"Biogas – a promising renewable energy source for Europe"

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A paper for further discussion during or after the workshop!

The Future of Biogas in Europe: Visions and Targets until 2020

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Introduction

Biogas can be produced of nearly all kinds of organic materials. It is closely linked to agricultural activities and human consumption. Wherever there is a large population, and thereby a comprehensive quality food production of a broad mixture of vegetable and animal foods, the right conditions exist for biogas production. In the future the large volume of biogas will be integrated into the European farming systems. There are quite a few biogas process volumes at the current wastewater treatment plants, landfill gas installations, and industrial biowaste processing facilities. However, the largest volume of produced biogas will, by 2020, originate from farm biogas and from large co-digestion biogas plants, integrated into the farming- and food-processing structures.

The EU policy concerning renewable energy (RES) has set forward a fixed goal of supplying 20% of the European energy demands from RES. It is without doubt, that a major part of the renewable energy will originate from European farming and forestry: as biomass conversion to gaseous, liquid and solid biofuels. The gaseous part – the biogas production - has its own, more and more consolidated platform. The forecasts look promising. At least 25% of all bioenergy in the future can originate from biogas, produces from wet organic materials, like animal manure, whole crop silages, wet organic food/feed wastes etc. The forecasts for a very flexible utilisation of biogas are prosperous, but it implicates that the biogas is to be cooled, dried, cleaned and upgraded to natural gas quality, in order for the application and utilisation routes to be plentiful.

Biogas resource bases;

Energy crop potential

In the presented predicted energy crops potential, general units of energy are used. It is not indicated, whether the biomass will be converted into fuel, electricity, or any other form. For simplifying the calculations, it was assumed, that the heating value of 1 kg dry matter biomass is equal to 18 MJ. For further recalculations, 1 Mtoe (mill ton of oil equivalent) is equal to 44.8 PJ. Heating value of methane is equal to 40.3 MJ per $m^3 CH_4$.

All the data concerning total area, agricultural and arable land are taken from the FAO database (2003) (FaoStat). The eventual changes in land use (decrease or increase of arable land) are not taken into consideration. All the calculations are based on "today's" arable area.

Table 1 contents registered data of total area of land use for 27 European countries (EU-27). Data shown for the areas of specific interests for biomass production conditions are the total agricultural area and arable land. It is important to underline that forest and permanent grassland might be partly interesting for future energy farming, specifically the forestry areas. The fallow areas might also soon be integrated in arable land or non-food areas. The calculation of biogas potential was taken into consideration only on arable land.

Table 1. Data of total area and areas of interest for biomass production for each member of EU-27; area data in millions of hectares (Holm-Nielsen, et al, 2006)

	Total area (10^6 Ha)	**Agricultural area (10^6 Ha)**	**Arable land (10^6 Ha) (% of total area)**		**Hectares of agricultural land per capita**
Austria	8.4	3.4	1.4	17	0.42
Belgium	3.1	1.4	0.8	27	0.13
Bulgaria	11.1	5.3	3.3	30	0.68
Cyprus	0.9	0.1	0.1	11	0.18
Czech Republic	7.9	4.3	3.1	39	0.42
Denmark	4.3	2.7	2.3	53	0.49
Estonia	4.5	0.8	0.5	12	0.63
Finland	33.8	2.2	2.2	7	0.43
France	55.2	29.7	18.5	33	0.49
Germany	35.7	17.0	11.8	33	0.21
Greece	13.2	8.4	2.7	20	0.77
Hungary	9.3	5.9	4.6	50	0.60
Ireland	7.0	4.4	1.2	17	1.09
Italy	30.1	15.1	8.0	26	0.26
Latvia	6.5	2.5	1.8	28	1.08
Lithuania	6.5	3.5	2.9	45	1.02
Luxemburg	0.3	0.1	0.06	24	0.28
Malta	0.03	0.01	0.01	31	0.03
Netherlands	4.2	1.9	0.9	22	0.12
Poland	31.3	16.2	12.6	40	0.42
Portugal	9.2	3.7	1.6	17	0.37
Romania	23.8	14.7	9.4	39	0.66
Slovakia	4.9	2.4	1.4	29	0.45
Slovenia	2.0	0.5	0.2	9	0.26
Spain	50.5	30.2	13.7	27	0.73
Sweden	45.0	3.2	2.7	6	0.36
U. K.	24.4	17.0	5.7	23	0.28
EU-27	**433.1**	**196.6**	**113.5**	**26**	**0.41**

