Urban Waste for Biomethane Grid Injection and Transport in Urban Areas

Project No: IEE/10/251

URBAN BIOGAS
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Biogas & Biomethane Production in Graz

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Abbreviations

BGP	biogas plant
BGUP	biogas upgrading plant
CH_4	methane
CHP	combined heat and power
CO_2	carbon dioxide
DM	dry matter content
L_{org}	organic load [kg_{oDM}/m^3_R*d]
oDM	organic dry matter content
t_R	retention time [d]
Y_{gas}	specific biogas yield [m^3_N/kg_{oDM}]
Y_{CH4}	specific methane yield [m^3_N/kg_{oDM}]
m	million
Nm³	standard m³

1 Introduction

Graz has about 270.000 main residences and 30.000 second residences. The area is about 128 square kilometres with 40 percent green spaces. There are 57.000 buildings with 110.000 households.

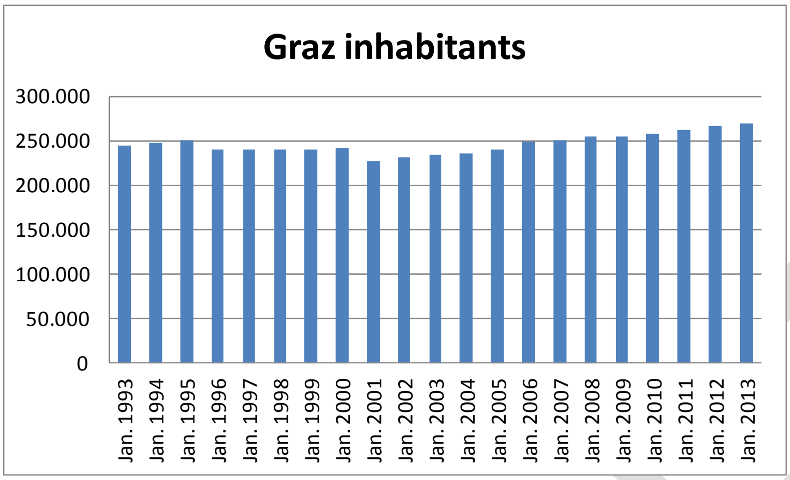

Figure 1: Development of inhabitants in Graz from January 1993 – January 2013
(Source: Magistrat Graz, Präsidialamt, Referat für Statisik)

The "greater area" of Graz (including the surroundings) has about 439.000 inhabitants.

At the moment the municipal waste in Graz is collected at approximately 34.000 sites where bins for residual waste (non-recycleable waste), organic waste, paper, glass, metal and plastic are located. In general, organic waste in Graz is separately collected from households by brown bins. Larger amounts of green waste can be deposited at the Recycling Centre Sturzgasse.

Organic and green waste are mixed and pre-treated at the organic waste treatment plant Sturzgasse Graz and then treated in the composting plant in Frohnleiten (bio-mechanical organic waste treatment plant). Unfortunately, the potential energy from organic waste is not used optimal at the moment, but the landfill gas is used in two CHP plants for electricity and heat generation.

As already mentioned in the waste management report in WP3 there is the intention of the municipality, the local energy supplier and the waste management companies to use the organic waste from the households of the city of Graz and its surroundings together with other organic waste from restaurants, caterings, supermarkets and the food industry in a biogas plant in or near Graz. The goal is to upgrade the biogas to biomethane, to feed it into the natural gas grid and to use it on one side for the (public) transport and on the other side as a green product "Naturgas" which can be sold to households, companies, etc. for using it for example in CHP plants to use the heat locally at site and to get a attractive feed in tariff for the green electricity.

In the following report the above mentioned key players in Graz are named "consortium partners Graz" as they are planning all the activities concerning the potential biogas/biomethane plant in Graz together. Up to now there is no written agreement about the collaboration but this is going to follow as one of the next steps.

2 Survey of available feedstock (incl. results of WP3)

2.1 Municipal solid waste, organic in Graz and its vicinity

In Graz approximately 130.000 tons of waste are collected per year, consisting of 44.000 t/a residual waste (non-, 26.200 t/a paper, 20.400 t/a recyclable waste (metal, plastic), 18.200 t/a biowaste, 8.400 t/a glass, 6.700 t/a green waste (garden waste), 400 t/a hazardous waste and 7.000 t/a others. In the year 1990, the annual amount of waste accounted for 118.170 tons and then steadily increased up to the year 2005 (131.515 t). Only 17.500 t/a are land filled, the majority is used energetically or material. Figure 2 and

Figure **3** show the development of the amount of waste in Graz from 1990 to 2005. While Figure 2 represents absolute numbers,

Figure 3 represents the amount of waste per inhabitant.

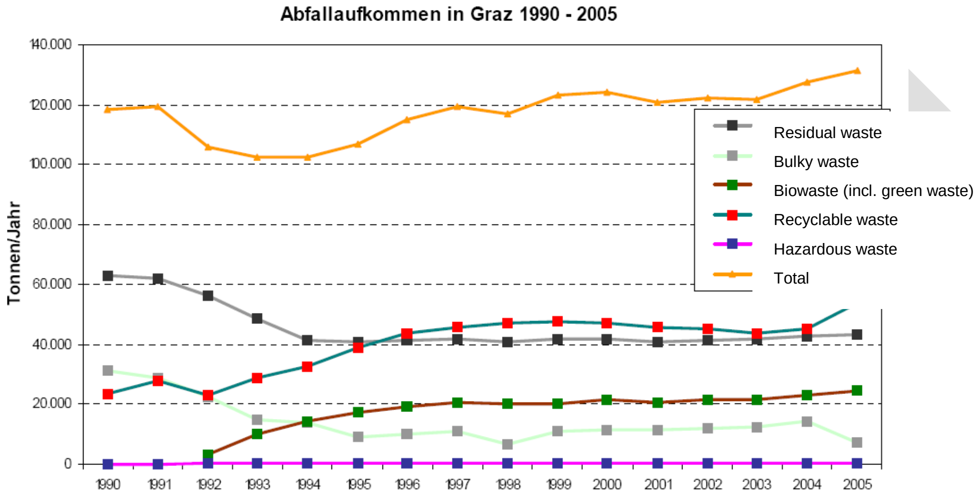

Figure 2: Development of the yearly amount of waste in Graz from 1990-2005 (Source: Stadt Graz - Umweltamt, 2007)

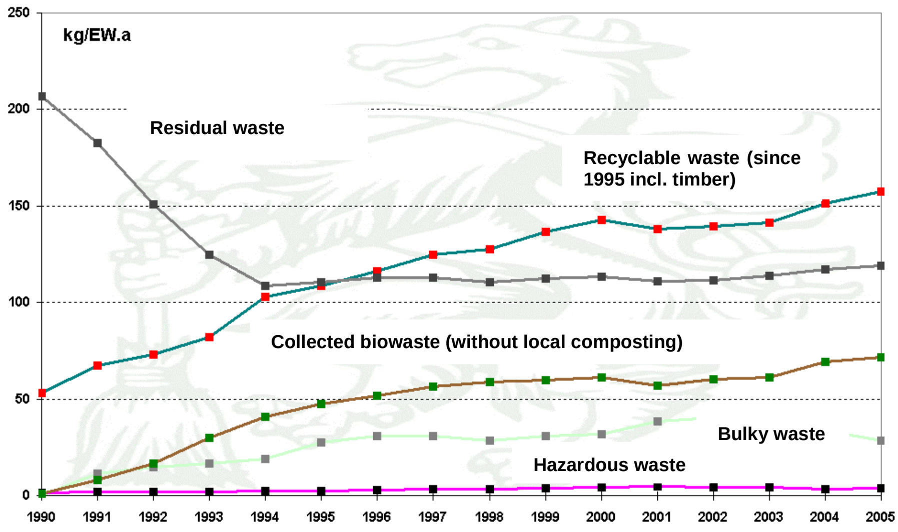

Figure 3: Development of the waste amount in Graz from 1990-2005 per inhabitant (Source: Stadt Graz - Umweltamt, 2007)

