunities.

(Directive 2009/28/ EC on the Promotion of the Use of Energy from Renewable Sources of the European Parliament and of the Council)

[2] EEA 2006 "How much bioenergy can Europe produce without harming the environment?"

2 Biogas basics

Various bacteria stains break down organic matter and generate a burnable gas.

Biogas as a secondary energy carrier can be produced out of many different kinds of organic materials and its options for utilisation can be equally versatile. Biogas can be used to generate electricity, heat and biofuels. Also the fermentation residues, called digestate, can be used, for example as a fertiliser.

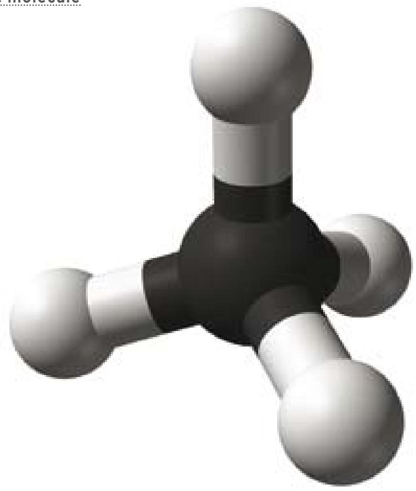
The term "biogas" includes all gas produced by anaerobic digestion of organic matter. In the absence of oxygen various types of bacteria break down the feedstock to form a secondary energy carrier, a burnable gas which mainly consists of methane and carbon dioxide (see table below).

Composition of biogas

Matter	%
Methane, CH_4	50 - 75
Carbon dioxide, CO_2	25 - 45
Water vapor, H_2O	1 - 2
Carbon monoxide, CO	0 - 0,3
Nitrogen, N_2	1 - 5
Hydrogen, H_2	0 - 3
Hydrogen sulfide, H_2S	0,1 - 0,5
Oxygen, O_2	traces

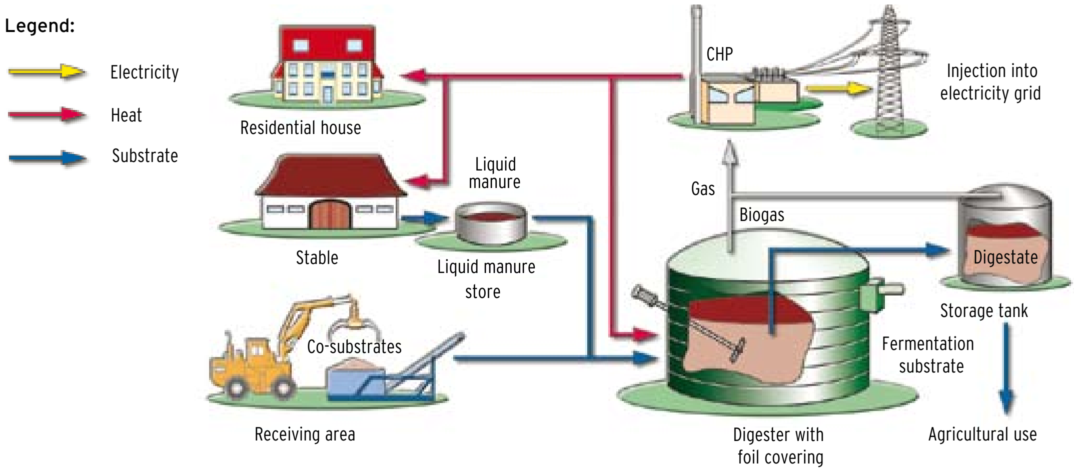
The speed of this process is mainly influenced by the composition of the feedstock. The digestion times differ from close to infinity (lignin degradation), several weeks (celluloses), a few days (hemicelluloses, fat, protein) to only a few hours (low molecular sugars, volatile fatty acids, alcohols). Therefore woody biomass is not suitable for biogas production due to its high lignin content.

Methane molecule



A similar kind of biogas can also be produced from wood or woody biomass in a thermal gasification process. Although the product is the same (methane with a renewable origin), it is often referred to as SNG (Synthetic Natural Gas). This technology has also great potential, but will not be discussed in this roadmap.

Example of agricultural biogas CHP [3]



[3] Biogas – an introduction, Fachagentur Nachwachsende Rohstoffe, 2009

3 Feedstock and environmental advantages

All organic material except wood can be used in digestion processes for biogas production, which can help solving various waste problems.

Historically, a simple gas collector installed over a pile of cattle or pig manure can be seen as the simplest and earliest version of a biogas plant. This principle was already known to the ancient Persians.

Today many different feedstocks are used for biogas production. A general distinction can be made between biomass from agriculture like by-products (manure) or dedicated crops for biogas and various waste streams (see table below).

High water content impacts the biogas yield per ton fresh mass as illustrated below. The figure shows that maize silage has the highest biogas yield of the described feedstock (waste like grease or molasses offer an even higher biogas output). Due to its high water content liquid manure has the lowest yield and therefore should be processed close to where it is produced in order to save transportation costs.

Biogas feedstocks

Feedstocks for biogas	
Agriculture	Waste streams
Manure	Landfill
Energy crops, catch crops	Sewage sludge
Landscape management	Municipal solid waste
Grass	Food waste
Other by-products	Other waste

ENVIRONMENTAL ASPECTS REGARDING THE VARIOUS RAW MATERIALS:

LANDFILL

In landfills covered organic waste forms biogas (landfill gas) which builds up and is able to create an explosive mixture if mixed with oxygen. This gas can be collected and used for energetic purposes. However, it is often just flared right away. This can be seen as a waste of resources as the utilisation of this side product could offer a second income for the operator of the landfill site and prevent unnecessary CO_2 and CH_4 emissions.

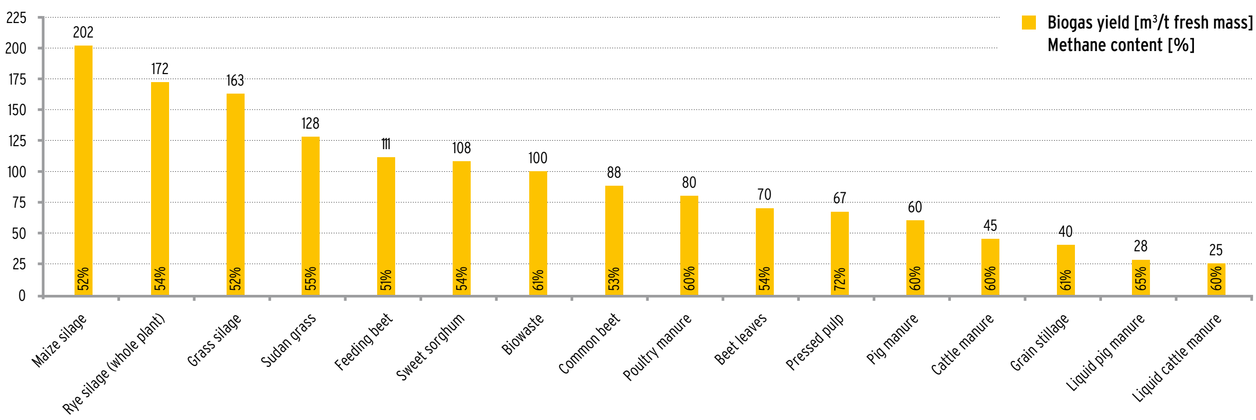
SEWAGE SLUDGE

Sewage sludge is a by-product of wastewater treatment. After the use as a feedstock for anaerobic digestion the remaining bio solid can either be used as soil conditioner or be disposed of in a landfill, according to its toxicity (especially concentration of heavy metals), or burned in a waste incinerator. Digestion also decreases the sewage sludge volume which reduces the disposing costs and problems.

