biogasmax

A DRIVING FORCE

Technical success of the applied biogas upgrading methods

Keywords:
Biogas, biomethane, upgrading, water scrubber, pressure swing adsorption, chemical absorption, physical absorption, membrane separation, cryogenic distillation

Abstract:
This deliverable aims to give a short and compact overview on both the status and the technical success of the applied biogas upgrading methods of partners in the BIOGASMAX project. Furthermore, it describes other upgrading methods that are currently not available in the project.

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1. INTRODUCTION

This deliverable aims to give a short and compact overview of both the status and the technical success of the applied biogas upgrading methods of partners involved in the BIOGASMAX project. It includes specific information of all project plants in the form of a fact sheet, and furthermore provides data focused on the main upgrading step "CO_2 reduction" demonstrated as CH_4 concentrations in the raw biogas and biomethane for all 3 upgrading methods used in the project.

Furthermore, it describes other upgrading methods currently not included in the BIOGASMAX project.

At the beginning of the project it had been planned also to monitor a membrane system as well as a cryogenic system but both systems had not been constructed within the project. Therefore the monitoring and evaluation did not materialize.

By a decision on 30-09-2010, both plants of Lille site won't be part of the evaluation because they had not been in continuous operation mode by the end of the project.

More detailed information of the plant evaluation will be found in deliverable D3.6.
A cost comparison of several biogas upgrading systems will be found in deliverable D3.7.

2. BIOGAS UPGRADING METHODS FOR CO_2 REDUCTION

The main step of the production of biomethane is the removal of CO_2. The market available upgrading technologies can be separated in 4 groups shown in Figure 1:

1. Adsorption
2. Absorption
3. (Gas) Permeation
4. Cryogenic upgrading (to LBG or CBG)

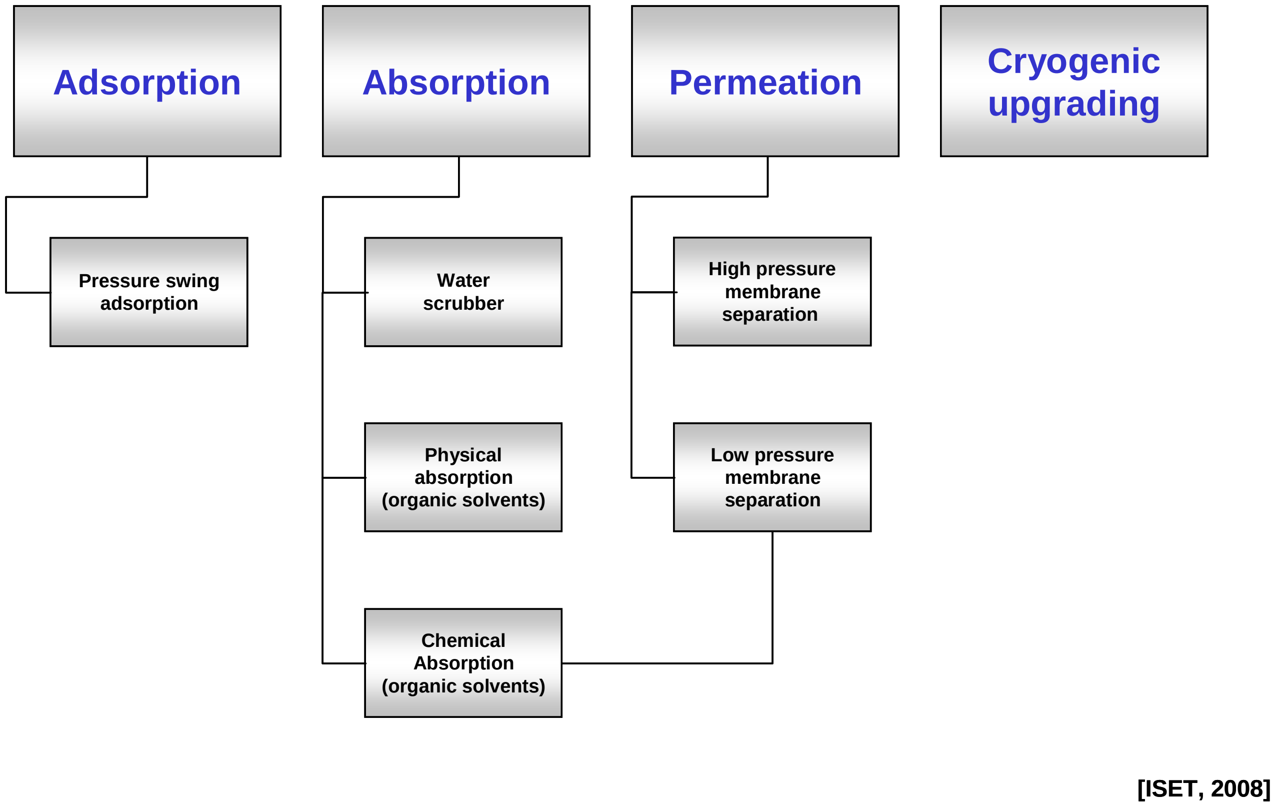


Figure 1: Overview biogas upgrading technologies for CO_2 removal.

The following chapter describes different methods for biogas upgrading to biomethane.

It is separated in two sub chapters. In section 2.1, all methods monitored in the project will be described. Section 2.2 will give an overview of methods that are currently not part (anymore) of the BIOGASMAX project.

2.1. Biogas Upgrading Methods available in the project

The following chapter will give an overview of the biogas upgrading methods that were part of the BIOGASMAX project.

2.1.a. Pressure Swing Adsorption (PSA)

The pressure swing adsorption (PSA) is an adsorptive upgrading technology. For the central unit, there are mostly used carbon molecular sieves. Besides CO_2, also other compounds like H_2O, H_2S, N_2 and O_2 can be separated from the gas stream. In a practical use, it is required to do a desulfurization and drying of the raw biogas before it enters the molecular sieve. Typical pressures are in the range from 4 to 7 bars. Typical CH_4 concentrations in the product gas stream are >96%. Because the exhaust gas stream includes >1% CH_4 (related to the CH_4 mass flow of the biogas), an exhaust gas cleaning is recommended.

Figure 2 describes the PSA process in Lucerne (4 modules) and shows the places in the process where H_2S, H_2O and CO_2 are separated.