2.1.1 Organic waste accumulation in Graz

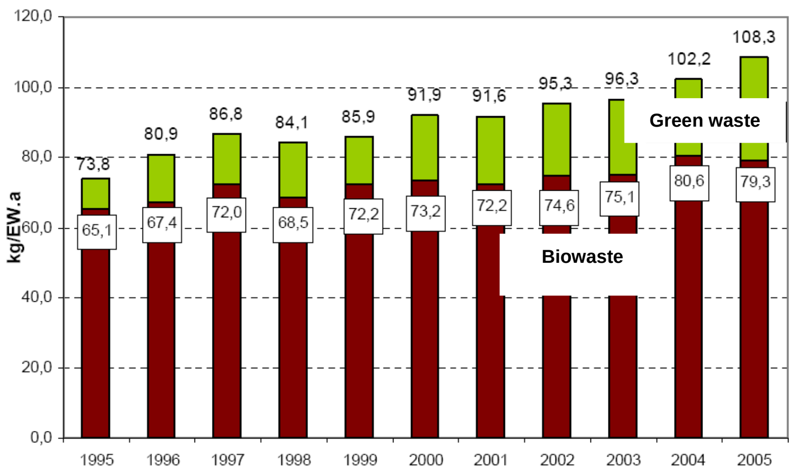

Figure 4: Amount of organic waste from separated municipal solid waste collection in Graz (Source: Stadt Graz - Umweltamt, 2007)

Figure 4 shows the amount of organic waste from the separated municipal solid waste collection in Graz per inhabitant per year. It contains compostable municipal solid waste, like kitchen waste, garden rubbish, waste resulted from food market and cemetery waste. Organic waste composted by inhabitants themselves (approximately 12% of the population of Graz) is not included in that figure (source: Stadt Graz – Umweltamt 2007)

There is additional organic waste induced by the industry (e.g. restaurants, super markets, caterings, etc.) which are not quantifiable.

2.1.2 Collection of organic waste from municipal solid waste

The Holding Graz, a company of the city of Graz, is in charge for the waste collection and the waste treatment in the area of Graz. At approximately 34.000 sites in Graz, bins are located for residual waste (non-recyclable waste), organic waste, paper, glass, metal and plastic. In general, organic waste in Graz is separately collected by the households themselves in special brown bins. Larger amounts of green waste can be deposited at the Recycling Centre Sturzgasse. Furthermore there is a chaff service for e.g. tree-cut material for treatment directly in the garden. Cooking oils and fat are collected separately in yellow buckets or bins.

2.1.3 Utilization of organic waste

Organic and green waste are mixed and pre-treated (e.g. metals and plastic elements are removed) at the organic waste treatment plant Sturzgasse in Graz. Then the waste is further treated in the composting plant in Frohnleiten. The bio-mechanical organic waste treatment plant in Frohnleiten is owned by SERVUS ABFALL a company which closely cooperates with the city of Graz through a public-private partnership. Additionally, in some households in Graz and especially in the surroundings of Graz organic waste is composted and used in agriculture.

The collected cooking oil is recycled to biodiesel, soaps, cleaning agents and machine oils. The city of Graz serves as an exemplary model, because they use biodiesel (made of cooking oil) for the public bus transfer.

Unfortunately, the potential energy from organic waste is not used at the moment, but the landfill gas at the site in Frohnleiten is used in two CHP plants for electricity and heat generation.

2.1.4 Key players involved

Figure 5: Public-private partnership (Source: SERVUS ABFALL Online)

In the year 2002, the SERVUS ABFALL Dienstleistungs GmbH & CO KG was founded as a public-private partnership between the Holding Graz and the EBG (Entsorgungsbeteiligung Graz GmbH NFG & CO KG). Through this public-private partnership, the strengths of all partners are bundled and they focus on clean solutions.

The public part of the partnership is represented by the Holding Graz GmbH, which is together with SERVUS ABFALL, responsible for the separated collection of paper, glass, municipal solid waste and organic waste. Furthermore, the Holding Graz runs the above mentioned biological waste treatment plant for municipal solid waste at Sturzgasse. The Holding Graz GmbH is owned by the city of Graz.

The private part of the partnership is represented by the EBH (Entsorgungsbeteiligung Graz GmbH NFG & CO KG), which consists of the “Gemeindebetriebe Frohnleiten”, the “Saubermacher AG”, the “Hans Hütter GmbH” and “entsorgt”.

Commercial waste in Graz is collected by Saubermacher, ASA, Müllex or others.

2.2 Current and future costs of disposal

Since 1990, Styria has continuously expanded the infrastructure for the separate collection of waste and operates now of a very convenient collection system (more than 400 waste collection centres and problem material collection centres). The federal region of Styria subsidised the municipalities with 21,2 million €. The widespread services concerning waste management are cost intensive and are passed down to the responsible municipalities. Figure 6 shows the costs of disposal in Austria from 1995 to 2006. The annual costs of disposal in Austria per person amounted to 66,4 € and per household to 154 € in 2006.

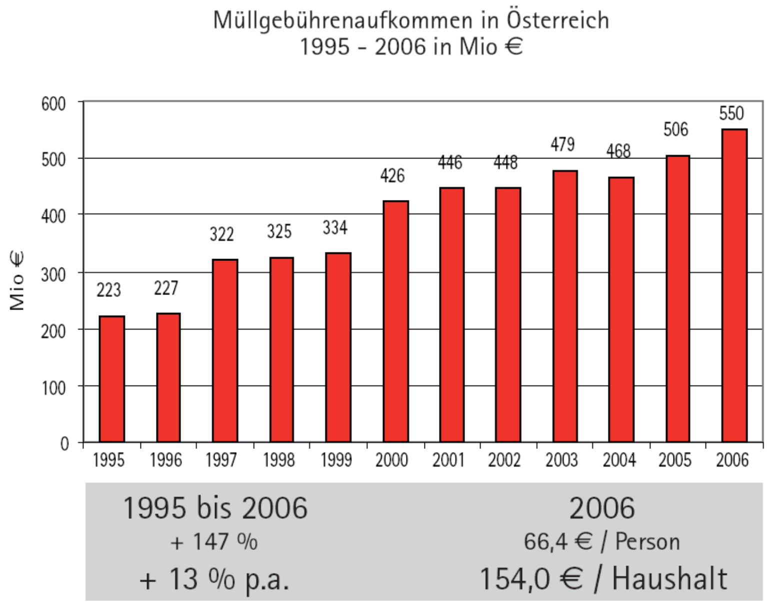

Figure 6: Costs of disposal in Austria (Source: Land Steiermark – FA 19D, 2008)

In contrast to that, the costs of disposal in the federal region Styria are much lower and accounted in 2006 to 115 € per household. The costs of disposal consist of a base fee and a variable fee. The base fee is independent from the amount of waste and covers 2/3 of the waste management costs. It is calculated per accommodation unit, household or person. The variable fee is depending on the amount of waste and covers 1/3 of the waste management costs.