MANURE

Manure is normally stored on farms for several months and then used as fertilizer. The manure already contains micro-organisms responsible for biodegradation and anaerobic digestion creating methane, ammonia and carbon dioxide which are released into the atmosphere during storage.

Biogas yields[4]



[4] Handreichung Biogas, Fachagentur Nachwachsende Rohstoffe, 2006; Energiepflanzen, KTBL, 2006

The right micro organisms are selected according to the feedstock and constantly monitored

Source: Shaumann Bioenergy

The use of manure for biogas production offers several benefits:

- **it avoids CH_4 emissions during the storage of the manure**
- **it reduces CO_2 emissions by replacing fossil fuels**
- **it offers an additional energy carrier that does not compete with other uses**
- **the substrate as final product after the biogas production is a valuable fertilizer**

Compared to fossil transportation fuels like petrol and diesel, biogas from liquid manure is extremely efficient in reducing CO_2 emissions overall (minus 180 %, well-to-wheel), because of low fossil inputs and because it avoids natural emission during storage. Thus manure as renewable energy feedstock provides an efficient source of nutrients for crop cultivation and reduce green house gas emissions at the same time.

ENERGY CROPS

Energy crops for biogas are dedicated crops planted on agricultural land to be used as feedstock for biogas production. Typical crops are maize or sweet sorghum.

The mix of maize and manure is the most commonly used feedstock for decentralized agricultural biogas plants. Energy crops maximize the yield (dry matter per hectare) and offer high conversion efficiencies (see figure on page 6).

OTHER AGRICULTURAL FEEDSTOCK

Second crops, or catch crops, planted after the harvest of the main crop, can also be used as biogas feedstock. This system allows two harvests per year on one piece of land. Green cuttings, material from landscape maintenance can also be used as biogas feedstock. This type of feedstock should be available within a small radius of the biogas plant, as the transportation of feedstock with high water content is costly, both from an economic and ecologic point of view.

WASTE STREAMS FOR BIOGAS

Different by-products of the food industry – breweries, sugar plants, fruit processing, slaughter houses, etc. but also food waste, used kitchen oil, the organic fraction of municipal solid waste (MSW) can be used as biogas feedstock and thus increase the energy offered from biomass.

Biogas is a good example to demonstrate the great complexity of bioenergy and the different policies that have to be considered.

- Agricultural policy
- Waste policy
- Energy policy

The absence of coherent and interconnected policies for the biogas sector can be a bureaucratic trap in some countries and therefore limit the development.

4 Versatility of biogas use

Biogas covers a variety of markets, including electricity, heat and vehicle fuels.

- Production of heat and/or steam
- Electricity production / combined heat and power production (CHP)
- Industrial energy source for heat, steam and/or electricity and cooling
- Injection into the gas grid
- Vehicle fuel
- Production of Chemicals
- Combustible for fuel cells

To get a good combustible gas, the "raw" biogas is cooled, drained, dried and cleaned from H_2S because of its corrosive effect. The obtained gas can be either applied directly or upgraded to natural gas standard – biomethane (98% methane).

BIOGAS:

- Production of electricity and heat (cogeneration)
- Production of electricity alone
- Production of heat alone

Source: Thöni in licence cooperation with Kompogas - Passau (Germany)

UPGRADED BIOGAS (BIOMETHANE): options as above for biogas and in addition

- Injection in the gas grid
- Transportation fuel
- High tech process energy
- Raw material for the chemical industry

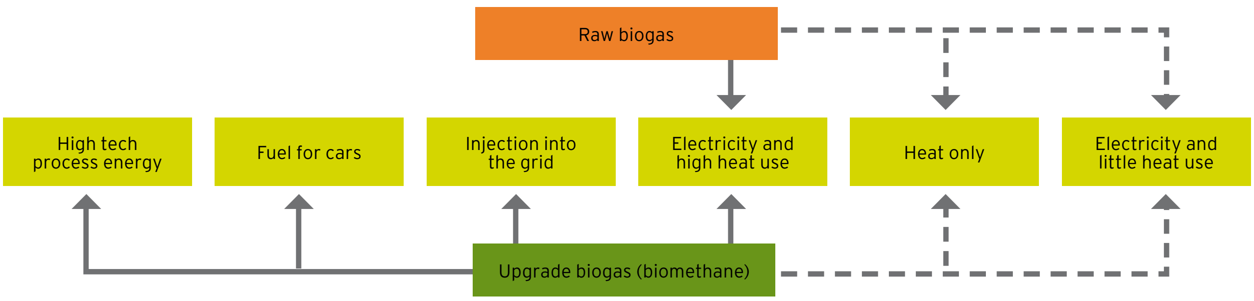
In the last year different concepts for the organisation of biogas plants emerged:

- Decentralised plants on farms etc.: production of electricity and use of heat (but using the heat is often not obvious)
- Decentralised plants in combination with biogas pipelines, transporting the biogas to a cogeneration unit situated in proximity to a district heating system. Therefore the cogeneration can make full use of the heat
- Decentralised plants delivering the raw gas in biogas pipelines to a upgrading station and injecting the biomethane in a gas grid. The biomethane can be used for cogeneration, transportation fuel or high tech process energy.
- Centralised plants in areas with high feedstock availability

The efficient use of biogas not only needs a biogas plant but also an integrated infrastructure such as biogas pipelines, upgrading stations and heat networks, in order to be able to use the heat of the cogeneration units.

As biogas/biomethane is an energy carrier with high exergy[5] it should not be used as source of heat alone but mainly for electricity production in combination with the use of the heat, as transportation fuels, for process heat in industry or as raw material for the chemical industry, or even for fuel cells. The upgrading to biomethane is especially interesting to further reduce Europe's dependency on imported fossil fuels for transportation and high temperature process energy which cannot be provided with other biomass fuels.

Efficient biogas pathways (bold arrows)



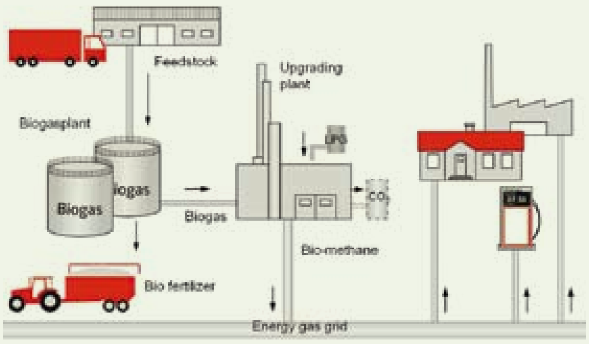
[5] Exergy describes the "value" of different types of energy. High-value energy such as electricity is versatile and can easily be converted into other energy forms, whereas energy with a very limited convertibility potential, such as heat close to ambient air temperature, is low-value energy.

Biogas upgrading and injection into the gas grid

Introducing biomethane into the natural gas grids widens up the opportunity to utilize biogas in several ways depending on society needs. An efficient way of integrating the biogas into the entire European energy sectors are by upgrading the biogas to natural gas quality and injecting it into the natural gas grid.