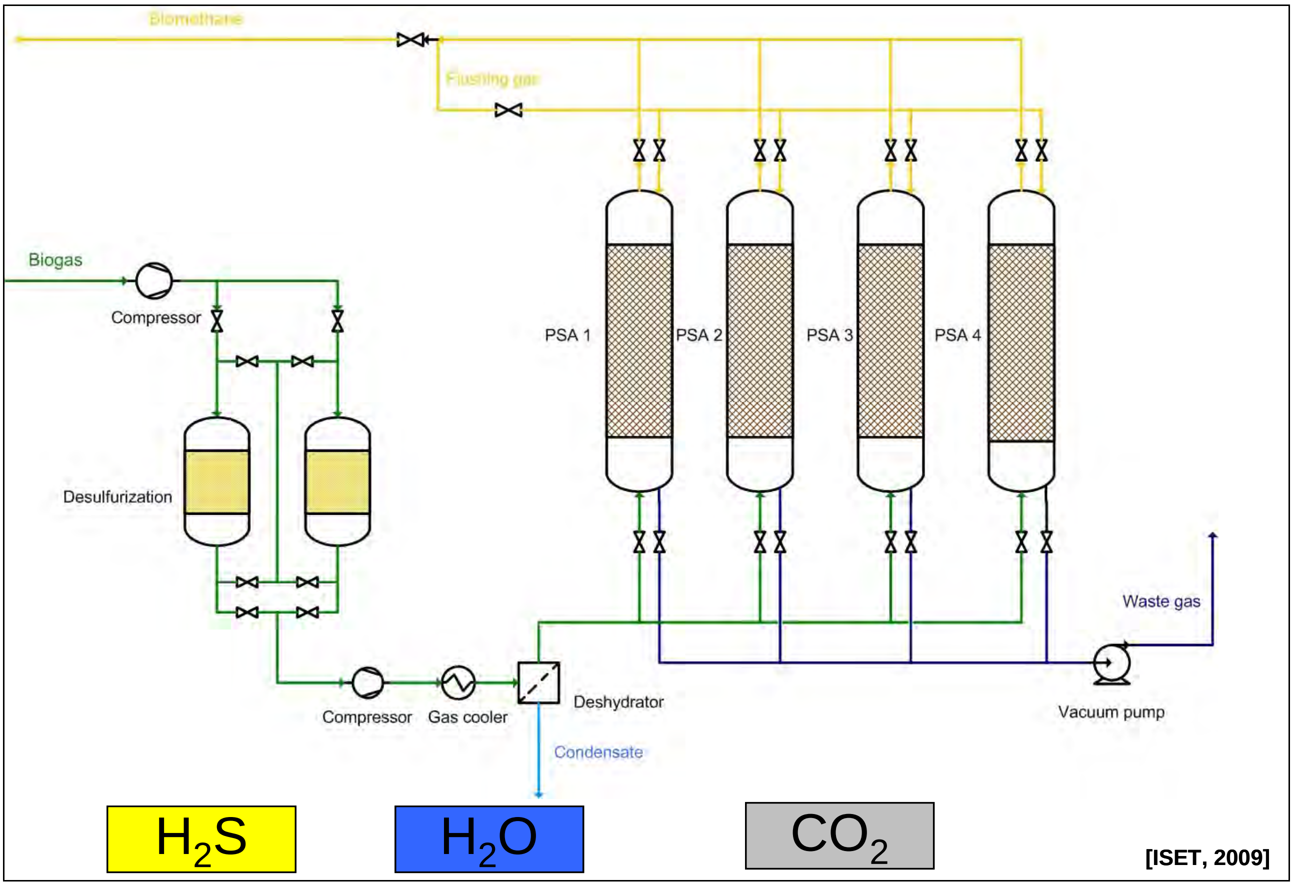


Figure 2: Flow chart pressure swing adsorption.

Figure 3 shows the CH_4 concentrations of the raw biogas compared to the product gas. The negative peaks of the biomethane stream are caused by shutdowns of the plant because the plant is not in operation continuously.

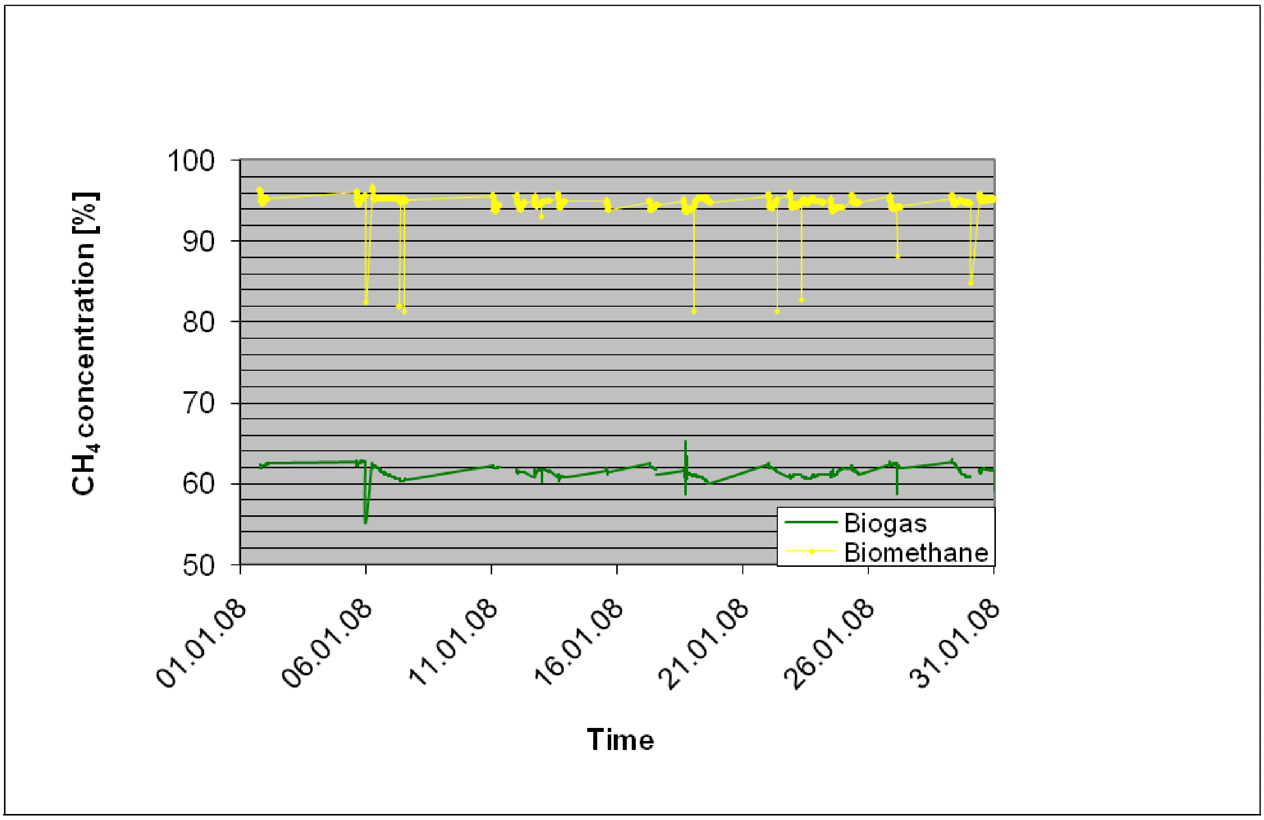


Figure 3: Methane concentrations in raw gas and upgraded gas of the PSA system in Lucerne in month 01-2008

2.1.b. Water Scrubber

The water scrubber technology is an absorptive method for separating CO_2 from the gas stream. Besides CO_2, also H_2S and NH_3 can be separated. Normally it is not required (and also not included in current plants) to schedule a desulfurization step before the raw gas enters the absorption column. But this can be helpful to avoid significant H_2S emissions into the atmosphere by the exhaust gas, or alternatively if there is an exhaust gas treatment technology installed, it will avoid SO_2 emissions. Pressures in the absorption column are in the range from 7 – 10 bars. Typical CH_4 concentrations in the product gas stream are ~97% depending on the raw gas composition.