The tariffs of disposal for the city of Graz are constituted by the Holding Graz GmbH. For municipal solid waste the tariffs consist of a base and a performance fee based on waste quantity, whereas the performance fee includes a collecting and disposal fee. The basis for calculating the fee is the collected amount of waste per removal (depending on the size of the bins) and the number of removals. For the collection of organic waste there is an additional fee ("Biozuschlag" – table 1).

Table 1 shows the tariff system in Graz for 120 l bins (status May 2013).

Tarif A zur Grazer AbfO 2006 (Gebühr in Euro pro Jahr excl. gesetzlicher Umsatzsteuer)						
Behälter-größe	Entleerungen	Grund-gebühr	Leistungs-gebühr	Gesamtgebühr mit Kompostbonus	Bio-zuschlag	Gesamtgebühr ohne Kompostbonus
120 Liter	1 x pro Woche	115,23	252,03	367,30	60,39	427,70
	2 x pro Woche	230,46	504,05	734,50	120,78	855,30
	14-tägig	57,61	126,01	183,60	30,81	214,40
	vierwöchig	29,17	62,03	91,20	17,25	108,50

Table 1: Tariff system for costs of disposal in Graz (Source: Holding Graz Online)

3 Product biomethane

3.1 Calculation of prospective biogas and biomethane yield

The estimated potential of organic waste, which could be utilized in the potential biogas plant Graz, accounts for approximately 48.000 t/a and consists of [redacted] organic waste from the brown organic waste bins (dry matter about 30%), [redacted] food waste from restaurants caterings and the food industry (dry matter about 20%), [redacted] expired food from supermarkets and suppliers (dry matter about 20%), and [redacted] t/a old bread from bakeries (dry matter about 65%).

[redacted]

Figure 7: Estimated potential of organic waste for plant Graz

[redacted] t/a organic waste arise directly in Graz; the rest comes from its surrounding districts, e.g. from Graz-Umgebung, Voitsberg, Leibnitz, Bruck and Bad Radkersburg. One of the most important targets is to have transport routes from the waste collection points to the biogas plant which are as short as possible. In order to fulfil this criteria the biogas plant has to be situated near Graz. The definite site is not yet determined up to now.

A detailed study about the bio-waste potential in Styria was carried out by the Landesenergieverein Steiermark in the project “Biogas Feasibilitystudy Steiermark” (LEV – Biogaspotentialstudie für das Land Steiermark, 2005)

With the above mentioned feedstock, about 5,3m m³ biogas with an average methane content of about 59% can be produced per year. Upgrading to biomethane (98% methane) results in about 3,2m m^3 biomethane per year.

The following figure shows the detailed calculation of the biogas volume for the plant Graz and the assumptions concerning dry matter content, specific biogas yield and methane content of the different feedstock materials:

[redacted]

Table 2: Calculation of biogas volume for plant Graz

Compared with the heating demand of households, 3,2m m³ of biomethane correspond to 36.000.000 kWh/a or the annual heating demand of about 5.000 households.

The city of Graz has a district heating net and a natural gas grid for supplying households, offices, companies etc. with energy for heating and industrial processes (more details see WP 5 and Figure 8). There are areas with mainly gas supply and other areas with mainly district heating supply. For feeding the biomethane into this natural gas grid connections to level 3 (< 10 bar) can be used.

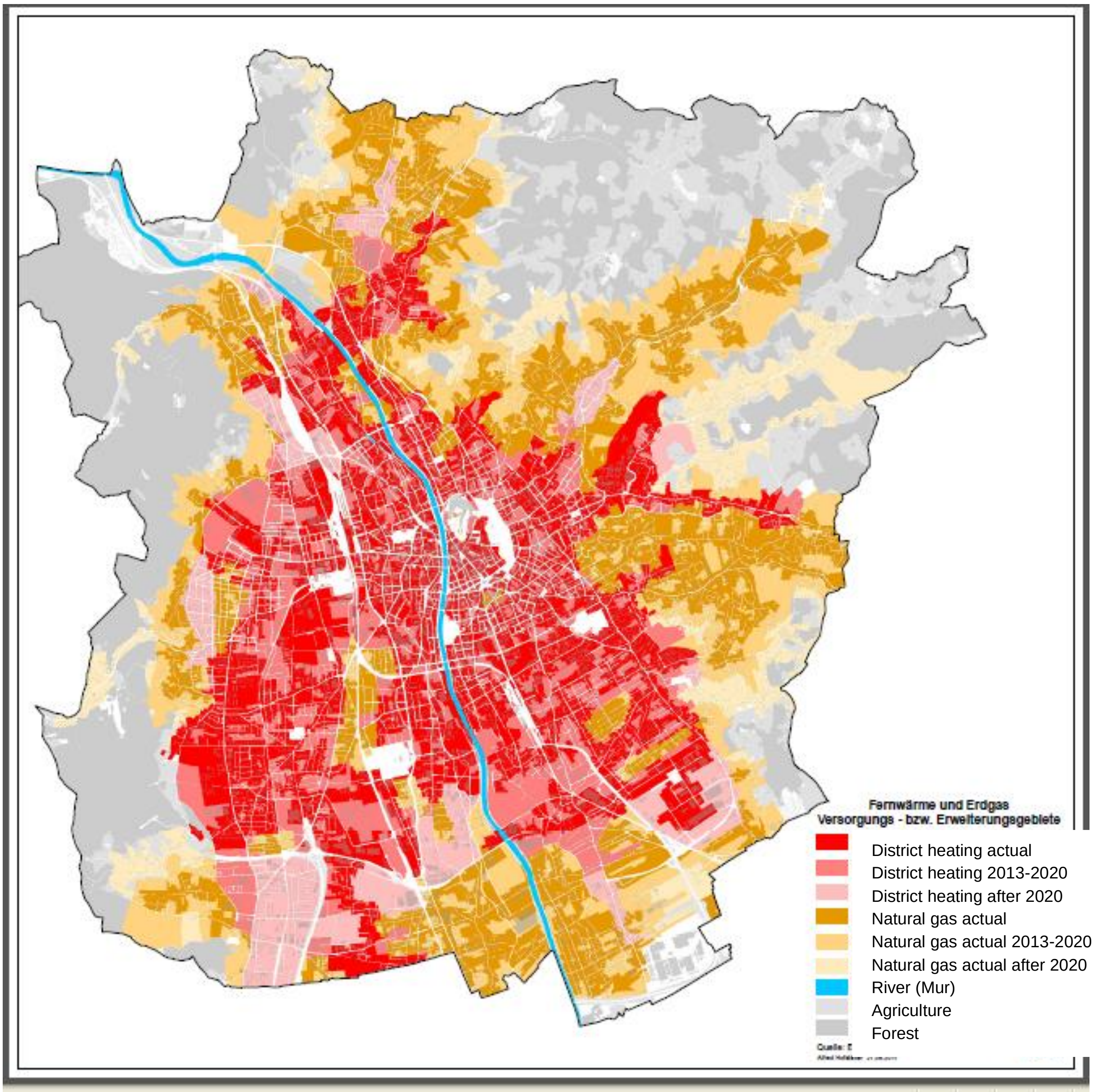

Figure 8: Actual and prospective district heating and natural gas supply area in Graz (source: Stadt Graz Stadtplanung / Energie Graz, status 2011)