This option will be increased due to liberalisation of the energy markets in all European countries, but it requires reaching natural gas quality by advanced treatment technologies. It offers a wide range of gas consumers, from house units for heating or fuel cells to decentralised CHP plants, to industrial costumers and to larger energy consumers as power plants. The coming decade will boost this development, when the installed capacities are increasing rapidly in numbers exemplified by the German biogas growth rate in this decade. The utilisation cannot be centred nearby the biogas production units in the farming areas, the biogas has to be upgraded and transported to the large energy consumption areas where the population concentration is situated.

The current bottleneck in this area is the cost of biogas upgrading (e.g. via pressure swing adsorption; amine or water scrubber or cryogenic separation treatment of the biogas). It is obvious that the treatment price will be reduced in coming years due to the increasing numbers of upgrading facilities installed and also by the economically downscaling of the upgrading facilities fitting to the modular biogas plants existing in countries like Germany and Austria.



Source: E-ON Bioerdgas

Biomethane as vehicle fuel

Advantages	Challenges
• The existing natural gas filling stations can be used for biomethane • Energetic efficiency relatively high • Injection into the natural gas grid after upgrading possible • High fuel equivalent output per hectare. The use of catch crops can further increase the output and decrease the competition for arable land • More and more gas-vehicles enter the market. Improved cruising range and comfort. • Favourable combustion properties (e.g. the emission of nitrogen oxides and reactive hydrocarbon can be reduced up to 80% compared to petrol and diesel)	• Costly cleaning and upgrading of biogas • Legislative framework (e.g. subsidies for natural gas in some countries) • Initial cooperation with natural gas needed (in order to increase the market share of vehicles running on gas) • Methane slip (the upgrading technology that removes unwanted CO_2 sets free methane as well; latest technologies reduce the slip to less than 0,1%) • High conversion costs of existing vehicles • Low number of gas vehicles in Europe • Gaseous fuel reduces the cruising range compared to liquid fuels • Gas storage

Source: Göteborg Energi AB

5 Economics of biogas

The initially high investment costs have to be spread over several years.

The size of a biogas plant has to be adapted to the individual situation, especially to the availability of input material in close proximity to the facility. Units of agricultural biogas plants normally reach sizes of 100 to 500 kWel (gas production around 28 to 140 m^3/h). Larger plants are economic if the input material is readily available in close range, for example cattle breeding, fields of dedicated biogas crops or waste water treatment facilities. The economy of scale especially plays an important role for upgrading the raw biogas to natural gas standards.

Due to feed-in regulations (Germany) many equipment suppliers have focused on optimizing 500 kWel units and therefore big biogas plants sometimes consist of several standardised units.

INVESTMENT EXAMPLES FOR BIOGAS PLANT AND CHP

A 500 kWel biogas plant on a farm costs around two million Euro (including CHP; without the costs for the distribution of the heat)[6]. Table below gives an overview of typical investment costs for biogas engines and biogas plants for different sizes in Germany and Italy. The specific costs per kW electric are significantly lower for larger plants.

INVESTMENT EXAMPLE FOR BIOGAS UPGRADING, GRID INJECTION AND FUEL STATION

If the biogas is intended to be used as vehicle fuel, an upgrading facility and biomethane filling stations have to be taken into account in addition to the biogas plant. If more plants cooperate, longer grid networks for transporting the raw biogas are necessary.

The investment costs for units with 1 mio Nm^3/year (biomethane) ranges between 3,4 M€ for stand alone plants and 3,9 to 4,7 M€ for gas grid connected plants, depending on the length of the gas grid to the upgrading station and/or to the biomethane filling stations. The economic sizes of biomethane plant ranges between 1 and 2 millions Nm^3 biomethane per year. In certain places bigger plants could be more economical. The higher transport cost for the feeding material and the fermentation residues compensate the lower specific investment costs.

The rapid development of the biogas sector was mainly driven by favourable feed-in tariffs for electricity. Table 5 shows examples from selected European countries.

Investment costs per kWe, example from Germany[7] and Italy

	Germany		Italy	
	kWe	€/kWe	kWe	€/kWe
CHP (gas engine)	150	900		
CHP (gas engine)	250	740		
CHP (gas engine)	500	560		
Biogas plant	up to 100	5,000 - 3,000	200	4900
Biogas plant	100 to 350	3,000 - 2,500	500	3800
Biogas plant	above 350	< 2,500	1000	3200

Investment costs for biogas plants and upgrading for use as vehicle fuel (M€ per 1 million Nm^3/year per unit - equal to a plant with 500 kWe capacity)[8]

	Stand alone plant	Cooperation of 3 biogas plants 5 km gas grid network for each plant	Cooperation of 6 biogas plants 10 km gas grid network for each plant
Biogas plant	2,0	2,0	2,0
Gasgrid network	0,2	1,0	2,0
Upgrading plant	0,7	0,5	0,4
Biomethane (CNG) filling station	0,5	0,4	0,3
Total investment costs M€ for a 1 Mio Nm^3/year unit	3,4	3,9	4,7

[6] Austrian Biomass Association
[7] Handreichung Biogas, FNR, 2006; Federal Research Institut for Rural Areas, Forestry and Fisheries (vTI)
[8] Calculation by Josef Plank, Austrian Biomass Association

Biogas park in Anklam, Germany

Examples of feed-in tariffs in Europe (c€/kWh)[9]

Country	Austria	Germany	France	Italy	Spain	Netherlands
Sewage sludge	5,93	6.16 - 7.11*	7,5	18	10,75 - 15,89	7,9
Landfill	4,03	6.16 - 9*	7,5	18	10,75 - 15,89	7,9
Agriculture 100 KW	16,93	11,67 - 30,67**	9*	22 - 28*	10,75 - 15,89	7,9
Agriculture 500 KW	13,98	9,46 - 25,46**		22 - 28*	10,75 - 15,89	7,9
Agriculture 1000 KW	12,38	8,51 - 17,51**	7,5*	22 - 28*	10,75 - 15,89	7,9
Condition	Plant efficiency of at least 60% (CHP).	Electricity generated from biogas withdrawn from a gas network is eligible only if it is from CHP generation	Plant size smaller than 12 MWe Higher tariffs for overseas territory	Plants smaller than 1 MWe can choose between the guaranteed feed-in tariff and the green certificate system	Main fuel is biofuel or biogas from anaerobic digestion of agricultural and livestock wastes, biodegradable industrial waste and sewage sludge or landfill gas	If the subsidies applied for exceed the funds available, subsidies are granted in the order of the date of submission of the application
Guaranteed years	10 (+2)*	20	15	15	15	12
	*reduced feed-in-tariff for the 11th and 12th year	*technology bonus of 1-2 € ct/kWh possible **depending on additional bonuses like co-digestion, use of manure, energy crops, efficiency, air quality, etc.	*plus additional bonuses	*depending on source of energy; maximum tariff at the moment is 22c€, 28 are planned		

[9] Source: http://res-legal.de (links to the according national laws can be found there); SenterNovem

6 Current status of biogas in Europe

Many European countries have established favourable conditions for electricity production from biogas (see feed-in-tariffs in chapter 5 Economics of biogas). Germany has a leading role in Europe with almost 4000 biogas plants, most of them on farms for cogeneration. New legislation often requires the use of heat as well in order to reach a better efficiency.