Because the exhaust gas stream includes >1% CH_4 (related to the CH_4 mass flow of the biogas) an exhaust gas cleaning is required.

Figure 4 describes the water scrubber process of the Malmberg system (Falköping and Stockholm-Henriksdal) and shows the places in the process where H_2S, H_2O and CO_2 are separated.

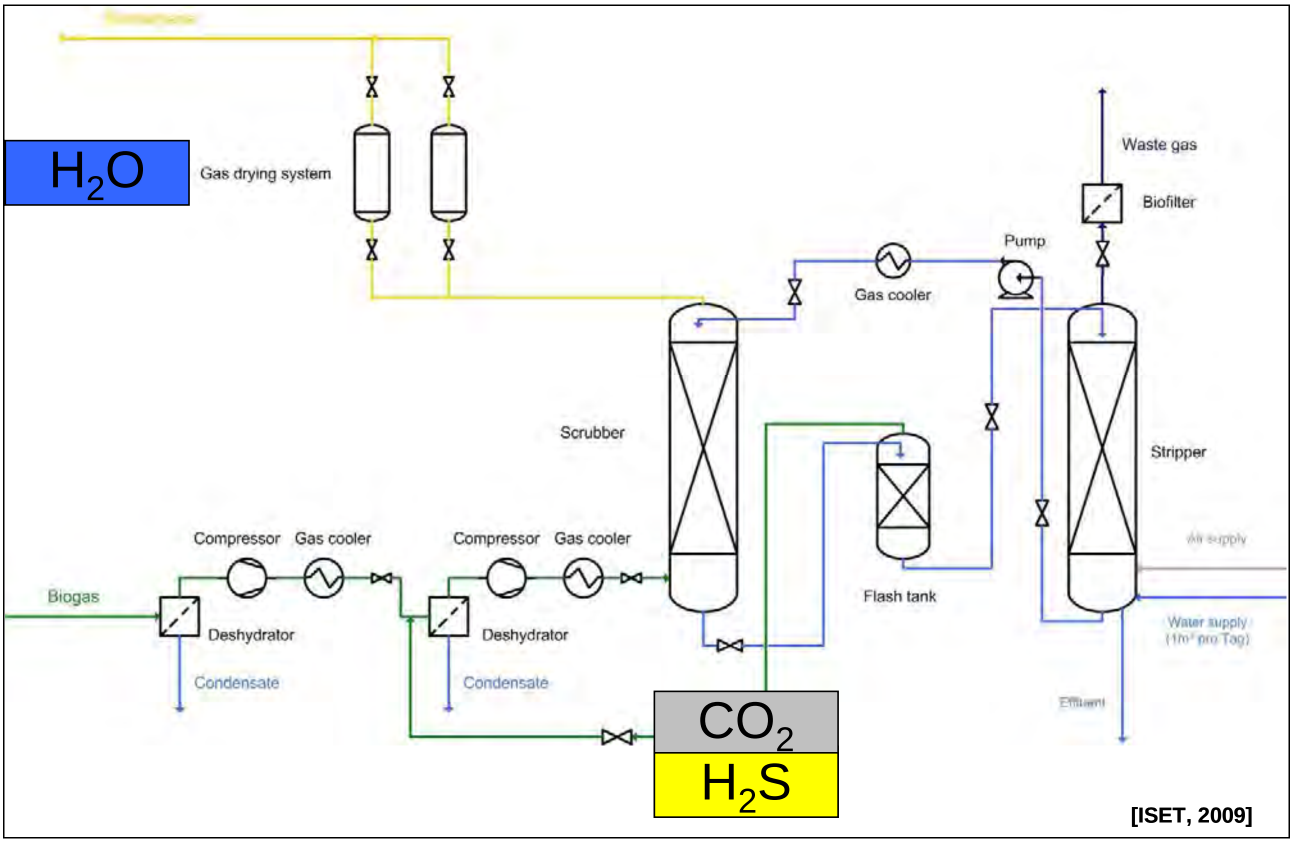


Figure 4: Flow chart water scrubber (with regeneration).

Figures 5-6 next show concentration levels at the Malmberg water scrubber system of Falköping. The negative peaks of CH_4 in the biomethane flow can be caused by N_2 or O_2 in the raw gas flow. Beside, CH_4 concentrations > 98% can be seen as very positive results of the application of this technology.

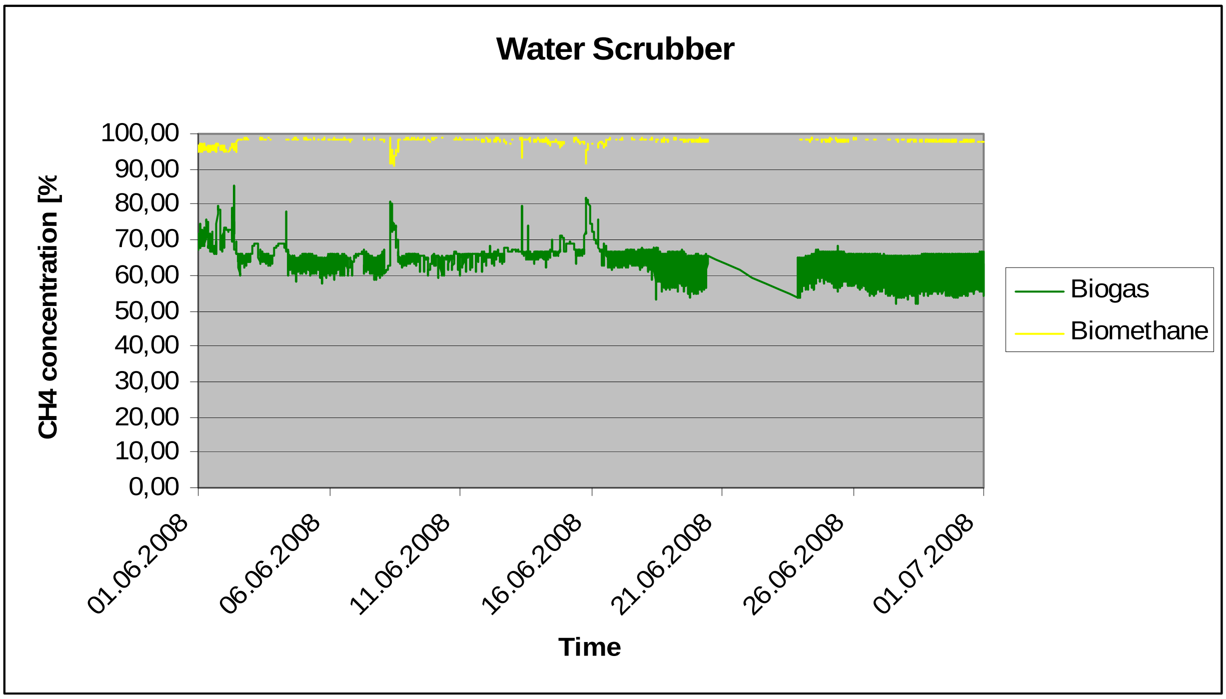


Figure 5: Methane concentration (biogas and biomethane) of the water scrubber system in Falköping of month 06-2008.