Based on the data from the Table 1, the possible energy crops potential was calculated. The results in PJ and Mtoe are presented in Table 2. The countries with good potential to produce biomass for energy are the ones with high ratio hectares of agricultural land per capita. The new member states: Bulgaria and Romania, with high hectares of agricultural land per capita (both almost 0.7), could make the development and implementation of EU bioenergy policies easier. The average of the EU-27 is 0.4 hectare/capita.

Table 2. Energy crop potential in EU-27, depending on percentage of utilized arable land and achieved crop yield

Yield	10% arable land in EU-27		20% arable land in EU-27		30% arable land in EU-27	
10 t TS/ha	2,042 PJ	46 Mtoe	4,084 PJ	91 Mtoe	6,127 PJ	137 Mtoe
20 t TS/ha	4,084 PJ	91 Mtoe	8,169 PJ	182 Mtoe	12,253 PJ	274 Mtoe
30 t TS/ha	6,127 PJ	137 Mtoe	12,253 PJ	274 Mtoe	18,380 PJ	410 Mtoe

TS = Total solid = dry matter – biomass. Mtoe = million tons of oil equivalents.

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. The average total crop yield of around 20t TS/ha is considered feasible in the near future. According to Perlack et al., the average yields for switchgrass clones, tested in several places in the US, varied from a low 10 total solids per hectare to a high 25 total solids per hectare, with most locations having average from 13 to 20 tTS/ha. These results indicated that future yields could be estimated to 20 tTS/ha. Maize and various other crops will increasse in importance European wide. Crop paradigm changes are in progress.

The above values were calculated for complete combustion of the biomass. The biogas conversion efficiency can be assumed for 80% due to the fact that not all of the compounds from biomass can be digested through AD process like the lignin. Table 3 presents recalculated energy crop potential in amount of produced methane through anaerobic digestion process. Furthermore, it has to be taken into account that only around 25% of the energy crop will be dedicated for biogas production. The rest will be applied in other renewable energy production processes (solid and liquid biofuels).

Table 3. A case example; Methane potential originated from energy crops from 5% of the arable land in EU-27 with the cropping yield equal to 10, 20, and 30 tTS/ha. Areas reserves as well for solid- and liquid biofuels.

Energy crop yield	10 tTS/ha	20 tTS/ha	30 tTS/ha
Methane potential	25.3 billion m^3CH_4	50.7 billion m^3CH_4	76.0 billion m^3CH_4
	22.8 Mtoe	45.5 Mtoe	68.5 Mtoe

Manure resources

Biogas from anaerobic digestion can be produced from a variety of biomass types. The primary source is manure from animal production, mainly from cattle and pig farms. It also delivers the necessary micro-organisms for biomass biodegradation and is one of the largest single sources of biomass from food/feed industry. In the EU-27 more than 1500 mill tonnes of animal manure is produced every year. When untreated or managed poorly, manure becomes a major source of ground and fresh water pollution, pathogen emission, nutrient leaching, and ammonia release. If handled properly, it turns out to be renewable energy feedstock and an efficient source of nutrients for crop cultivation. Table 4 depicts the amount of cattle and pig manure produced every year in the European Union.