While the biogas sector grows impressively every year, it hasn't received the same attention as for example liquid biofuels for transportation. The majority of people are not aware that natural gas powered vehicles have been available for a long time and that biomethane could play an important role in the transportation sector. So far only Sweden has established a market for biomethane-driven cars. Due to its relatively low prices for electricity, Sweden has traditionally used biogas for heat production (today around 50% of biogas) and focused less on electricity (8%). About 25% of the produced biogas is upgraded and used as vehicle fuel (the rest is flared or used for other applications). The upgraded biogas is injected into the existing natural gas grid in 7 sites with an injection capacity of 220 GWh (replacing 2% of the natural gas in the system). The injection capacity is planned to increase to 1.6 TWh (10-15% renewable in the natural gas system) within 5 years.

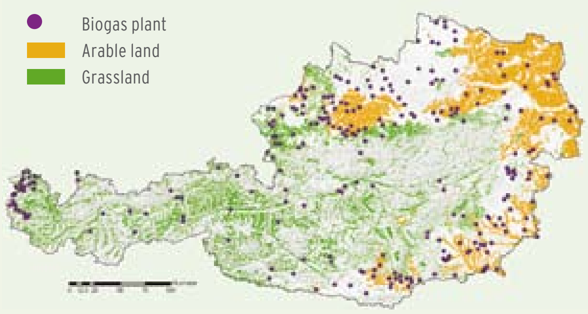
Austria: Biogas on farms

294 biogas plants were producing green electricity in Austria in 2008. The average size of 260 kWe installed power shows the decentralized structure of biogas. The feedstock is available in close proximity to the plants (manure, maize, grass) and transportation costs are kept to a minimum.

The produced biogas is combusted in a gas engine which generates electricity and heat.

Only plants also using the heat (excluding the heat used for the fermentation process) are permitted to feed-in electricity into the grid with favourable conditions, leading to better overall efficiency.

Distribution of Austrian biogas plants according to land use



Source: Raumberg/Gumpenstein

Germany: Industrial scale

ELECTRICITY/HEAT

With 20 MW electric power fed into the grid the new biogas park in Pekun, north-eastern Germany, is currently the world's largest biogas installation. The park consists of 15 hectares and 40 standardised modules with a capacity of 500 kWhel each and it can be enlarged if necessary. 84.000 t of manure and maize from 6000 hectares in immediate vicinity will be processed every year.

For a plant of this size, the harvesting, feedstock delivery and storage have to be optimized in order to guarantee a steady supply of feedstock.

BIOMETHANE INJECTION

The upgrading of biogas to natural gas standard is more economical in larger installations – the bigger the better.

Example: Schwandorf plant (e-on Bioerdgas)
Input material: 80.000 t/year of crops
Production of raw biogas: 2.000 m^3/h
Biomethane production: 90 Mio. kWh/year
Gas quality: 11,1 kWh/m^3 (H-Gas)
Investment: M€ 18

A new development is the cooperation of small, decentralised biogas plants that send their raw biogas via pipes to a central upgrading facility, thus significantly reducing feedstock transportation and upgrading costs.

Sweden: Biomethane as vehicle fuel

The market for biogas as vehicle fuels has been growing rapidly in recent years in Sweden. 2008 there were 17.000 vehicles driving on upgraded biogas/natural gas. There are currently 38 upgrading plants and in 2008 about 25% of Sweden's biogas production was used as vehicle fuel and 60 % of the total gas volume sold as vehicle fuel was biogas and only 40 % consisted of natural gas.[10]

The awareness of the advantages of biogas is increasing, such that the demand for biogas as a vehicle fuel is greater than the supply in some regions, such as the Stockholm area. New technologies for the purification and transport of biogas have been developed and the number of filling stations for biogas in Sweden amounts to more then 120 and the number are continuously increasing.

[10] Swedish Gas Association

As can be seen from the table on page 13, the biogas sources vary distinctively among the members of the European Union. Germany, Austria and Denmark produce the largest share of their biogas in agricultural plants using energy crops, agricultural by products and manure, whereas the UK, Italy, France and Spain predominantly use landfill gas. This source might not increase further in the medium and longer term as the EU directive on landfill waste foresees a gradual reduction of the land filling of biodegradable municipal waste (by 2016 to 35 % of the level in 1995).