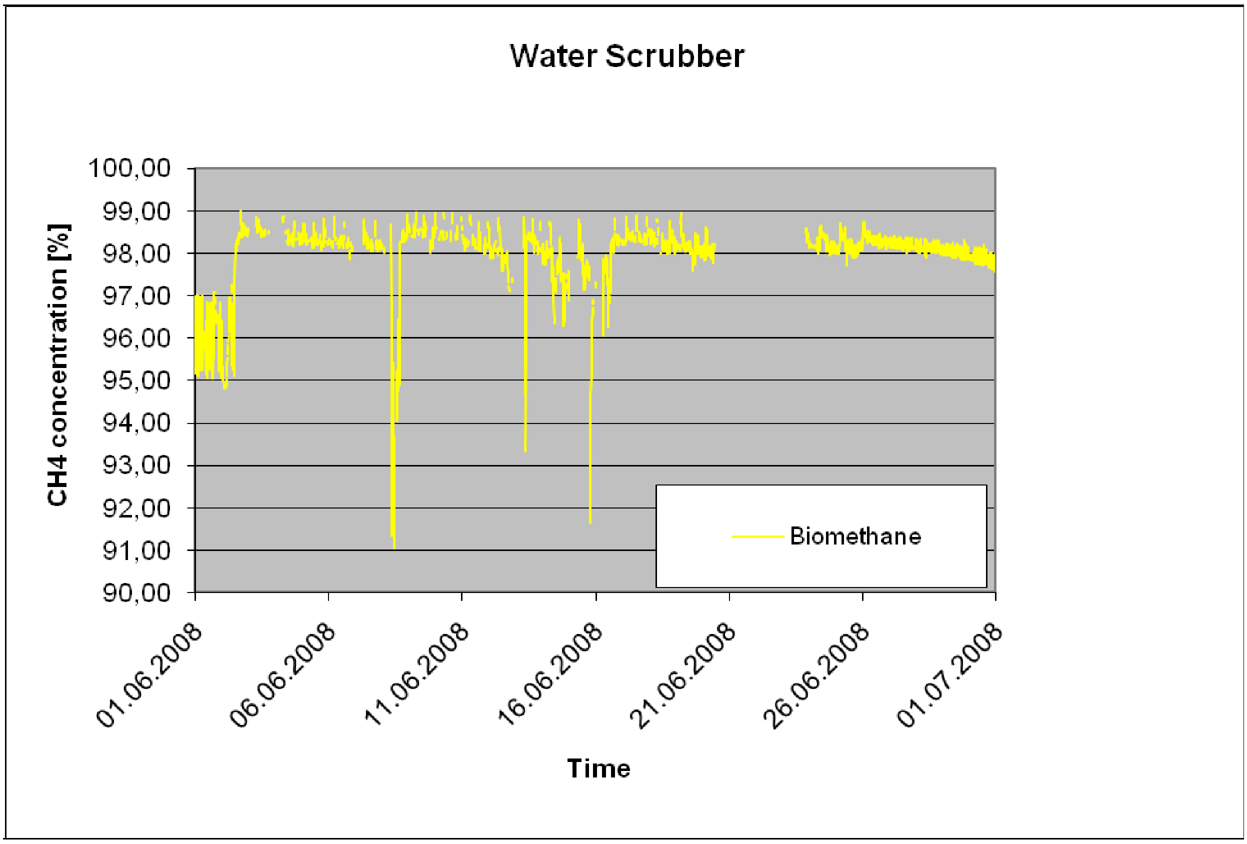


Figure 6: Methane concentration (only biomethane) of the water scrubber system in Falköping of month 06-2008.

2.1.c. Chemical Absorption (organic solvents)

The chemical absorption technology using organic solvents (mostly MEA or DEA) is a combination of a physisorption and a chemisorption. Besides CO_2 also H_2S and NH_3 can be theoretically separated. In practical use, a desulfurisation step is required before the biogas enters the absorption column to avoid unwanted reactions in the process. The pressure in the absorption column is normally only a few mbars. For regeneration in the desorption column, a temperature level of 120–160°C is required. Typical CH_4 concentrations in the product gas stream are in the range from ~99 % if there is no N_2 and/or O_2 in the biogas flow. An exhaust gas treatment is not necessary.

Figure 7 describes the process and shows the places in the process where H_2S, H_2O and CO_2 are separated.