3.2 Prospective demand, set targets from WP 5

The produced biomethane should be used in CNG cars/vans, CNG busses for the public transport in Graz and CNG trucks on the one hand and on the other side, the biomethane should be sold to potential customers as “Naturgas”. “Naturgas” is a brand name of the Energie Steiermark for a gas product which includes a defined percentage (10% to 100%) of biomethane. If this “Naturgas” is used, for example, in combined heat and power plants (CHP-plants), the produced electricity can be fed into the grid and it is possible to get good subsidies for this green electricity called “Ökostrom”. The prospective demand and shares among the partners of the “consortium Graz” is shown in the following figure and list (confidential data):

Figure 9: Sales concept of the produced biomethane in Graz

Shares according to groups of users:

3.3 Comparison of biomethane production and demand, conclusion

A rough calculation shows that there are enough potential users for biomethane in the consortium and their customer groups. For example at the moment there are about 135 busses in Graz which need about 4m liters of Diesel per year, which is an energy demand of about 39m kWh/a (about 3,6m m³/a of biomethane). Energie-Steiermark already has the product “Naturgas” in their product portfolio (because they have the upgrading plant in Leoben), but in the last year the demand from potential customers was higher than in the last 2 years the output of the plant in Leoben was very low because of legal and technical adaptation works at the plant).

But it is necessary to strongly push the demand for biomethane to ensure a long term use of this product. A higher demand for biomethane should be created, e.g. through the organisation of campaigns and workshops.

Furthermore, the markets have to be boosted (e.g. the market for CNG-vehicles, especially for larger sized ones like trucks and busses) and the situation about the feed-in tariff for green electricity from CHP plants driven with biomethane has to be more transparent (total funding budget, confirmation of the feed in tariff immediately after request and not months/years later, etc. – for more details see WP 5).

4 Biogas Production

Good practice plant

Rostock, Germany (reference: UrbanBiogas Best practice sheet)

The biogas/biomethane plant Rostock was chosen as a good practice model for the planned plant in Graz, because the initial situation and frame conditions are quite similar.

Municipal organic waste of the municipalities Hansestadt Rostock, Bad Doberan, Nordvorpommern and Güstrow is treated at the organic recovery center (ORC) in Rostock. Before the biogas plant was built, incoming waste had been used to produce compost and to substitute fossil fuel in an incineration plant. Since 2010, when the operation of the biogas plat has started, the digestible organic waste fraction has been used to produce biogas in a biogas plant. E.ON Hanse Wärme GmbH (energy utility) uses the biogas in two CHP plants for the cogeneration of electricity and heat. Since February 2011 the surplus biogas production has been upgraded to biomethane and injected into the public gas grid.

Biogas plant - technical details

Start of operation	2010	Biogas production	1000 m^3/h
Implementation time	No data	Hydraulic retention time	12-16 d
Number of digesters	3	Organic load	No data
Volume of digesters	3.600	Biogas quality	> 55 Vol.%
Gas storage volume	No data	Energy consumption	No data

Feedstock

Total amount of feedstock	40.000 t/y	100%
Food waste	4.000 t/y	10%
Municipal waste	36.000 t/y	90%

Biogas upgrading plant – technical data

Start of operation	2011	Plant availability	>96%
Upgrading system	Water scrubber	Biomethane utilization	Gas grid injection
Plant manufacturer	Cirmac	Waste air treatment	No data
Upgrading capacity (raw gas eq)	350 m^3/h	Methane loss	No data
Methane content	>98%		

The biogas plant in Rostock reduces the CO_2 emissions in the region by 15.200 t/a through the production of biomethane, heat and electricity.

Figure 10: Biogas/biomethane plant Rostock, Germany (Source: EVG Entsorgungs-und Verwertungsgesellschaft mbH Rostock)

Planned plant in Graz

In the task force meetings with the members of the “consortium Graz” a first plant concept for the potential plant in Graz was figured out. The main framework conditions for the further detailed planning are:

Main objective: treatment of organic urban waste; biogas production; upgrading to biomethane and feeding into natural gas grid; using digestate as fertilizer (at the moment usage as liquid fertilizer is planned)

Feedstock: organic urban waste; food waste from restaurants, caterings and the food industry; expired food from supermarkets and suppliers; old bread from bakeries; mainly from the city of Graz and its surrounding districts

Plant size: 48.000 t organic waste per year; storage for digestate for 6 months

Technology: wet digestion

Location: surrounding districts of Graz; maximum distance to city boundary about 10km; good (close) connection to natural gas grid; acceptance of neighbourhood

4.1 Technology

Based on the above mentioned framework conditions the rough concept of the biogas plant and the upgrading plant was developed.

4.1.1 Biogas Plant

The main parts of the biogas plant are:

- Closed delivery hall with interim storage, shredding, separation and hygienisation
- Fermentation tanks
- Processing of fermentation residues with, dewatering, water treatment and storage

At the moment the usage of the digestate as a liquid fertilizer is planned as there is already one potential customer for this product.

There is a Styrian company called Komptech which has the expertise and capacity to equip biogas plants with complete system solutions, from input material to the desired end products. It is a central component vendor for builders and operators of fermentation plants - shredders for precise shredding, wet and dry screens, pulpers, presses and sand separators. Komptech is therefore one of the most preferred manufacturers for the biogas plant Graz.

That is also the reason why the following description of the biogas-process is mainly based on the data of the company Komptech. The following figure shows the whole biogas-production cycle in a schematic flow sheet.

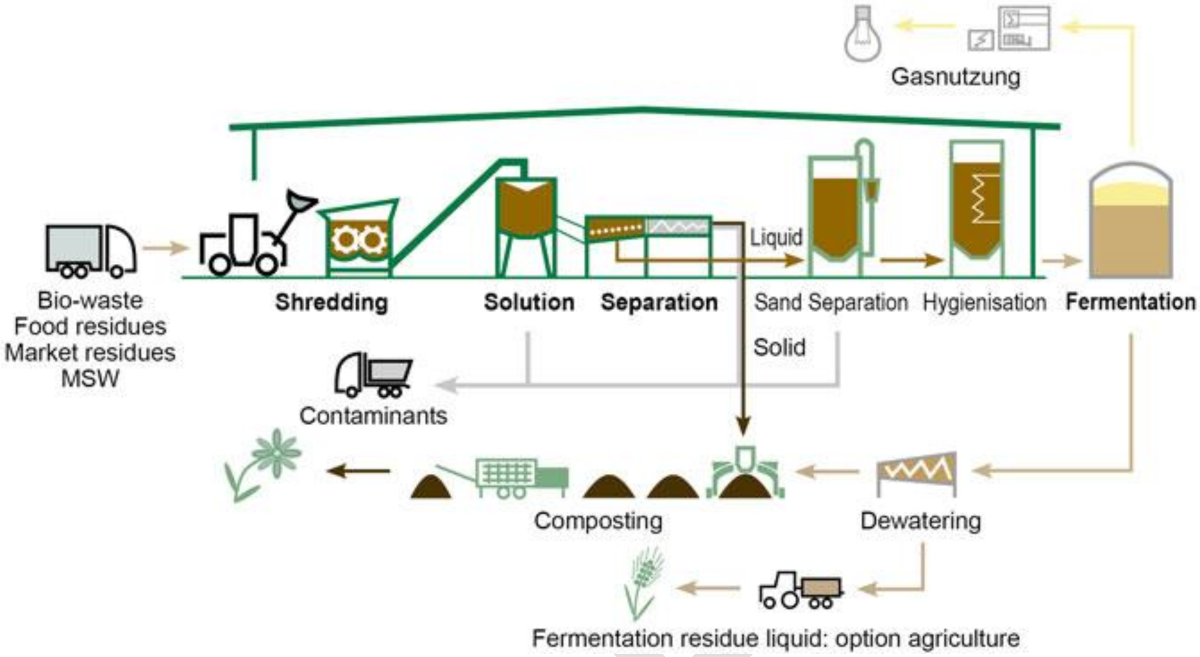

Figure 11: The biogas process (Komptech GmbH, http://www.komptech.com/en/waste/fermentation.htm)