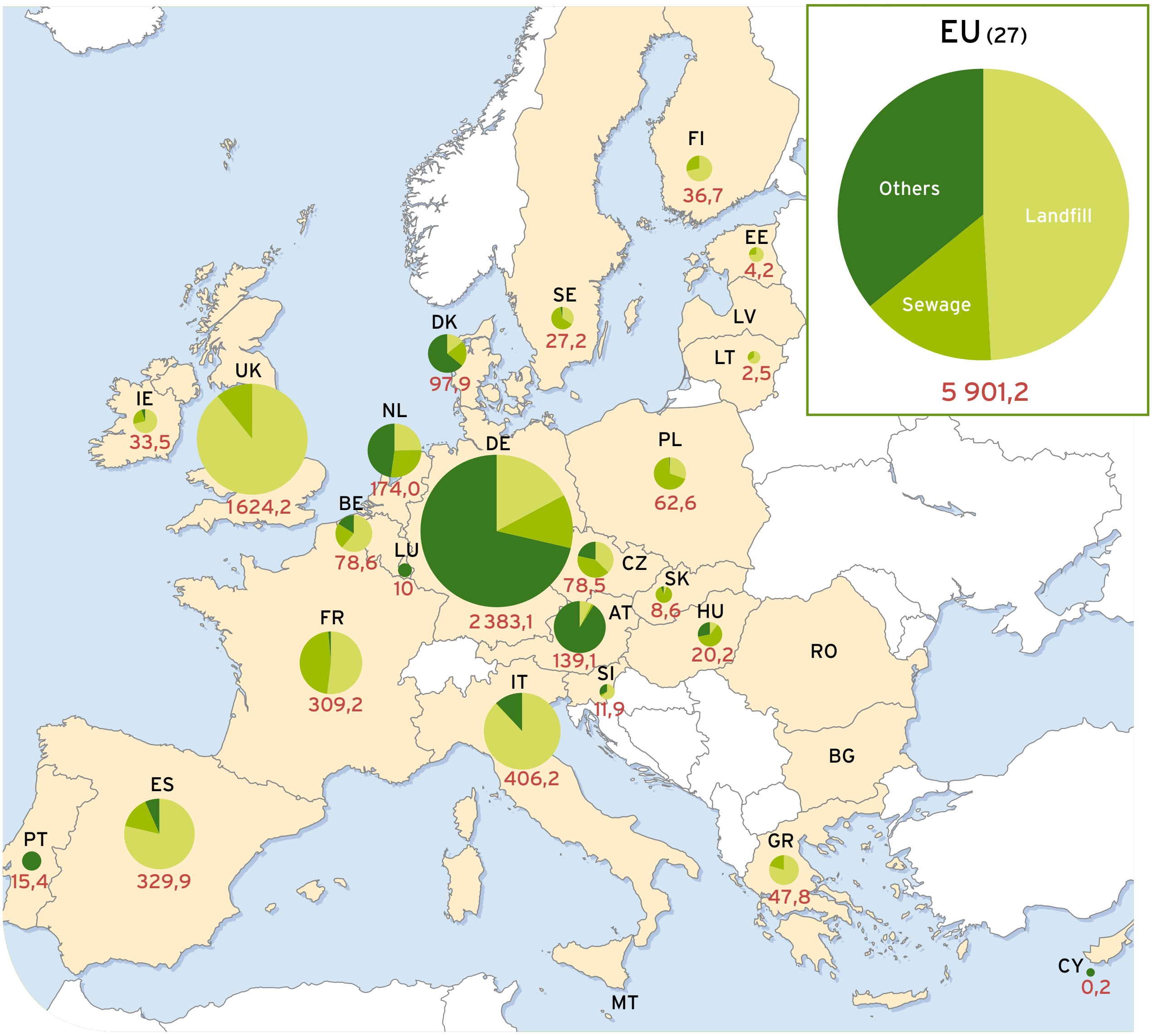

Source: Nahtec

Primary biogas production in the European Union 2006 and 2007 in ktoe

	2006				2007 (Estimate)			
Countries	Landfill gas	Sewage sludge gas	Others biogas (agriculture)	Total	Landfill gas	Sewage sludge gas	Others biogas (agriculture)	Total
Germany	383,2	270,2	1.011,7	**1.665,3**	416,4	270,2	1.696,5	**2.383,1**
UK	1.318,5	180,0	-	**1.498,5**	1.433,1	191,1	-	**1.624,2**
Italy	337,4	1,0	44,8	**383,2**	357,7	1,0	47,5	**406,2**
Spain	251,3	48,6	19,8	**319,7**	259,6	49,1	21,3	**329,9**
France	150,5	144,0	3,6	**298,1**	161,3	144,2	3,7	**309,2**
Netherlands	46,0	48,0	47,1	**141,1**	43,2	48,0	82,8	**174,0**
Austria	11,2	3,5	103,4	**118,1**	10,7	2,0	126,4	**139,1**
Denmark	14,3	21,0	57,6	**92,9**	14,3	21,0	62,6	**97,9**
Belgium	51,0	17,6	9,1	**77,6**	48,1	18,0	12,5	**78,6**
Czech Rep.	24,5	31,1	7,8	**63,4**	29,4	32,1	17,0	**78,5**
Poland	18,9	43,1	0,5	**62,4**	19,1	43,0	0,5	**62,6**
Greece	21,2	8,6	-	**29,8**	38,0	9,8	-	**47,8**
Finland	26,1	10,4	-	**36,4**	26,4	10,3	-	**36,7**
Ireland	25,4	5,1	1,8	**32,3**	23,9	7,9	1,7	**33,5**
Sweden	9,2	17,1	0,8	**27,2**	9,2	17,1	0,8	**27,2**
Hungary	1,1	8,0	3,1	**12,2**	2,1	12,4	5,7	**20,2**
Portugal	-	-	9,2	**9,2**	-	-	15,4	**15,4**
Slovenia	6,9	1,1	0,4	**8,4**	7,6	0,6	3,8	**11,9**
Luxembourg	-	-	9,2	**9,2**	-	-	10,0	**10,0**
Slovakia	0,4	6,9	0,4	**7,6**	0,5	7,6	0,5	**8,6**
Estonia	3,1	1,1	-	**4,2**	3,1	1,1	-	**4,2**
Lithuania	-	1,5	0,5	**2,0**	1,6	0,8	-	**2,5**
Cyprus	-	-	0,0	**0,0**	-	-	0,2	**0,2**
EU 25	2.007,3	867,8	1.330,8	**4.898,9**	2.905,2	887,2	2.108,0	**5.901,2**

Source: EurObserv'ER 2008

Primary energy production of biogas in Europe in 2007 (source: EurObserv'ER)



In the European Union both the primary production of biogas and the gross electricity production from biogas increased by almost 18 % between 2006 and 2007. The greatest share of this growth was achieved in Germany and German biogas companies expanded their business in 2008 as well, despite rising costs for substrate.

Small scale electricity production with biogas is very effective concerning the ratio of the co-generated heat and power. Technological advances in recent years allow parity in the energy output - 1 kW electric for every kW thermal.

Table on page 15 shows the influence of specific requirements for biogas plants in order to be eligible for feed-in tariffs. For example, at first the feed-in law in Austria had no efficiency requirement which led to many electricity-only plants, because of high prices for electricity but low ones for heat. So plant operators had no economic incentive to care for the heat at all. This was changed afterwards, but finding a suitable heat user is often difficult in rural areas.

EU gross electricity production from biogas 2006/2007 in GWh

	2006			2007 (Estimate)		
	From Electricity plants	From CHP plants	**Total electricity**	Electricity	CHP	**Total electricity**
Germany	-	7.446,0	**7.446,0**	-	9.520,0	**9.520,0**
UK	4.424,0	463,0	**4.887,0**	4.795,6	503,4	**5.299,0**
Italy	1.061,9	241,8	**1.303,7**	1.125,6	256,3	**1.381,9**
Spain	610,3	56,0	**666,3**	631,1	56,0	**687,1**
France	487,3	35,4	**522,7**	505,3	35,7	**541,0**
Netherlands	146,1	215,2	**361,3**	274,2	223,2	**497,4**
Austria	424,1	23,0	**447,1**	469,8	22,8	**492,6**
Denmark	1,6	278,4	**280,1**	1,6	293,3	**295,0**
Belgium	158,3	120,6	**278,9**	152,0	127,4	**279,4**
Czech	63,1	112,8	**175,8**	80,3	142,6	**222,9**
Greece	69,3	38,5	**107,9**	91,3	84,0	**175,3**
Poland	0,0	160,1	**160,1**	0,0	160,1	**160,1**
Ireland	108,4	13,6	**122,0**	101,9	16,9	**118,8**
Portugal	25,2	7,4	**32,6**	58,0	7,3	**65,4**
Slovenia	8,6	26,1	**34,7**	8,9	39,2	**48,2**
Sweden	-	46,3	**99,0**	-	46,3	**99,0**
Luxembourg	-	32,6	**32,6**	-	36,6	**36,6**
Finland	0,9	21,4	**22,3**	0,9	21,4	**22,3**
Hungary	-	22,1	**22,1**	-	22,1	**22,1**
Estonia	1,1	13,0	**14,1**	1,1	13,0	**14,1**
Lithuania	-	5,4	**5,4**	-	6,3	**6,3**
Slovakia	-	4,0	**4,0**	-	4,0	**4,0**
Cyprus	0,0	0,2	**0,2**	-	1,4	**1,4**
EU 25	7.590,3	9382,9	**16.973,2**	8.297,7	11.639,5	**19.937,9**

Source: EurObserv'ER 2008; Swedish Biogas Association

7 Biogas potential

166 Mtoe is the theoretic potential of primary energy production from biogas in 2020, according to a German study.[11] Compared to the present use of 5,9 Mtoe this is a theoretical figure that will not be reached in the next decades.

1 TWh primary energy from biogas per 1 Million people in Europe.
This potential of 500 TWh (43 Mtoe) for the 500 million people living in the EU27 is derived from agricultural byproducts and waste alone (organic waste from households and industries, sewage sludge, manure, catch crops, landscape cleaning). These waste streams strongly correlate with the size of the population and studies from Austria, Sweden, Germany and the United Kingdom all arrive at a magnitude of approximately 1 TWh per 1 million people, which if used for example as a vehicle fuel could more than cover the 10% target for the share of renewables in the transportation sector for 2020.

20% yearly growth
In 2007 the production in Europe reached 5,9 Mtoe, an increase of over 20% compared to 2006.

Based on different studies and the experience of member countries the realistic potential for biogas until 2020 can be calculated for the EU 27 as follows:
AEBIOM assumes that 25Mio ha agricultural land (arable land and green land) can be used for energy in 2020 without harming the food production and the national environment. This land will be needed to produce raw materials for the first generation fuels, for heat, power and second generation fuels and for biogas crops. In the AEBIOM scenario

- 15 Mio ha land is used for first generation biofuels (wheat, rape, sugarbeet, etc.)
- 5 Mio ha for short rotation forests, miscanthus and other solid biomass production and
- 5 Mio ha for biogas crops.