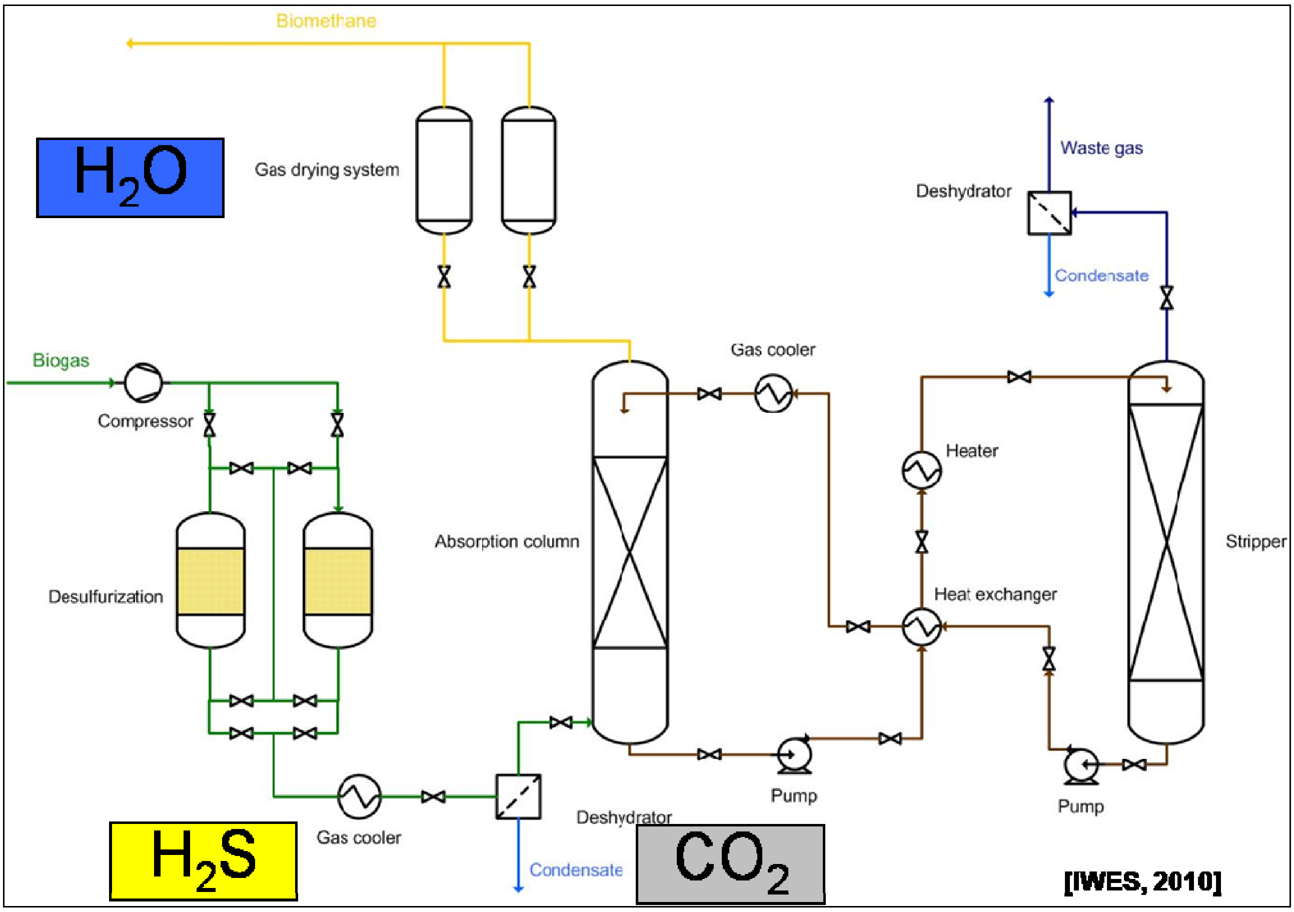


Figure 7: Flow chart chemical absorption (using organic solvents).

Figures 8 and 9 show the chemical scrubber system of Göteborg. The negative peaks of CH_4 in the biomethane flow can be caused by N_2 or O_2 in the raw gas flow. Figure 9 shows that the system with CH_4 concentrations >99% is running very stable and well for most of its operation time.

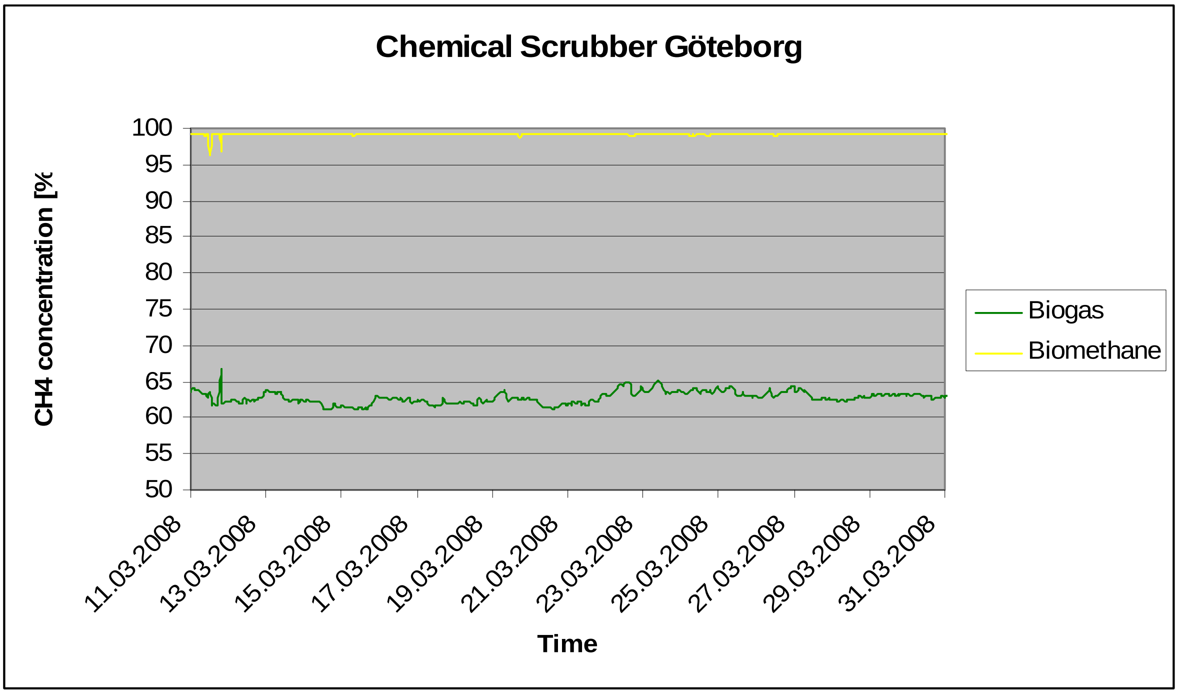


Figure 8: Methane concentration (biogas and biomethane) of the chemical scrubber system in Göteborg of month 03-2008.

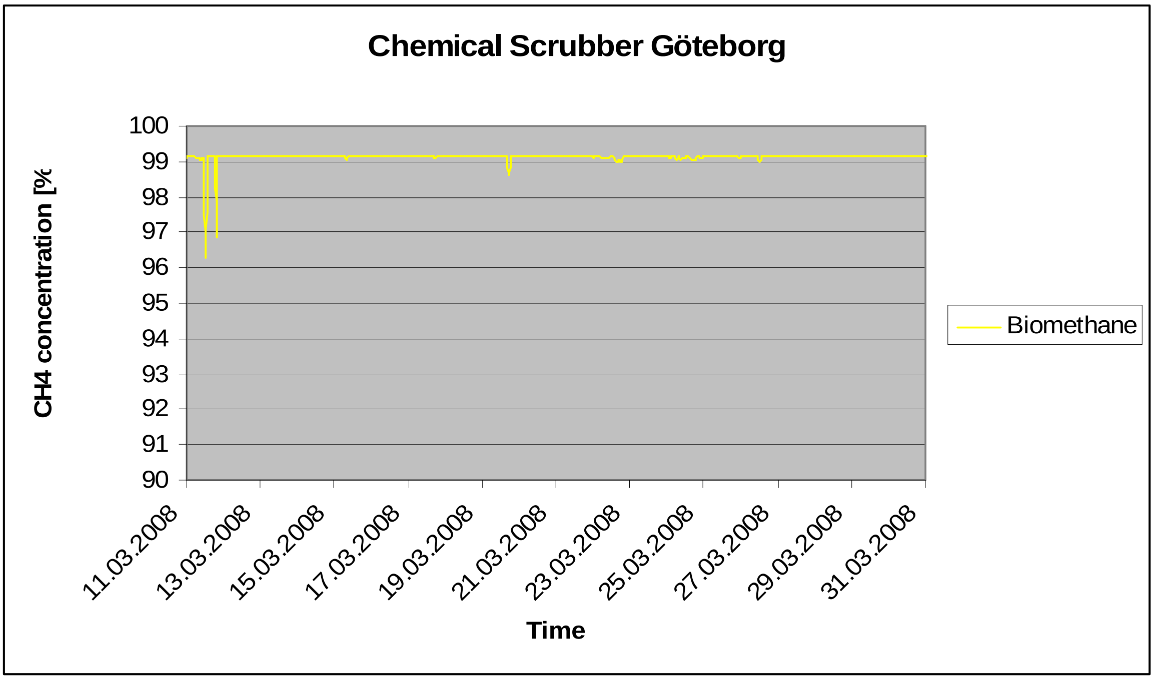


Figure 9: Methane concentration (only biomethane) of the chemical scrubber system in Göteborg of month 03-2008.