As the figure above shows, organic waste materials need a consequent pre-treatment of the incoming substrates, as there are impurities as stones, packaging materials, plastic bags, metals, etc. in the substrate. The following figure shows the pulper process in detail:

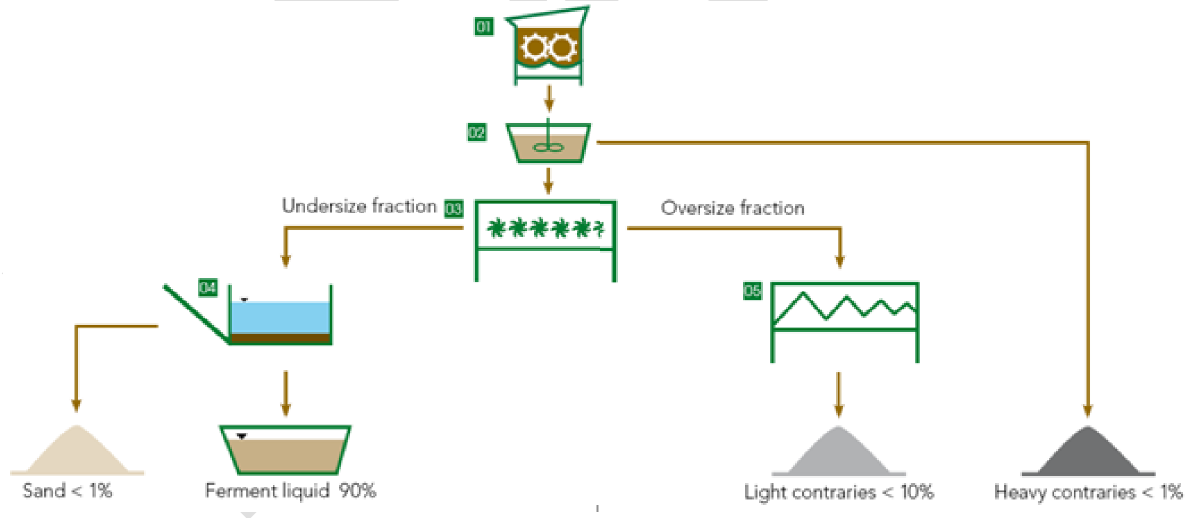

Figure 8: The pulper process (Komptech GmbH, http://www.komptech.com/en/waste/fermentation.htm)

Legend
01 Shredding
02 Pulping with heavy matter separation
03 Wet screening
04 Sand separation
05 Pressing of oversize fraction

The pulper process with precisely coordinated machines results in a liquid that is ideal for fermenting. The figure above shows the technology developed by Komptech. The process is ideally used for collected biodegradable waste, food scraps, expired foodstuffs and food industry waste.

1. **Shredding**
   Shredding at low speed opens up the organic material and prepares it for liquefaction. The aim of shredding is that the biodegradable, often contaminated waste, is reduced to a maximum particle size to reduce the danger of blockages. Contraries, like packaging, need to be shredded as gently as possible for subsequent screening.
2. **Pulping**
   In this step, the shredded material is turned into a liquid that can be separated in the subsequent wet screening step. Heavy contaminants are removed.
   The aim of this step is to turn the waste into a material with the right consistency for subsequent screening. It has to have a certain viscosity, so that the oversize fraction can be screened out of the ferment liquid. In the pulping step, waste is diluted with liquid and mixed at high turbulence in batches, to achieve the required viscosity level. After that, the fluid is sent on to wet screening. Within the process, a heavy material sluice periodically removes heavy items, like metal, glass, bones, stones and ceramics. This protects subsequent machines in the process from damage and excessive wear-out.
3. **Wet screening**
   In this step, oversize fraction and light contaminants are separated out.
   In order to achieve a contrary-free pumpable liquid, the pulp needs to be screened in the 10-20 mm range.
4. **Sand separation**
   In this step, abrasive fines are removed from the ferment liquid. It mechanically dewaters the oversize fraction with light contaminants. The ferment liquid is now ready for biogas production. A setting tank collects the sand from the pulp.
   The amount of oversize fraction and sand depends on the input material. The oversize fraction amounts to 5 percent by using food scraps and goes up to 15 percent with mixed garden and kitchen waste.

During hygenisation the substrate is heated up to about 70°C for one hour to eliminate bacteria as the waste product after the fermentation should be used as fertilizer in agriculture. After this step the fermentation substrate exhibits ideal properties for simple fermentation.

The ideal digester system is based upon the on-site conditions and kind and quality of the processed waste. For the designed capacity of the biogas plant Graz, a continuous operation process is a pre-condition. The size and the number of digesters have to be designed appropriately in the detailed planning step.

As the digestate used as a fertilizer can not be used throughout the whole year (crops don’t need fertilizing in winter) it has to be stored. Ideally, the storage facilities of the digestate are covered so that the biogas from the lower, but still ongoing anaerobic digestion can be used and the emissions (odour, methane, etc.) can be reduced. As the storage facilities of the substrates and the digestate should be at the same location as the biogas plant, adequate area has to be considered. As the exact framework-conditions with the potential customers of the fertilizer are not cleared up to now a storage time of about 6 months has to be considered for the needed storage volume in Graz.

4.1.2 Upgrading Plant

Biogas mainly consists of methane and carbon dioxide. For some applications, where a high energy content is necessary, the biogas has to be upgraded – like it is planned in the plant Graz. The energy content of biogas is directly linked to its methane concentration. Therefore, if biogas is upgraded the methane content of the gas is increased by removing carbon dioxide.

Table 3 shows the composition of biogas, landfill gas and natural gas.

Due to increased oil and natural gas prices, upgrading of biogas is getting increased attention in general. However, upgrading of course adds to the costs of biogas production. Because of that, the upgrading process has to be – in terms of energy consumption and efficiency - optimized. Furthermore, it is important to minimize or avoid methane emissions from the upgrading process. Nowadays, several techniques for biogas upgrading exist and several are still under development.

