Urban Waste for Biomethane Grid Injection and Transport in Urban Areas

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Economic Feasibility of WtB Concepts for Valmiera, Zagreb and Graz

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Authors: Uwe Hoffstede, Fraunhofer IWES, Kassel, Germany (Chapter 1,2,3, Annexes)
Michael Beil, Fraunhofer IWES, Kassel, Germany (Chapter 4, 5)

Editors: Dominik Rutz, WIP, Munich, Germany
Ilze Dzene, Ekodoma, Riga, Latvia

Contact: Uwe Hoffstede
Fraunhofer IWES
Königstor 59
34119 Kassel, Germany
Tel.:+49 561 7294 438
Fax: +49 561 7294 432
uwe.hoffstede@iwes.fraunhofer.de

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1 Introduction

Within this report the local concepts "Biogas & Biomethane Production" in the cities of Graz, Valmiera and Zagreb will be reviewed and commented concerning their economic feasibility. Neither the cities of Gdynia nor Rzeszow, both Poland, provided a biogas concept for the project UrbanBiogas. The city of Abrantes, Portugal, did not provide a concept precise enough and in time to be assessed economically.

The calculation tool of EKODOMA for the biogas concept of the target city of Valmiera was found a more than appropriate mean for the economic assessment of the biogas concepts and forms the basis for the following evaluations for Valmiera and Zagreb.

2 Economic Feasibility of the Biogas Concept of Valmiera

2.1 Available Feedstock and Client Base

The availability of municipal solid waste has been assessed in the Waste Management Concept for Valmiera City and the draft North Vidzeme Regional Waste Management Development Plan 2014-2020. According to these investigations the amount of organic waste available for biogas production is given in Figure 1. The amount of organic waste gradually increases from ~10000 t/a to ~15000 t/a in 2030.