2.2. Biogas Upgrading Methods currently not available in the project

The following chapter will give an overview about the biogas upgrading methods that are currently not part of the BIOGASMAX project. ISET/IWES had several talks in the past with plant manufacturers. There is the opportunity to also evaluate (thanks to receiving process data of the plant manufacturers) a physical absorption system (Genosorb scrubbing, primarily planned for use in Jona/Switzerland) from HAASE and a cryogenic upgrading from GtS (primarily planned for use in Falköping/Sweden).

2.2.a. Physical Absorption (organic solvents)

The physical absorption technology using organic solvents (mostly Selexol or Genosorb) is basically comparable with the water scrubber technology. Besides CO_2 also H_2S, NH_3 and H_2O can be separated. Normally it is not required (and also not built in the most of the current plants) to schedule a desulfurization step before the raw gas enters the absorption column. But it can be helpful to avoid significant H_2S emissions to the atmosphere by the exhaust gas or alternatively if there is an exhaust gas treatment technology installed, it will avoid SO_2 emissions. The pressure in the absorption column is normally ~8 bars. For regeneration in the desorption column, a temperature level of ~50°C is required. Typical CH_4 concentrations in the product gas stream are in the range of 93–98 %.

Because the exhaust gas stream includes >2% CH_4 (related to the CH4 mass flow of the biogas) an exhaust gas cleaning is required.

Figure 10 describes the process and shows the places in the process where H_2S, H_2O and CO_2 are separated.

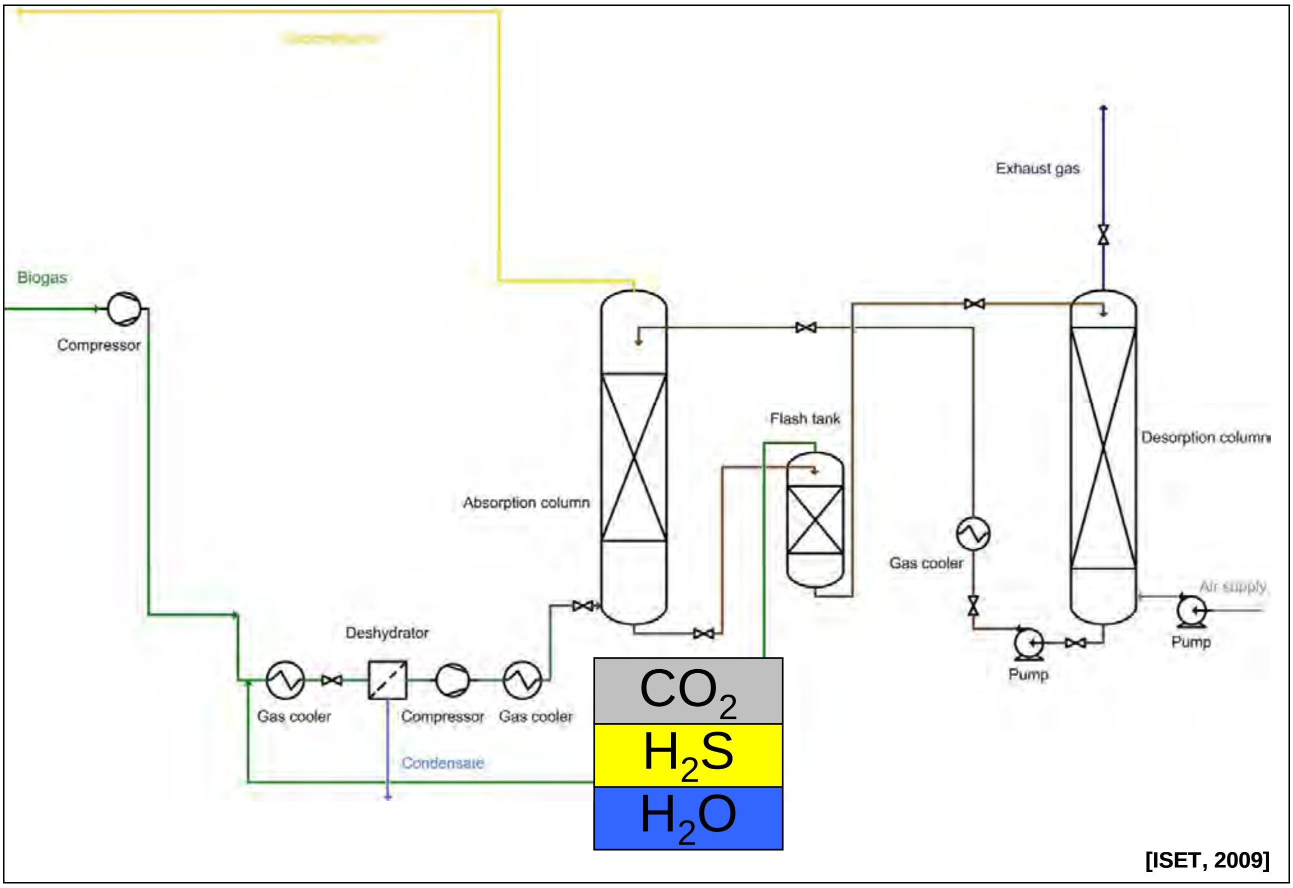


Figure 10: Flow chart physical absorption (using organic solvents).

2.2.b. Membrane Separation

Basically there are two different membrane separation technologies available: a dry high pressure one and a low pressure one that is a combination of a permeation and a chemical absorption using organic solvents. For the practical use, there are currently only dry high pressure systems relevant. CO_2, H_2O, H_2S and NH_3 pass through the membrane nearly complete and will be found in the permeate stream. The retentate stream consists mainly of CH_4. In practical use, generally two stage systems will be found. To increase the lifetime of the membrane modules, it is mostly required to install a desulfurization and drying step before the raw gas enters the membrane.