On this basis the potential for biogas in 2020 is estimated as follows:

Biogas potential in 2020

		2020		
Origin (according to template for National Renewable Energy Action Plans)	**Potential Billion m³ Biomethane**	**Assumed percentage of use until 2020**	**Primary energy Billion m³ Biomethane**	**Primary energy Mtoe**
Agriculture	58,9	62 %	36,4	31,3
Agricultural crops directly provided for energy generation (5 % of arable land; calculation in annex)	27,2	100 %	27,2	23,4
Agricultural by-products / processed residues	31,7	28 %	9,2	7,9
• straw	10,0	5 %	0,5	0,4
• manure	20,5	35 %	7,2	6,0
• rest (landscape management)	1,2	40 %	0,5	0,4
Waste	19,0	50 %	9,5	8,2
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	3,4
Biodegradable fraction of industrial waste (including paper, cardboard, pallets)	3,0	50 %	1,5	1,3
Sewage sludge	6,0	66 %	4,0	3,4
Total	77,9	59 %	45,9	39,5

Source: AEBIOM

[11] IE Liepzig, 2007

The realistic potential of methane derived from animal manure and energy crops and waste lies in the range of 40 Mtoe in 2020 as compared to a production of 5,9 Mtoe in 2007. The use of catch crops for biogas production was not considered in the calculation and offers an additional potential.

In 2020 biogas could deliver more than a third of Europe's natural gas production or around 10 % of the European consumption (433,7 Mtoe in 2007, see front page)

Within the overall potential of biomass for energy in Europe biogas could reach 15 % to 25 % of total bioenergy, as compared to 7 % in 2007. The biomass potential for energy as a whole is much bigger than its present use, but this potential has to be developed by activities on local, regional, national and international level (see recommendations in chapter 8 and 9).

Looking at the overall contribution to bioenergy, forest based biomass is currently the main contributor, but the agricultural sector has a greatest potential and could be already the most important energy supplier by 2020. Biogas will especially profit from this development as it offers effective alternatives for the fast growing sectors of bioelectricity and vehicle fuels.

Outlook for bioenergy sources in Mtoe

Source	2004		2020*	
Forest based biomass	61,5	(85 %)	75	(34 %)
Agriculture based biomass	3,5	(5 %)	97	(44 %)
Waste	7,3	(10 %)	23	(11 %)
Imports	-		25	(11 %)
Total	72,3		220	

* AEBIOM estimates

Maize is already established as an energy crop for biogas production and in the future other energy crops will be used in order to optimize the yield per hectare agricultural land. Together with manure from animal production (mainly cattle and pig farms) decentralized co-digestion plants have the greatest potential for biogas production but also the use of sludge and food industry waste and household waste offers big opportunities.

At the moment about 109 million hectares arable land exists in Europe. If 5 % of this land is used for energy crops a yield of 15 tons of solid dry matter per hectare could provide 23,4 Mtoe of energy if converted into biogas (see Table 10).

In the coming 10-20 years an increasing utilisation of crops for energy and industrial purposes is expected to be seen. Scenarios of 10-20 or 30 % of the arable land shifting from food and feed towards energy farming will gradually occur. Large European countries, with significant fertile agricultural area of cropland, might play a major role in bioenergy production; examples can be Ukraine and France. An average total crop yield of around 20 t/ha is considered feasible in the near future. Maize, sugar beet and various other crops will increase in importance European wide. Crop paradigm changes are in progress.

Table 10 shows the amount of manure accumulating in the EU-27 every year. The over 1.500 million tons of manure in the EU 27 is the largest single source of biomass from the food/feed industry and equals a theoretical biogas output of 17,3 Mtoe. At the moment only Germany has already established a high use of manure in biogas production (around 20 %). A 35 % use of manure for biogas production in 2020 would equal to 6,04 Mtoe (or 7,2 billion m^3 biomethane).

A case example: Calculation of biogas potential from energy crops and manure for 2020 (FAOSTAT 2009, AEBIOM calculations)

Country	Arable land	Biogas potential	Total manure from crops*	Biogas potential from manure**	Total biogas potential
		5 % land; yield 15t/ha	Cattle and pigs	35 % manure used	5 % land & 35 % manure
UNIT	1000 ha	Mtoe	Mt	Mtoe	Mtoe
Austria	1382	0,30	34,0	0,13	0,43
Belgium	840	0,18	48,6	0,19	0,37
Bulgaria	3086	0,66	10,7	0,04	0,71
Cyprus	115	0,02	1,7	0,01	0,03
Czech Republic	3032	0,65	24,6	0,10	0,75
Denmark	2306	0,50	47,2	0,18	0,68
Estonia	598	0,13	4,1	0,02	0,14
Finland	2253	0,49	15,7	0,06	0,55
France	18433	3,97	299,1	1,16	5,13
Germany	11877	2,56	225,8	0,88	3,43
Greece	2548	0,55	10,5	0,04	0,59
Hungary	4592	0,99	17,2	0,07	1,06
Ireland	1060	0,23	97,2	0,38	0,61
Italy	7171	1,55	102,9	0,40	1,94
Latvia	1188	0,26	6,1	0,02	0,28
Lithuania	1835	0,40	13,9	0,05	0,45
Luxembourg	61	0,01	2,9	0,01	0,02
Malta	8	0,00	0,4	0,00	0,00
Netherlands	1059	0,23	73,7	0,29	0,51
Poland	12502	2,69	113,4	0,44	3,13
Portugal	1083	0,23	24,0	0,09	0,33
Romania	8553	1,84	53,8	0,21	2,05
Slovakia	1377	0,30	9,2	0,04	0,33
Slovenia	177	0,04	7,4	0,03	0,07
Spain	12700	2,74	138,6	0,54	3,27
Sweden	2643	0,57	25,0	0,10	0,67
United Kingdom	6085	1,31	149,3	0,58	1,89
EU 27	**108564**	**23,39**	**1556,9**	**6,04**	**29,43**

* see calculation example in the annex
Approximately 5 Mio ha land in Europe

** Assumed methane content in biogas 65 %;
assumed yield of 20 m³ biogas per ton of manure

The fermentation of manure alone does not result in high biogas yield, but its high buffer capacity and content of diverse elements has a positive impact on the anaerobic digestion process stability. Higher methane yield can be achieved through co-digestion of manure with other substrates, such as energy crops and agricultural by-products. The theoretical potential of methane achieved from 35 % of all European animal manure and energy crops (5 % of the arable land in EU-27) produced through anaerobic digestion process could supply 29,4 Mtoe which equals almost a fifth of Europe's natural gas production or 6,7 % of the consumption in 2007 (433,7 Mtoe, BP Statistical Review of World Energy June 2008).

As a rule of thumb it can be said, that 1/5 of the biogas could come from manure, 1/5 from different by-products and waste streams and 3/5 from energy crops. Until 2020 biogas could deliver 2-3 % of the total primary energy, predominantly as electricity, vehicle fuel and as heat.

8 Biogas within the nREAP

By June 2010 the member states of the European Union have to develop their renewable energy action plans (REAP). These plans will have to present the detailed targets for final heat, electricity and transport, the share of RES in each of these markets, the measures to reach the targets and to mobilize more energy from biomass. It is of outstanding importance that the member states integrate energy from biogas in an appropriate way in these plans. This publication will support the member states in this task.