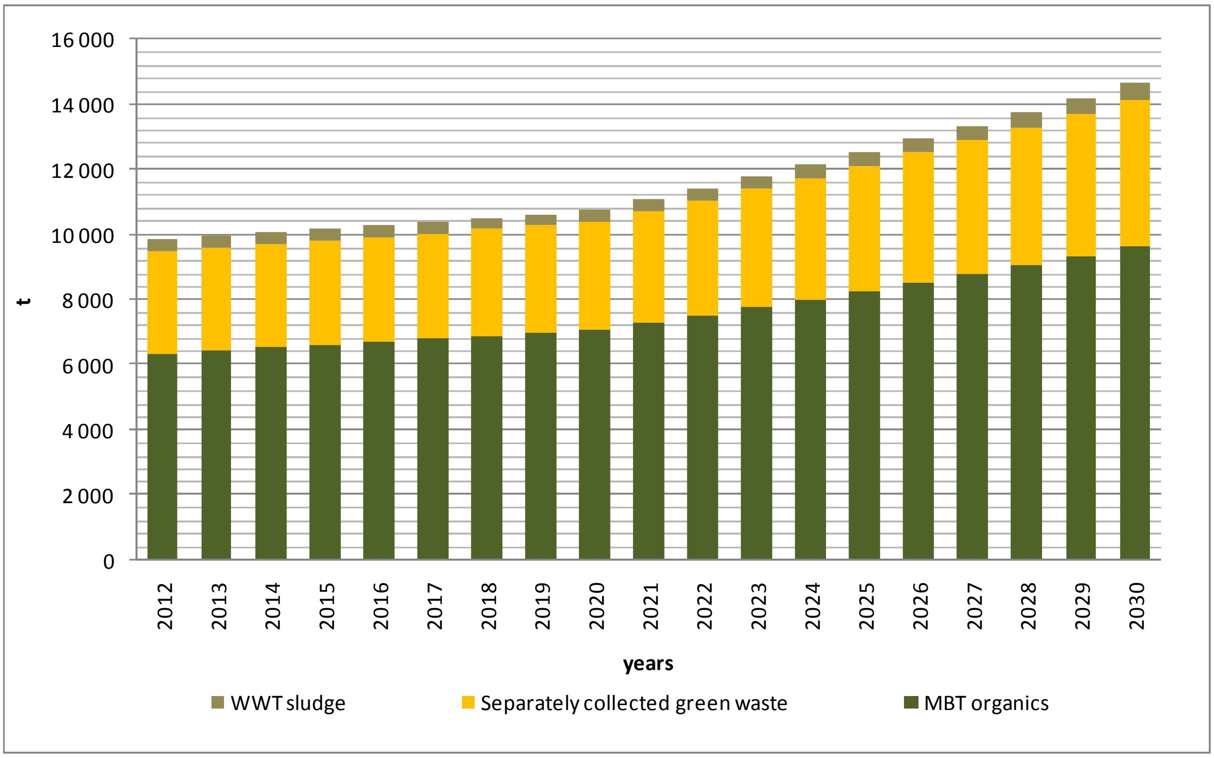

Figure 1: Availability of organic waste for biogas and biomethane production in Valmiera (LV)

Industrial organic waste particularly from food and beverage processing is not considered because in most cases these residues are used in agriculture and are bound with contracts.

Surplus sludge from waste water treatment plants in and around Valmiera sums up to 2,000 t/a in 2012. Available amounts range from 350 t/a in 2012 to 500 to/a in 2030.

Residues from the agriculture and energy crops are not considered – not even as an option – since there are eight biogas plants in the region with an installed capacity of more than 6 MW_{el} which are consuming this feedstock.

At present there is no demand for biomethane in Valmiera city. This is due to the absence of a biomethane infrastructure. In order to create the demand for compressed biomethane in the transport sector, the gradual change of existing vehicles to CNG/CBG vehicles is necessary. Discussions with Valmiera city council regarding the transition of the public transport fleet has started during the biomethane task force meetings and will be continued during the first years of operation when electricity only is produced with the biogas plant. There is no market at all for the product biomethane in Latvia; and this is true for the next couple of years; without incentives no market for transport fuel will develop; and there are no standards for grid injection; currently a monopolist rules the access to the gas grid; finally neither a legal framework nor technical standards rule the access to the gas grid.

2.2 Prospective Plant Location

The preferred option is the Daibe landfill which is operated by ZAAO already. Figure 2 shows that the Daibe landfill is located in the central part of the North Vidzeme region in Pargauja district.

The Daibe landfill is located in a remote area and has a potential to extend the territory, so the prospective biogas plant can either be located on site or very close to the landfill. The area is connected to a 20 kV power line. Pargauja district is crossed by the major state road A3 and the Daibe landfill is located approximately 7km from the main road A3 (see Figure 3). Also the main gas transmission pipeline is crossing North Vidzeme region, however not over the Pargauja district. Therefore at Daibe the access to the pipeline is not yet provided.

Figure 2: Location of Daibe landfill (source: http://www.zaao.lv/public/lat/par_sia_zaao/)

Around the landfill there are neither major residential areas nor industrial or commercial areas. And there are no historical sites in the vicinity.

In 2009 the project on landfill gas extraction and its use in a CHP has started. The capacity of the CHP unit was 175 kW_{el} and 201 kW_{th}. In 2010 the 2^{nd} part of the landfill gas collection project was launched by increasing the landfill gas extraction rate and installing an additional CHP unit. Electricity generated in the CHPs is sold for the feed-in tariff. On the preferred location, Daibe landfill, the future biogas plant could be connected with the existing CHP plant. The capacity of the plant allows the combustion of more biogas since the amount of landfill gas which is collected from the landfill body is decreasing over the years.