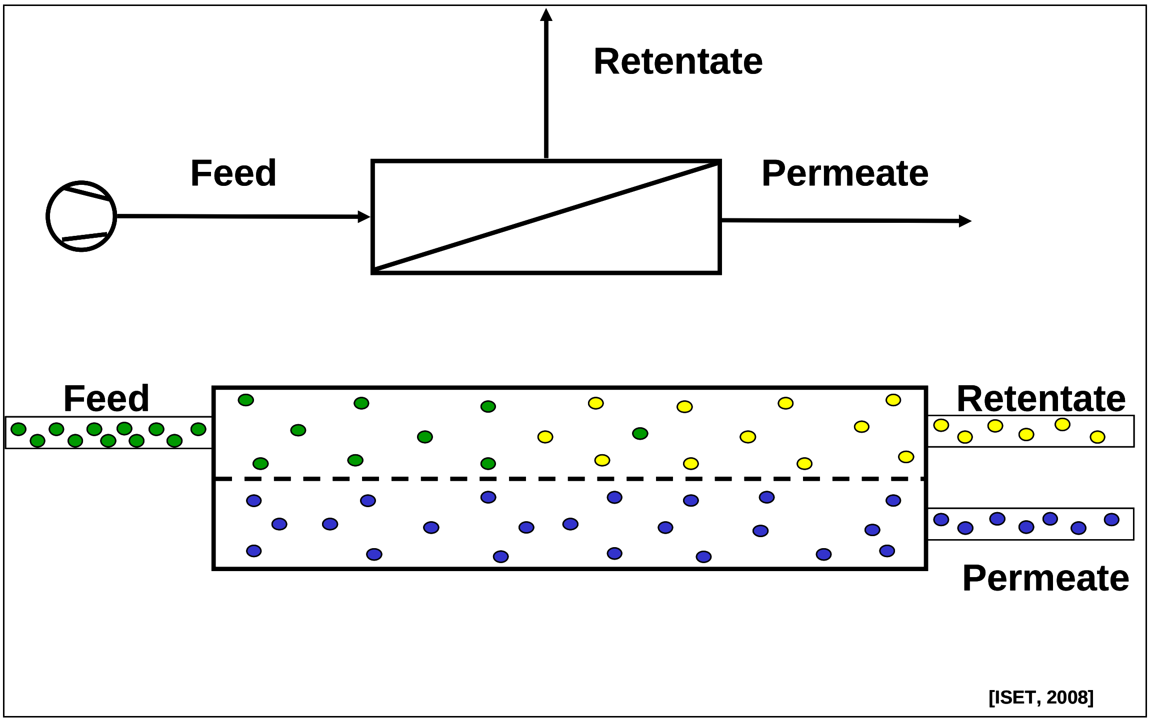


Figure 11: Description of the CO2 separation step of membrane systems.

2.2.c. Cryogenic Distillation

The cryogenic biogas upgrading shown in figure 12 is an example of the Netherlands company GtS. The process is separated in 5 steps:

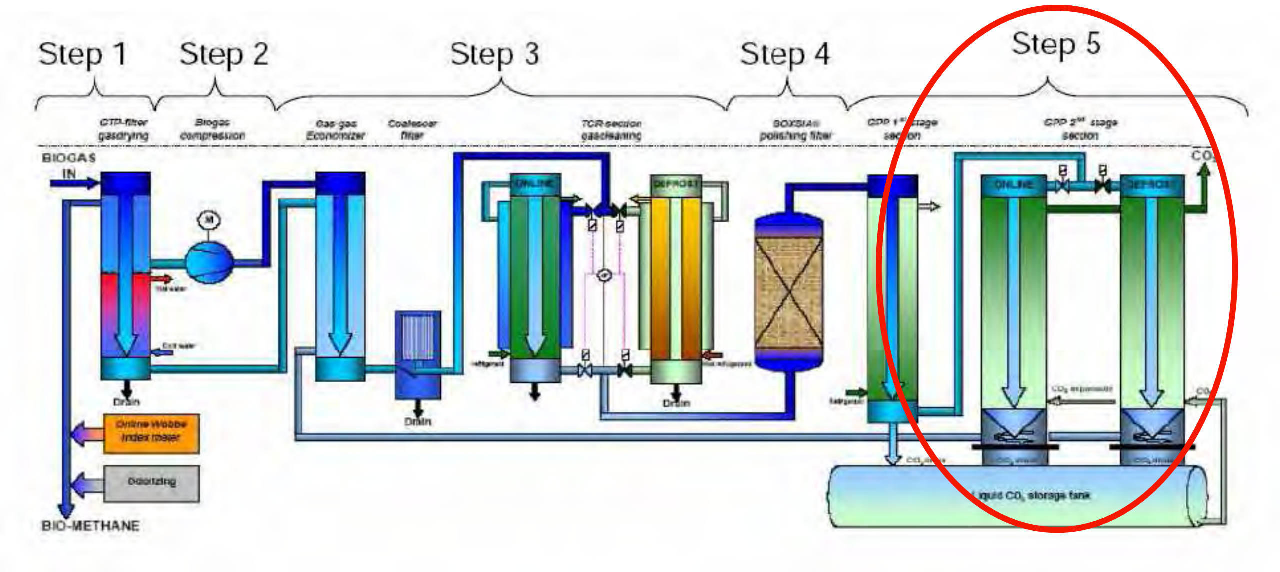
Step 1: Gas drying.

Step 2: Compression.

Step 3: Gas cleaning – siloxane removal.

Step 4: Desulfurization.

Step 5: Carbon dioxide removal.



[GTS, 2008]

Figure 12: Overview cryogenic upgrading process (Example: GPP® of GtS).

3. CONCLUSION

Currently, three different biogas upgrading technologies are part of the monitoring programme in the BIOGASMAX project. For each technology, there are at minimum one plant with operational experiences available at the moment. No partner reported critical problems with their implemented biogas upgrading technology. In this report it could be demonstrated that all 3 monitored upgrading systems are applicable for the upgrading of biogas to biomethane. So it can be asserted that the **water scrubber** technology, the **pressure swing adsorption** technology and the **chemical absorption** technology are state-of-the-art for biogas upgrading to biomethane.

4. APPENDIX: SITE DATA

This chapter gives a common overview of all biogas upgrading plants included in the BIOGASMAX project.

4.1. Berne and Lucerne

	Unit	1st plant	2nd plant
Country		Switzerland	Switzerland
BGX Site		Bern	NOVA
BGX partner		ARB	NOVA
City		Berne	Lucerne
Plant name		ARA Region Bern ag (arabern)	ARA Region Luzern
In operation since / inauguration planned		10.01.2008	06.January 2005
Manufacturer of biogas upgrading unit		CarboTech Engineering GmbH	CarboTech Engineering GmbH
Operating company of biogas upgrading unit		ARA Region Bern ag	Gemeindeverband für Abwasserreinigung Region Luzern (GALU)
Operating company of biogas production unit		ARA Region Bern ag	Gemeindeverband für Abwasserreinigung Region Luzern (GALU)
CO_2 removal technique		PSA	PSA
H_2S removal technique		Activated Carbon	Activated Carbon
Biogas volume flow (average in 12/2007)	[Nm³/h]		115
Biomethane volume flow (average in 12/2007)	[Nm³/h]		70
Operating hours foreseen	[h/a]	6.050	4.700
Actual operating hours (2007)	[h/a]		3.800
Biogas composition (average in 12/2007):			
CH_4-concentration	[%]	65,20	61,00
CO_2-concentration	[%]	33,70	37,00
O_2-concentration	[%]	0,50	0,20
H_2S-concentration	[ppm]	<25	-

Biomethane composition (average in 12/2007):			
CH_4-concentration	[%]	97,50	95,70
CO_2-concentration	[%]	2,00	1,30
O_2-concentration	[%]	0,02	0,09
H_2S-concentration	[ppm]	-	-
Manufacturer warranty:			
Plant capacity: Biogas volume flow	[Nm³/h]		110 - 140
Plant capacity: Biomethane volume flow	[Nm³/h]	192	60 - 85
CH_4-concentration in the biomethane	[%]	>96	96,00
Kinds of feedstock		Primary and biological sludge, dairy and food wastes, slaughterhouse wastes	
LPG conditioning	YES / NO	NO	NO
Pressure	[bar]		4,00
Biomethane distribution		Grid injection	Grid
Biomethane utilisation		Vehicle fuel for public transport	Vehicle fuel

Table 1: Biogas upgrading plant sheet Berne and Lucerne.