It is recommended that until 2020 at least 35 % of the manure, 40 % of the available organic waste suited for biogas production and the sludge of water treatment is used to produce biogas. If this raw material is supplemented by energy crops, cultivated on 5 % of the arable land, biogas could contribute in average 2 to 3 % of the electricity production, 1 – 2 % of the transportation fuels and 1 % to the heat supply. Each member state shall elaborate a biogas concept within the national action plans which defines in detail the contribution of energy from biogas to the heat, electricity and fuel market.

In a second step the measures will have to be defined, that will be taken to reach these targets. Important measures in this context are:

- **The integration of the waste policy of the communities in the energy concept**
- **The financial support for the needed infrastructure such as biogas pipelines, upgrading stations, biogas plants, heat networks to use the heat from cogeneration plants**
- **Various incentives to increase the number of gas driven vehicles**
- **Feed in tariffs especially conceived to use manure and green cuttings or catch crops for biogas production**
- **Green certificate schemes in favour of biogas (for countries without feed-in tariffs)**
- **Fair grid access for biomethane without fees for using the grid**

Source: Thöni NATURGAS plant in Maccastorna (Italy)

9 Policy recommendations

EU level

REGULATE/ENSURE AN EASY ACCESS TO THE ELECTRICITY AND GAS GRIDS (PRIORITY FOR BIOGAS, GUARANTEE, NON DISCRIMINATION, FREE ACCESS).
This proposal has been included into the renewables directive and according laws have already been introduced in several member states (e.g. GNZV in Germany), where it has proven to be a stimulator for market development.

EU SHOULD URGE MEMBER STATES TO ENSURE THE LONG LASTING INVESTMENT SECURITY IN NREAP. THE REGULATION SHOULD GUARANTEE THE LONG TERM PRICE.
Biogas is particularly capital intensive and needs long term financing possibilities and security of income. The German feed in system offering fixed and high prices up to 20 years has proved to be very successful.

SPECIFIC DIRECTIVES LIKE WASTE FRAMEWORK DIRECTIVE AND WATER FRAMEWORK DIRECTIVE AND NITRATES DIRECTIVE SHOULD BE REVIEWED TO TAKE THE SPECIFIC NEEDS OF BIOGAS INTO ACCOUNT.
Biogas project developers have to face many regulations related to waste management, soil protection, prevention of water table pollution by nitrogen, etc. The excess of such non technical barriers is a main obstacle to a quicker implementation of biogas plants in Europe. In the future directives should better take the biogas case into account.

Biogas is the future

FULLY CONSIDER BIOGAS IN THE EUROPEAN BIOFUELS TECHNOLOGY PLATFORM (EBTP)
It seems that the EBTP is focusing very much on biodiesel, bioethanol and the so called second generation biofuels, while biomethane is almost not considered. This is a mistake because biomethane is highly productive per ha, has an enormous potential, and is technologically ready both for production (upgrading of biogas) and use in natural gas engines. The CO_2 balance is extremely high (more than 100 % reduction because of avoided methane emission in reference scenario without biogas).

FINALIZE THE BIOWASTE REGULATIONS (MAKE IT CLEAR AND SHARP) IN ORDER TO REDUCE THE BARRIERS FOR BIOGAS USE.
The landfill directive is banning progressively biowaste from landfilling, but many member states are still lagging behind the EU targets for maximum percentage of biowaste going to landfills. This is partly due to the lack of alternatives. Biological treatments are so far not regulated at EU level. A possible Biowaste directive might close this gap and propose standards.

FERTILIZER LEGISLATION
Treated digestate should be allowed to replace artificial fertiliser all over Europe. This could be tied into GHG reductions through reduced use of oil.

National and regional level

MAKE BIOGAS PROJECTS ELIGIBLE FOR EU FUNDING OF RURAL DEVELOPMENT.

The regional authorities responsible for the planning and implementation of support to Rural Development under the EU Common Agricultural Policy should make the additional funds available through the "Health Check" (3.2 bln Euros in 2010 to 2013) for the "new priorities" (one of which is renewable energy) fully accessible for investments into all types of biogas projects.

MAKE BIOGAS FOR TRANSPORT COMPETITIVE AS COMPARED TO FOSSIL FUELS (CO_2 TAX AND LOWER EXCISE DUTIES).

Biomethane for transport competes with fossil natural gas as the vehicle technology is similar. Governments should look for ways to improve this competitiveness for the end users for example by introducing a general CO_2 tax, which led to a favorable development in Sweden. Biomethane could receive special subsidies (e.g. a bonus per m^3 biomethane used as fuel) in countries where natural gas is detaxed, most prominently Italy (which has by far the highest number of gas driven vehicles). This incentive should bridge the gap between the costs of natural gas and biomethane as transport fuel.

INCENTIVES FOR ECO-CARS SHOULD BE INTRODUCED (E.G. TAX ADVANTAGES, LOWER PARKING FEES, ALLOW CIRCULATION DURING HIGH EMISSION PERIOD).

Biomethane cars have especially low emissions (NOx, particulates) and should be promoted by providing advantages such as low tax (upon buying them and using them), lower parking fees (successfully implemented in Swedish cities), and permission to drive even during period of high pollution.

PUBLIC TRANSPORTATION SHOULD RUN ON BIOGAS, INCENTIVES FOR BIOGAS-TAXIS AND COMPANY CARS.

Bus fleets with steady and regionally bound fuel consumption are a perfect first step to introduce biomethane and biomethane filling stations to urban areas.

A significant tax reduction for company cars running on biomethane would offer a great market for clean cars.

SUPPORT OF REGIONAL GAS INFRASTRUCTURE

The gas grid capacity should be adapted in order to allow biomethane injection into the system.

ADOPT DESIGN OF GREEN CERTIFICATE SYSTEMS

The current systems often only aim at the most cost-efficient solutions and do not take into account GHG savings, use of waste or advanced biofuels – all of which favorable to biogas.

ELIMINATE THE BARRIERS TO GET PERMISSIONS FOR BUILDING BIOGAS PLANTS.

Getting permits for new biogas plants is a long lasting process in all member states. Regulations are too numerous (see above) and the public misperception is the rule (misunderstanding about odors, transport, waste handling, pollution). Efforts should focus on communication and coordination between relevant administrative bodies for permits.

SUPPORT R&D FOR ENERGY CROPS, BIOGAS TECHNOLOGY, FERMENTATION BIOLOGY, EFFICIENCY OF ENERGY USE.

Biogas is highly productive per ha and is versatile regarding its uses. Still the potential for improvements through R&D are significant (best crops and by-products for fermentation, automatisation, biological process enhancement, cleaning, use in micro-turbines and fuel cell, etc.)

ACCEPT DIGESTATE AS A REPLACEMENT OF ARTIFICIAL FERTILIZER TO MEET CROP NEEDS.

The nitrate directive limits the organic fertilizer to a maximum of 170 kg N/ha. It is a pity that in some cases mineral nitrogen is used instead of biogas digestate because this limit has been reached. Digestate is an upgraded organic fertilizer with advantages (nitrogen less susceptible to water pollution, homogeneous, better management and storage opportunities) and should be better promoted and used instead of artificial fertilizers.

FULLY INCLUDE BIOGAS INTO THE NATIONAL RENEWABLE ENERGY ACTION PLAN - nREAP.