Table 4. Estimated amounts of animal manure in EU-27 (based on Faostat, 2003)

Country	**Cattle** [1000Heads]	**Pigs** [1000Heads]	**Cattle** 1000livestock units	**Pigs** 1000livestock units	**Cattle manure** [10^6 tons]	**Pig manure** [10^6 tons]	**Total manure** [10^6 tons]
Austria	2051	3125	1310	261	29	6	35
Belgium	2695	6332	1721	529	38	12	49
Bulgaria	672	931	429	78	9	2	11
Cyprus	57	498	36	42	1	1	2
Czech R.	1397	2877	892	240	20	5	25
Denmark	1544	13466	986	1124	22	25	46
Estonia	250	340	160	28	4	1	4
Finland	950	1365	607	114	13	3	16
France	19383	15020	12379	1254	272	28	300
Germany	13035	26858	8324	2242	183	49	232
Greece	600	1000	383	83	8	2	10
Hungary	723	4059	462	339	10	7	18
Ireland	7000	1758	4470	147	98	3	102
Italy	6314	9272	4032	774	89	17	106
Latvia	371	436	237	36	5	1	6
Lithuania	792	1073	506	90	11	2	13
Luxembourg	184	85	118	7	3	0	3
Malta	18	73	11	6	0	0	0
Netherlands	3862	11153	2466	931	54	20	75
Poland	5483	18112	3502	1512	77	33	110
Portugal	1443	2348	922	196	20	4	25
Romania	2812	6589	1796	550	40	12	52
Slovakia	580	1300	370	109	8	2	11
Slovenia	451	534	288	45	6	1	7
Spain	6700	25250	4279	2107	94	46	140
Sweden	1619	1823	1034	152	23	3	26
U.K.	10378	4851	6628	405	146	9	155
EU-27	**91364**	**160530**	**58348**	**13399**	**1284**	**295**	**1578**

The animal production sector is responsible for 18% of the green house gas emission, measured in CO_2 equivalent and for 37% of the anthropogenic methane, which has 23 times the global warming potential of CO_2. Furthermore, 65% of anthropogenic nitrous oxide and 64% of anthropogenic ammonia emission originates from the same animal production sector (Steinfeld et al., 2006). Table 5 shows the biogas and energy potential of pig and cattle manure in EU-27.

Table 5. Energy potential of pig and cattle manure in EU-27. Realistic implementation level and utilisation will be 40-70%

Total manure [10^6 tons]	Biogas [10^6 m^3]	Methane [10^6 m^3]	Potential [PJ]	Potential [Mtoe]
1,578	31,568	20,519	827	18.5

Methane heat of combustion: 40.3 MJ/m^3; 1 Mtoe = 44.8 PJ
Assumed methane content in biogas: 65%

Table 5 reveals that huge amounts of animal manure are produced in Europe. Biogas production through anaerobic fermentation of animal manure is an effective way to reduce greenhouse gas emission, especially ammonia and methane from manure storage facilities. 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. The digested substrate resulted after the process can be further refined and serves as organic fertilizer, rich in nitrogen, phosphorous, potassium and other macro- and micro-nutrients necessary for the growth of the plants. Utilisation of large amounts of animal manure for bioenergy purposes will reduce the nutrient runoffs and diminish the contamination of surface- and ground- water resources by further biotechnological processing and upgrading the liquid and solid biofertilizers for replacement of chemical fertilizers in the European crop farming.

To sum up the biogas production potential, in the year 2020, 45.5 Mtoe of methane from energy crops can be achieved under crop yielding 20 tTS/ha additionally 18.5 Mtoe will be available from cattle and pig manure. The added potential is equal to 64 Mtoe, which would correspond to 71.2 billion m^3CH_4. Of this a fulfilment rate of 50-75% is uptainable.

Biogas utilisation applications

Biogas can be utilized in several ways. It can either be applied raw or upgraded, minimum it has to be cooled, drained and dried right after production, and most likely it has to be cleaned for the content of H_2S as well, which in a short time interval will corrode the energy conversion technologies if the H_2S content is above 500 ppm.

There are various ways of biogas utilisation:

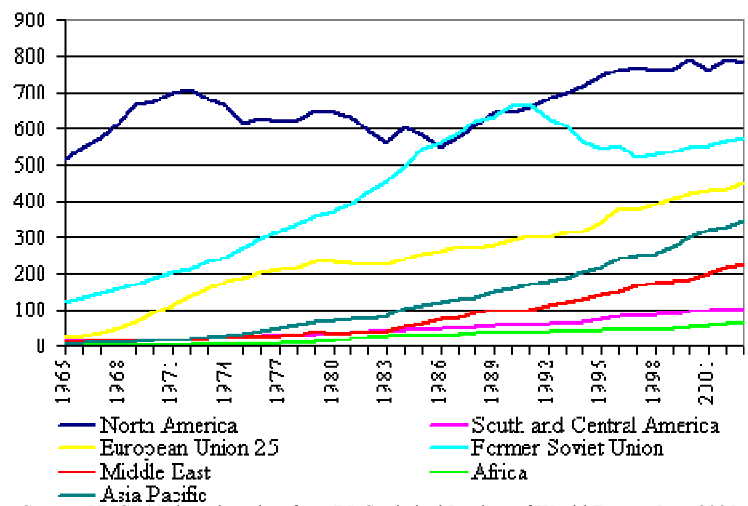
- Production of heat and/or steam
- Electricity production / combined heat and power production (CHP)
- Industrial energy source for heat, steam and/or electricity and cooling
- Vehicle fuel
- Production of Chemicals
- Fuel cells

It can be fuelled to generate heat and/or electricity or applications of combined heat and power (CHP) plants and upgraded to vehicle fuel standards; these will be the most voluminous application routes. One case example of biogas for vehicle fuels is Sweden. The market for biogas as vehicle fuels has been growing rapidly the last 2-3 years. Today there are 12.000 vehicles driving on upgraded biogas/natural gas and the forecast predicts 500 filling station and 70.000 vehicles by 2010 (Persson, 2007).

The most efficient ways of integrating the biogas into the entire European energy sectors are by upgrading the biogas to natural gas quality and integrating it into the natural gas grid. The bottleneck in this area is the economy of each treated m^3-biogas, but various upgrading technologies exists (Persson et al., 2006). In the coming years the economy of scale of upgrading facilities will be met by competition from economy of numbers of installations. It is obvious that the treatment price will be reduced 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.

Introducing biomethane into the natural gas grids widen up the opportunity to utilize biogas in several ways depending on society needs. This option will be increased due to liberalisation of the energy markets in all European countries, but it requires natural gas quality by advanced treatment technologies. It will be as widely utilisation as for natural 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.

Figure 1 presents world's natural gas consumption.



Source: UNCTAD based on data from BP Statistical Review of World Energy June 2005

Figure 1: World's natural gas consumption in billion cubic metres, 1965-2004 (International Energy Outlook 2007, Energy Information Administration)

Natural gas consumption has increased in the last 30 years. It accounts for almost one quarter of the world's energy consumption. Much of the world's natural gas is used for industrial sector purposes. It is projected to account for 43% in 2030. The share of Europe in total natural gas consumption was 19.1% in 2000, equals to 459.3 billion cubic metres (International Energy Outlook 2007, Energy Information Administration). The theoretical potential of methane achieved from animal manure and energy crops (only from 5% of the arable land in EU-27) produced through anaerobic digestion process could supply 15.5% of the natural gas consumption in Europe.

Due to the placement of the feedstock for anaerobic digestion process, centralized biogas plants are located in the countryside, whereas the natural gas network is developed in the areas with increased inhabitant density. However, in recent years more interest arises in consumption of CO_2 neutral fuels like biogas. The future of combining upgraded biogas and natural gas will bring combined utilization of those two energy carriers. Biogas produced from energy crops, animal manure, and industrial organic waste can supply nearly half of the European natural gas consumption in the coming decades as stipulated by the calculations in this study.

Gaseous energy sources are more difficult to store and transport than liquid fuels, but this disadvantage is offset by much better combustion properties. The emission of several toxic compounds like nitrogen oxides and reactive hydrocarbon can even be reduced up to 80% compared to petrol and diesel.

Conclusion

Whereas biogas production is the best to utilize manure, not all the energy crops should be converted into biogas. Energy diversity brings stability. Energy crops should be 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). Gaseous – liquid and solid biofuels will in diversified combinations with wind, solar and hydro be integrated into the European energy sectors. The bioenergy will have the possibility of covering more than 50% of the renewable energy supply of the fixed goals of the year 2020. But when the renewable energy share is increasing towards 2050 and the fossil fuels faces out there will be needs for advanced hybrid systems, larger energy saving, and energy efficiency programmes.

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