	Biogas	**Landfill gas**	**Natural gas (Danish)**
Methane (vol-%)	60-70	35-65	89
Other hydro carbons (vol-%)	0	0	9.4
Hydrogen (vol-%)	0	0-3	0
Carbon dioxide (vol-%)	30-40	15-50	0.67
Nitrogen (vol-%)	~0.2	5-40	0.28
Oxygen (vol-%)	0	0-5	0
Hydrogen Sulphide (ppm)	0-4000	0-100	2.9
Ammonia (ppm)	~100	~5	0
Lower heating value (kWh/Nm^3)	6.5	4.4	11.0

Table 3: The composition of biogas, landfill gas and natural gas (Source: Petersson/Wellinger, 2009)

Upgrading plant technologies

The following figure shows the upgrading technologies which can be separated in 4 groups:

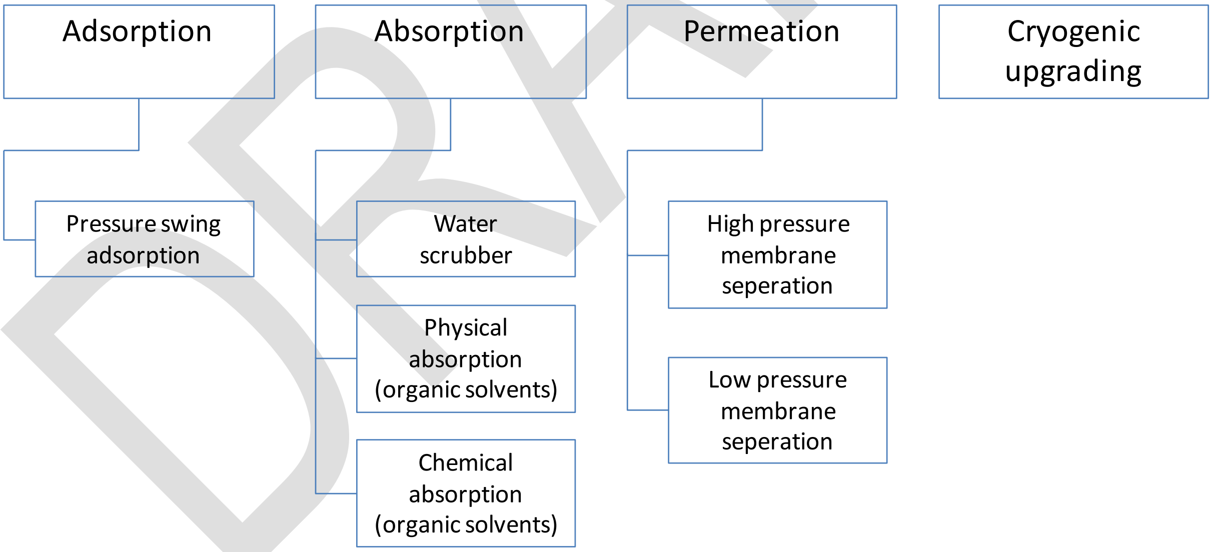

Figure 12: Overview of biogas upgrading technologies

A detailed description of the different upgrading technologies can be found in the report “Biomethan – Technologie & Rahmenbedingungen” a product of the IEE Bio-Methane Regions project (LEV 2012).

The following figure shows a summary of the main specifications of the different technologies.

Parameter	**Pressure swing adsorption (PSA)**	**Water scrubber**	**Physical absorption**	**Chemical absorption (Amine scrubber)**	**Membrane technology**
Typical plant size [m³/h biomethane]	300 - 800	200 – 1.200	300 – 1.500	400 – 2.000	50 - 500
Gas quality [CH4 content in %]	95 - 99	95 - 99	95 – 99	> 99	> 98
Methane slip [% of RBG]	< 2%	< 2%	< 4%	< 0,1%	20 – 0,5
Operation pressure [bar]	4-7	4 - 8	4-8	0	4-7
Electricity consumption[kWh el /m³ biomethane]	0,46	0,46	0,49-0,67	0,27	0,25-0,43
Heat demand and temperature level	no	no	Medium (70 – 80°C)	High (120-160°C)	no
Demand for chemicals	no	no	yes	yes	no
Desulphurisation needed	yes	depending on substrate	yes	yes	yes
Part-load operational range	85-115	50-100	50-100	50-100	50-105
Number of reference plants	high	high	low	medium	low
Typical investment costs [€/(m³/h) Biomethane] for 250 m³/h	5.400	5.500	5.000	5.000	4.700-4.900
Typical investment costs [€/(m³/h) Biomethane] for 500 m³/h	3.700	3.500	3.500	3.500	3.500-3.700
Typical operation costs [€ct/m³ Biomethane] for 250 m³/h	10,1	10,3	10,2	12,0	7,7-11,6
Typical operation costs [€ct/m³ Biomethane] for 500 m³/h	9,2	9,1	9,0	11,2	6,5-10,1

Table 4: Upgrading plant technologies based on LEV 2012

For the plant in Graz the pressure swing adsorption (PSA)-technology is currently preferred, but also chemical absorption (amine scrubber) or membrane-technology are in discussion. Therefore the PSA-technology is described more in detail afterwards and for the economic calculation in 4.4 the PSA technology was considered.

Pressure Swing Adsorption (PSA)

With Pressure Swing Adsorption, carbon dioxide is separated from the biogas by adsorption on a surface under elevated pressure. The adsorbing material, usually activated carbon or zeolites, adsorbs the carbon dioxide and so the methane content of the biogas is increased. The adsorbing material is regenerated afterwards by a sequential decrease in pressure before the column is reloaded again. An upgrading plant, using the described technique, has 4, 6 or 9 vessels parallel working. When the adsorbing material in one vessel becomes saturated, the raw gas flow is switched to another vessel in which the adsorbing material has been regenerated. During regeneration, the pressure is decreased in several steps. The gas that is desorbed during the first and eventually the second pressure drop may be returned to the inlet of the raw gas, since it will contain some methane that was adsorbed together with carbon dioxide. The gas desorbed in the following pressure reduction step is either led to the next column or if it is almost entirely methane free it is released to the atmosphere. If hydrogen sulphide is in the raw gas, it will be irreversibly adsorbed on the adsorbing material. Furthermore water in the raw gas can destroy the structure of the material; due to that, hydrogen sulphide and water has to be removed before the PSA column (source: Petersson/Wellinger, 2009).

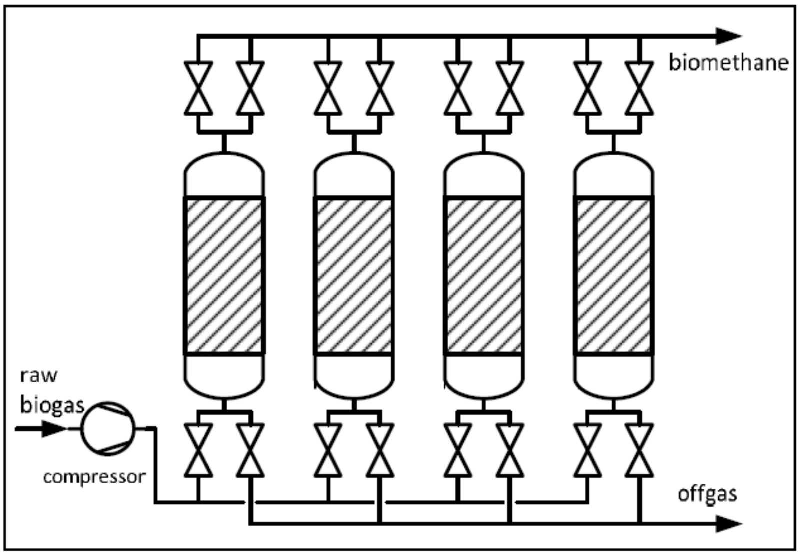

Figure 13: Flow chart of a PSA upgrading system (source: LEV 2012)

Main use / advantages:

- small and medium size installations (300 to 800 Nm^3/h)
- required methane concentration between 95% and 99%
- when biomethane is needed at a pressure level of about 4 to 7 bar no additional compression is necessary
- simple physical principle, high number of references

Disadvantages:

- desulfurization (and in most cases drying of raw biogas) necessary
- relatively high electricity demand
- disposal of activated carbon
- lifetime of adsorbing material

4.2 Technical and legal standards/requirements

The technical requirements for biogas plants are presented in the „Technische Grundlage für die Beurteilung von Biogasanlagen 2012“ (bmwfj). This document is actualized annually by the Federal ministry of economy, family and youth (bmWfi). The document contains actual requirements concerning technology and processes, dangers, information concerning operation and maintenance, an overview over the needed approval documents and an overview of relevant directives and guidelines.