Member states should consider biogas as an important contribution to reach their renewable targets and foresee measures for biogas deployment (see chapter 8).

Source: Shaumann Bionergy

Characteristic biogas figures, Abbreviations, Energy units, Conversion factors

CHARACTERISTIC FIGURES

1 kg biomethane: 50 MJ
1 Nm³ biomethane: density: 0,72
1 Nm³ biomethane: 35,5 MJ, rounded: 36 MJ = 10 kWh
1 Nm³ biogas contains appr.: 0,60 Nm³ biomethane.

DRY MATTER AND ORGANIC DRY MATTER

1 t maize contains: 95,0 % organic dry matter
1 t catch crops: 89,0 % organic dry matter
1 t green cutting: 88,0 % organic dry matter

GAS YIELDS

1 t organic maize produces: 350 Nm³ biomethane
1 t organic green cutting: 300 Nm³ biomethane
1 t organic catch crops: 320 Nm³ biomethane
1 t organic straw: 210 Nm³ biomethane
1 t organic cattle manure: 160 Nm³ biomethane
1 t organic pig manure: 310 Nm³ biomethane
1 t organic chicken litter: 290 Nm³ biomethane
1 t organic sludge: 260 Nm³ biomethane
1 t organic bio waste: 130 Nm³ biomethane

YIELD PER HA:

Maize (silage): 16 t/ha:
16*0,95*350 = 5.320 Nm³ = 191,52 GJ = 4,6 toe
Winter catch crop: 7,5 t/ha:
7,5*0,89*320 = 2.136 Nm³ =76,90 GJ = 1,8 toe
Autumn catch crop: 3,3 t/ha:
3.3*0,89*320 = 939,8 Nm³ = 33,83 GJ = 0,8 toe
Catch crop average: 5 t/ha
5*0,89*320= 1424 Nm³ = 51,26 GJ = 1,2 toe
Green cuttings: 8 t /ha:
8*0,88*300 = 2112 Nm³ = 76,00 GJ = 1,8 toe

CALCULATION EXAMPLE

5% of the arable land used for biogas in Europe (5,43 million ha) could provide 23,4 millions toe of primary energy = available area * yield per ha (dry) * percentage of organics matter * m³ biomethane yield
= 5,43 * 10^6 * 15 * 0,95 * 350 = 27,2 Gm³ biomethane
= 23,4 Mtoe

Conversion factors

	NCV kWh/Nm³	NCV MJ/m³	NVC toe/1000m³	Density kg/Nm³	NCV kWh/kg
Natural gas	9.9	36	0.86	0.73	13.6
Biogas (60 % methane)	6.0	21.6	0.52		
Biomethane (upgraded biogas)	9.5	36	0.86	0.73	13.0

Nm³: normal m³
NCV: Net Calorific Value

1 PJ = 0.278 TWh = 0.024 Mtoe
1 TWh = 3.6 PJ = 0.086 Mtoe
1 Mtoe = 41.868 PJ = 11.63 TWh

Decimal prefixes

10^1	Deca (da)
10^2	Hecto (h)
10^3	Kilo (k)
10^6	Mega (M)
10^9	Giga (G)
10^{12}	Tera (T)
10^{15}	Peta (P)
10^{18}	Exa (E)

AEBIOM

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AEBIOM is a non profit Brussels based international organisation whose mission is to represent interests of bioenergy stakeholders at EU level.
AEBIOM with its 33 national associations indirectly represents more than 4000 members including companies, research centres and individuals.
More than 70 bioenergy companies from all over Europe have also joined AEBIOM as associate members.

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Companies are welcome to join AEBIOM, and get the following services:

- First hand information on EU legislation.
- Invitation to several workshops per year.
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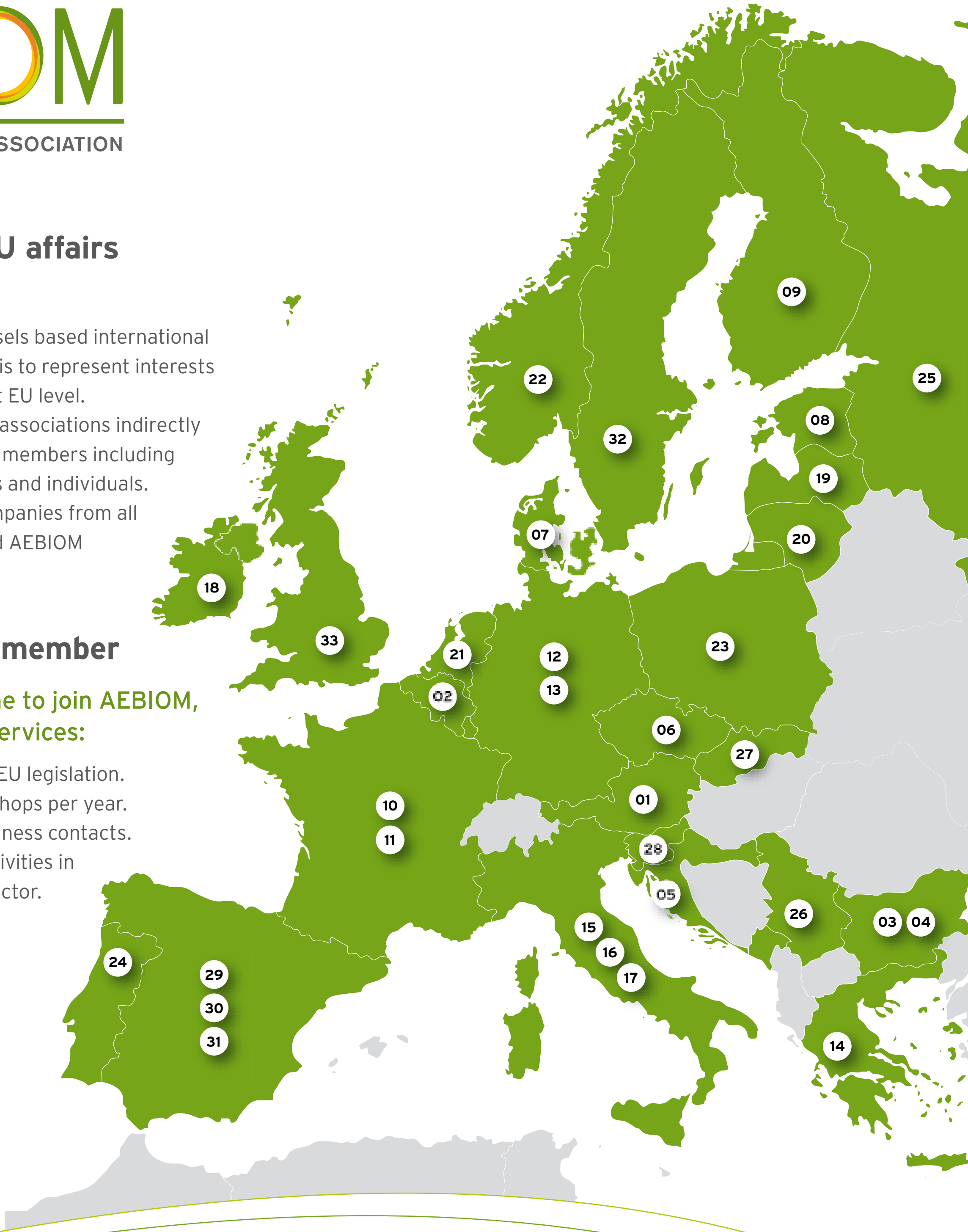

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