Picture 1: Biogas upgrading in Berne.

Picture 2: Biogas upgrading in Lucerne.

4.2. Göteborg

	Unit	1st plant	2nd plant
Country		Sweden	Sweden
BGX Site		Göteborg	Göteborg
BGX partner		GE	FK
City		Göteborg	Falköping
Plant name		Arendal	
In operation since / inauguration planned		2007-04-13	January 2008
Manufacturer of biogas upgrading unit		PURAC	Malmberg
Operating company of biogas upgrading unit		Göteborg Energi AB	Göteborg Energi AB
Operating company of biogas production unit		GRYAAB	Municipality of Falköping
CO_2 removal technique		Chemical Absorption	Water Scrubber
H_2S removal technique		Activated Carbon	Water Scrubber
Biogas volume flow (average in 01/2008)	[Nm³/h]	863	100
Biomethane volume flow (average in 01/2008)	[Nm³/h]	558	
Operating hours foreseen	[h/a]	8600	
Actual operating hours (2007)	[h/a]		
Biogas composition (average in 01/2008):			
CH_4-concentration	[%]	63	64
CO_2-concentration	[%]		
O_2-concentration	[%]	0.2	
H_2S-concentration	[ppm]		
Biomethane composition (average in 01/2008):			
CH_4-concentration	[%]	99	97,5
CO_2-concentration	[%]	Not measured	0.7
O_2-concentration	[%]	Not measured	0.5

H_2S-concentration	[ppm]	Not measured	0
Manufacturer warranty:			
Plant capacity: Biogas volume flow	[Nm³/h]	1.600	200
Plant capacity: Biomethane volume flow	[Nm³/h]		
CH_4-concentration in the biomethane	[%]	98,00	97,00
Kinds of feedstock		Sewage sludge	Sewage sludge, household waste
LPG conditioning	YES / NO	YES	NO
Pressure	[bar]	4,00	10,00
Biomethane distribution		Grid	Pipe from upgrading unit to filling station
Biomethane utilisation		Mostly vehicle use but also use in CHP and District Heating	Vehicle fuel

Table 2: Biogas upgrading plant sheet Göteborg site.

Picture 3: Biogas upgrading plant Göteborg [GE].

Picture 4: Biogas upgrading plant Falköping [IWES].

4.3. Lille

	Unit	1st plant	2nd plant
Country		France	France
BGX Site		Lille	Lille
BGX partner		LMCU	LMCU
City		Lille	Lille
Plant name		Marquette	Organic Recovery Center
In operation since / inauguration planned		March 2008	January 2008
Manufacturer of biogas upgrading unit		Flotech	Flotech
Operating company of biogas upgrading unit		SEMEN	Carbiolane
Operating company of biogas production unit		SEMEN	Carbiolane
CO_2 removal technique		Water scrubber	Water scrubber
H_2S removal technique		Water scrubber	Water scrubber
Biogas volume flow (average in 12/2007)	[Nm³/h]	100	750
Biomethane volume flow (average in 12/2007)	[Nm³/h]	> 30	487
Operating hours foreseen	[h/a]	> 8300	8.497
Actual operating hours	[h/a]	Start-up phase	Start-up phase
Biogas composition (average in 12/2007):			
CH_4-concentration	[%]	64,00	56,00
CO_2-concentration	[%]	35,00	
O_2-concentration	[%]		
H_2S-concentration	[ppm]	3.000,00	250,00
Biomethane composition (average in 12/2007):			
CH_4-concentration	[%]		97,00
CO_2-concentration	[%]		0,50
O_2-concentration	[%]		

H_2S-concentration	[ppm]		0,00
Manufacturer warranty:			
Plant capacity: Biogas volume flow	[Nm³/h]	100	1200
Plant capacity: Biomethane volume flow	[Nm³/h]	>30	670
CH_4-concentration in the biomethane	[%]	Gross calorific value > 10.7 kWh/Nm3	Gross calorific value > 10.7 kWh/Nm3
Kinds of feedstock		Sewage sludge	Source separated biowaste
LPG conditioning	YES / NO	no	no
Pressure	[bar]	9,00	9,00
Biomethane distribution		On-site	Dedicated pipeline (planned injection into natural gas grid)
Biomethane utilisation		Bus - Waste collection trucks	Bus - Waste collection trucks

Table 3: Biogas upgrading plant sheet Lille site.

Picture 5: Biogas upgrading in Lille [LMCU].

4.4. Stockholm

	Unit	1st plant
Country		Sweden
BGX Site		Stockholm
BGX partner		VK
City		Västeras
Plant name		
In operation since / inauguration planned		10/2004
Manufacturer of biogas upgrading unit		YIT
Operating company of biogas upgrading unit		Svensk Växtkraft AB
Operating company of biogas production unit		Svensk Växtkraft AB
CO_2 removal technique		Water scrubber
H_2S removal technique		Water scrubber
Biogas volume flow (average in 12/2007)	[Nm³/h]	355
Biomethane volume flow (average in 12/2007)	[Nm³/h]	226
Operating hours foreseen	[h/a]	na
Actual operating hours (2007)	[h/a]	na
Biogas composition (average in 12/2007):		
CH_4-concentration	[%]	63,40
CO_2-concentration	[%]	36,30
O_2-concentration	[%]	0,20
H_2S-concentration	[ppm]	1.000,00
Biomethane composition (average in 12/2007):		
CH_4-concentration	[%]	97,10
CO_2-concentration	[%]	2,90
O_2-concentration	[%]	na

H_2S-concentration	[ppm]	0,20
Manufacturer warranty:		
Plant capacity: Biogas volume flow	[Nm³/h]	550
Plant capacity: Biomethane volume flow	[Nm³/h]	
CH_4-concentration in the biomethane	[%]	>97
Kinds of feedstock		Raw gas from biogas plant and from sewage plant
LPG conditioning	YES / NO	yes
Pressure	[bar]	<= 4
Biomethane distribution		Pipeline to filling station for busses and cars + filling station for movable gas storages
Biomethane utilisation		As much as possible for vehicle fuel. Surplus gas for production of electricity and heat

Table 4: Biogas upgrading plant sheet Stockholm site.

Picture 6: Biogas upgrading in Västerås - Stockholm.