With regard to legal requirements, a biogas plant represents in Austria a typical cross-sectional matter. A biogas plant might be seen as an agricultural plant, an industrial plant or a waste treatment plant. The legal appraisal depends on the legal status of the operator, the used material and the type of energy production. Furthermore, the size of the plant and the quality of the basic products are important.

The approval process of such a plant depends on the criteria mentioned above. There is no standardized process.

Depending on the plant, the following departments might be affected:

Land use planning, civil engineering, fire protection, engine construction, process engineering, electrical engineering, explosion prevention, groundwater protection, protection of waters, air pollution control, noise protection, waste management, chemistry of waste, waste engineering, hygiene, industrial safety, traffic engineering.

The main aspects about technical requirements are also defined ÖNORM S 2201 “Organic waste - Quality requirements”, ÖNORM S 2207-1 “Fermentation plants – part 1: terms and definitions” and ÖNORM S 2207-2 “Fermentation plants – part 2: technical requirements for process technology”.

Further specific legal norms have to be considered, if the produced natural gas is fed into the natural gas grid. Natural gas grid operators have to allow the access to the grid for the feed-in of biogas, if the produced biogas complies with the ÖVWG-guideline G31 (for imported gas) and ÖVWG-guideline G33 (for gas from regenerative processes).

Approval process

As already mentioned, there is no standardized approval process for biogas plants in Austria and Styria.

The most common approval processes in Styria are (LEV, 2012, p. 17):

- Planning law approval (building law)
- Approval according to waste management law
- Approval according to animal materials act
- Approval according to protection of waters
- Approval according to trade law

Operation of biogas plants / training of the staff

All necessary requirements about the operation of a biogas plant are defined in the guideline ÖWAV-Regelblatt 515 (ÖWAV Regelblatt 515, 2013). This rule sheet is on a very actual basis and is also based on practical experiences. It includes:

- Basics about anaerobic waste treatment
- Requirements for the raw materials
- Operational management
- Requirements for products an residues

One of the most important parts within the operation of a biogas plant is the training of the staff. Four functions have to be distinguished, which are essential for a secure operation and an operation of the biogas plant, which conforms to law.

Plant manager: The person who is mentioned to the regulatory authority as responsible and natural person. This person has to be trained regarding possible dangers of a biogas plant. Furthermore the staff has to finish a training (incl. exam) according to ÖWAV rule sheet 516 (ÖWAV Regelblatt 516, 2009).

Operational plant attendant (gas engine or gas turbine): This person has to fulfil the requirements of the steam boiler operation law and the ordinance on steam boilers.

Control and monitoring of the power plant: The requirements depend on the specific Austrian province and are defined in the federal electricity industry and organisation law.

Fire protection officer: This person needs to be educated according to TRVB O 117.

4.3 Plant location

One of the most important targets is to have transport routes from the waste collection points to the biogas plant which are as short as possible. Because of that the biogas plant has to be situated near Graz. Further conditions that define the plant site are: Distance to the gas grid should be as short as possible (2 to 5 km), access to the motorway, access to water ways, sufficient electrical power supply, consideration of the neighbourhood due to noise, odour, lights, traffic volume and the presence of sceptical citizens. The definite site is not yet determined, 2 sites are in evaluation.

The following figures show the gas grid in Styria and in the south-eastern part of Austria. In Graz feeding into the gas grid on level 3 (<10 bar) would be possible as there are enough consumers for the calculated biomethane volume of the potential biogas plant Graz (confirmation of the local gas supplier already existing).

Figure 14: Gas grid Styria (Source: http://www.gasnetzsteiermark.at/)

Figure 15: Gas grid in the south eastern part of Austria (Source: OMV)

4.4 Economy

The total investment costs for the biogas plant, the upgrading plant and the feed-in go up to [redacted]. Planning costs etc. are already included. A detailed calculation of the investment costs was done by the consortium of the biogas plant Graz but it is highly confidential. The expected life time of the plant is 15-20 years. A rough calculation has shown that subsidies are strongly necessary to reduce the needed investment and to get attractive prices for the production costs of the biomethane. First negotiations with local and federal institutions (KPC – Kommunalkredit public Consulting, Energie- und Klimafond bmvit, SFG - Styrian Business Promotion Agency, Province of Styria) have already taken place and it was figured out that at best [redacted] of the investment costs ([redacted] mill. €) could be covered by subsidies. As the subsidies from Klima- und Energiefond, SFG and province of Styria would be individual special fundings for such a kind of plant, these institutions need more concrete data of the plant (detailed project description, detailed business plan, etc.) for further commitments.

The first calculation of the biomethane production costs was based on the following assumptions:

Investment:	[redacted] million €
Subsidies:	[redacted] %
Operation hours per year:	8.500 h/a
Depreciation period:	15 a
Period under consideration:	15 a (without residual value)
Average interest rate:	5 %/a
Costs for personnel (10 p):	[redacted] €/a
Costs for maintenance, spare parts for - biogas plant and grid feed-in:	2 %/a of the investment ([redacted] €/a)
- upgrading plant:	7,6 €cent/m³ biomethane ([redacted] €/a)
Electricity demand:	0,6 kWh/Nm³ biomethane (1.920 MWh/a); 0,3 for biogas plant, 0,3 for upgrading plant
Heat demand:	1,6 kWh/Nm³ biomethane (5.120 MWh/a)
Insurance:	[redacted] €/a

Price for electricity: 0,12 Euro/kWh

Price for heat: 0,028 Euro/kWh

Earnings from waste/transport costs:

- Organic waste €/t
- Food waste from restaurants €/t
- Expired food €/t
- Old bread €/t

Earnings from fertilizer + expense for digestate disposal: 0 €/t

Based on these data (including subsidies) the production costs are at about €/t €cent/kWh which is about 50% higher than the actual price for natural gas at the Austrian market. In this calculation no profit is considered. The following figure shows the break down to the different cost categories (substrate, transport substrate, fertilizer+transport, biogas plant, upgrading plant, grid feed-in).

Figure 16: Specific costs for a 3,2m m³ waste to Biomethane plant, Graz

4.5 Sales concept

As already mentioned in chapter 3.2 the usage of the biomethane is planned in the following way:

Figure 13: Sales concept of the produced biomethane in Graz

The share the biomethane use. . For the detailed use concept have a look at chapter 3.2.

At the moment the market price for 100% biomethane is at about 5,5 €Cent/kWh from urban waste and 6,5 €Cent/kWh from NAWARO (energy crops).

If the biomethane is used on site for refuelling cars (without feeding into the natural gas grid), there is no tax on this gas. If it is fed into the natural gas grid 6,6 Cent/m³ tax has to be calculated.

4.6 Operation

The operation of the biogas plant near Graz creates about 10 full-time jobs. To minimize plant shutdowns and to operate the plant correctly, the staff has to be professional. The high qualification of the staff is guaranteed by regular trainings and further education. Furthermore, the communication between the staff is especially important. For maintaining the plant, enough additional time has to be taken into account; that means that the actual operation time is shortened due to regular maintenance and repair.

With increasing know-how of the plant operators the optimisation of plants plays a major role in today's biogas/biomethane plant operation. In order to operate the plant safely it is necessary to record, control and analyse various plant parameters continuously. A good monitoring gives the operator a picture what is happening in the process and allows to identify critical situations in advance. The recording of the operating data, maintenance, inspections and repairs should be done in an operating diary (guideline in ÖWAV Regelblatt 515/2 p. 78). In the IEE-project Biomethane-Regions a monitoring guide for the continuous monitoring was developed which is a good guideline for plant operators (IEE Biomethane-Regions; D_5_1_Best_Practice_Monitoring (2012)).

Figure 17: Monitoring parameters according to the phase of the anaerobic digestion (source: IEE Biomethane-Regions; D_5_1_Best_Practice_Monitoring (2012))

5 Stakeholder

5.1 Investors/owners

Figure 18: Sales concept of the produced biomethane (Source: GEA project presentation)

The owners of the biogas plant Graz, shown in Figure 18, are:

There were also discussions with external investors but as they want at least 51% of the ownership this might be a knock-out criterion.

5.2 Additional parties involved

Figure 19 shows the stakeholder landscape.

Figure 19: **Stakeholder landscape**

Beside the companies involved directly in the “consortium Graz” (green circle) there are several other parties which have to be involved. In the following list there are also their main functions added.

- Authorities: increase acceptance for biogas plant Graz in their own group and in the population; positive push for good concept; fundings; permissions; etc.
- Utilities (like local gas supplier, public transport company): trading, promoting and using the product biomethane;
- Citizens’ committee: increase know-how regarding the product biomethane and the positive effects concerning clima protection etc.; increase acceptance for biogas plant Graz; function as a positive multipliers in the population;
- Waste disposal services: suppliers of feedstock (long-term contracts); promoters for good waste separation of organic urban waste;
- Filling stations: promoter of gas for mobility; product biomethane at their filling stations;
- Investors: financial participation;
- Plant builders and operators: consolidation of local companies to ensure acceptance at the market; create more jobs in the region;
- Households and car drivers: supplier of the feedstock – good waste separation in the households increases the quality of the organic urban waste; increase know-how regarding the product biomethane, how it can be used in the households and in transport; using the product biomethane in CHP plants, for heating, for filling their CNG cars, etc.

6 Proposal of preferable solution of biomethane production in Graz

The targets of the City of Graz were mentioned in detail in the waste management concept.

The main advantages for Graz and Styria resulting from using the organic waste in a biogas plant near Graz to produce biomethane are:

- Use of waste as a resource
- Sustainable waste management – closed material cycle
- Decrease in fossil energy imports
- Decrease in green house gas emissions
- Step 1: energetically utilization of organic waste; Step 2: use of the material
- Creation of jobs
- Replace diesel by biomethane in the transport sector and therefore decrease green house gas emissions by 60-70% and to decrease particle emissions and reduce noise.

It's important that the substrate mainly comes from Graz or the surrounding areas as transport costs are an important cost factor. Mainly municipal organic waste should be used as well as some commercial organic waste. Therefore, long-term contracts with waste disposers or the integration of these waste disposers into the consortium is important.

The location of the biogas/biomethane plant is a central factor. Not only for the economic efficiency of the plant (short distances for transport and to existing gas grid), but also for the public acceptance. As there were problems at some plants in Styria with the neighbourhood and the authorities in the past, this is also a critical factor. Excellent planning and preparation of the concept and presentation to the publicity is essential.

As there are very innovative and successful Styrian/Austrian companies working as plant or component suppliers it would be good to integrate their knowhow and their products.

A local company should operate the plant to reach the goal of providing new jobs and to stimulate the economy.

The produced biogas should be fed into the natural gas grid and moreover used in the traffic sector, to reach the target of an increase in low-emission vehicles. The public sector should serve as a reference example, meaning that, for example the public transport sector and the local energy providers use gas-powered vehicles.

The digestate could be used as fertilizer in agriculture and ensures a closed cycle. Organic waste is going to be used as a resource for the energy generation, meaning that it is firstly used energetically and afterwards as a fertilizer for agriculture. A sustainable waste management and material flow emerges. Biogas produced from urban waste is clean, renewable, permanently available and doesn't need any additional resources.

Information campaign

Municipal solid waste in Styria still contains a huge amount of organic waste. If the city of Graz utilizes organic waste in a biogas plant, the amount of organic waste included in the residual waste, seems to be a lost resource. An information campaign that shows the inhabitants how to separate waste and to raise awareness, should be prepared.

The main target of the information campaign is that the inhabitants of Graz correctly separate waste and therefore increase the amount of organic waste for the biogas plant by the amount of organic waste previously thrown into the municipal solid waste bin. Furthermore, the inhabitants should be educated to only throw the correct organic waste (without tree-cut etc.) into the organic waste bin to facilitate the pre-treatment of organic waste before utilizing it in the biogas plant.

7 Strategies for a successful biomethane production in Graz

7.1 Creating and maintaining a sustainable demand for biomethane

- The knowledge of users regarding the production and the use of biomethane should be increased. When doing so, the positive effects of that type of energy (climate protection etc.) as well as the negative effects (resource providing – competition to food; monocultures; adaptions of plants) should be pointed out.
- Information campaigns for plant operators as well as for users should be worked out.
- Existing information channels should be used; e.g. popular magazines and journals (especially with focus on technical and ecological issues, to inform about biomethane, the potential and advantages of feed-in)
- The current taxation of diesel and gasoline may promote the use of biomethane as fuel, as long as biogas and accordingly biomethane is not charged with a tax.
- There are already quite a lot of manufacturers and models of gas fuelled cars on the market but they are not promoted well. The communication about natural gas fueled vehicles, the presentation of good practice examples of companies using such cars etc. should be increased in the public which would result in a higher public acceptance.
- The feed-in tariffs for electricity from CHP plants driven by biomethane are quite attractive in Austria at the moment. For potential customers it is essential that there is enough biomethane on the Austrian market that the price for this product is acceptable for a economic way of operating CHP plants and that the feed-in tariff of the green electricity is available immediately after submitting the application to the authority.

7.2 Inspiring investors

An investment in renewable energies, like in biogas/biomethane plants guarantees:

- attractive returns
- a safe investment in a long-term emerging field
- an investment in forward-looking projects, that protect the nature for future generations

To invest in renewable energies is a global trend and helps to support people with the reorganisation of the energy system, towards an energy system consisting mainly of renewable energies. There are already some investors on the Austrian market who are interested in participating in new plants and who are also interested in upgrading existing biogas plants into biomethane upgrading plants.

7.3 Convincing authorities and oppositional groups

Important points to convince authorities and to inspire potential investors:

- Plants have to be planned and implemented according to the actual state of the art and it is essential to adhere to the law.
- Political support is needed.
- Concerns of oppositional groups have to be taken seriously.
- To deal with these concerns, it is necessary to approach the oppositional groups directly and to find agreements.
- Demands of oppositional groups have to be considered.

7.4 Safeguarding a sound plant operation

A sound plant operation is guaranteed by the following factors:

- Continuous and good quality of the substrate
- Professional staff (regular and advanced trainings)
- Regular maintenance and repair of the plants (shorter operation time due to regular maintenance)
- Continuous and consequent monitoring of the main plant parameters

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