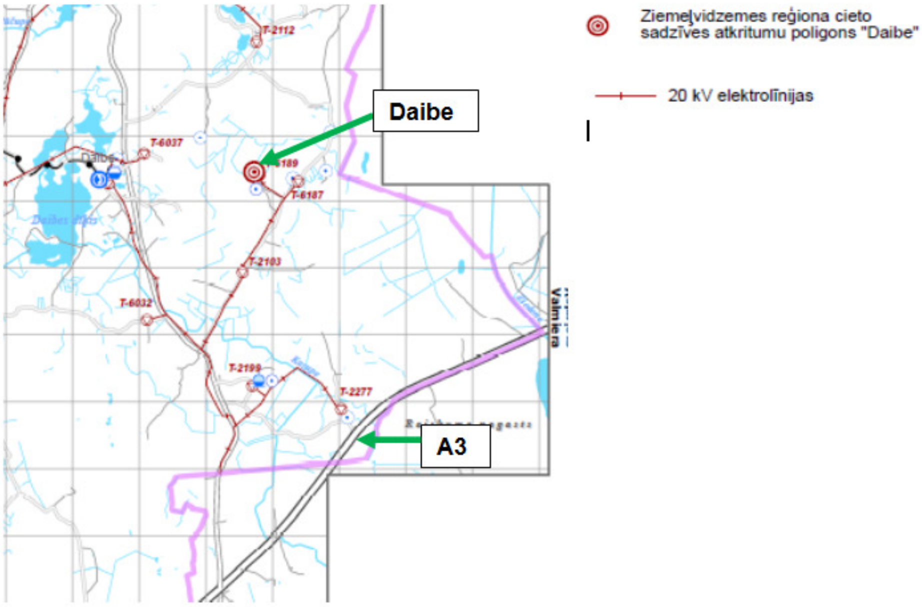

Figure 3: Location of Daibe landfill (source: http://www.pargaujasnovads.lv/lv/pargaujas-novada-teritorijas-planojuma-2013.-2024.gadam-galiga-redakcija---/)

2.3 Financial Feasibility

The calculation of the investment cost for the preferred technical solution - dry fermentation garage type biogas plant - is based on an offer provided by a biogas plant technology provider upon ZAAO call for quotations in 2012 (see Table 1).

Table 1: Investment costs for a dry fermentation unit (ZAAO, 2012)

Investments	Cost (excluding VAT)	
	LVL	EUR
Preparation of the site, local engineering works	17 570	25 000
Bering constructions	224 897	320 001
Technological equipment	768 692	1 093 756
Torch	10 191	14 501
Supply costs for technological equipment	2 811	4 000
Start-up, control, training	2 811	4 000
Unforeseen expenses (5%)	51 349	73 063
TOTAL:	1 078 321	1 534 321

The batch process has a number of advantages over other systems, in terms of lower costs of the process and the lesser sophisticated equipment behind it. This in turn has an adverse effect on process energy consumption and on maintenance costs. Operation and maintenance costs are assumed as an annual share of 5% of the total investment – 76,716 EUR/year. Operation and maintenance costs include regular maintenance of the biogas plant, staff, administration, energy (electricity) and insurance. Depreciation is equally distributed over the first 10 years.

The economical evaluation was done by using a cash flow analysis. Two subsequent scenarios were investigated:

- Dry fermentation + CHP until 2019
- Dry fermentation + CHP + biogas upgrading from 2020 on.

In the first phase the income is generated by sales of electricity according to the feed-in tariff. The guaranteed feed-in tariff for company “ZAAO Energija” (ZAAO Energy) is 212.64 EUR/MWh until 2019 and 170.11 EUR/MWh until 2029.

The revenues from the waste management in Latvia are kind of regulated and calculated with a complex equation where the profit margin for the waste management companies is limited. E. g. if costs for the long-term loan are included in the tariff costs, then the profit margin is limited to 3.5%.

Now the biogas part and waste management part in company ZAAO is legally separated. The daughter company “ZAAO Energija”, Ltd. has been established to operate CHP plants and sell electricity for the feed-in tariff. Mother company ZAAO is selling landfill gas to its daughter company “ZAAO Energija” and each company is keeping its own cash flow. In reality two separate cash flows would have to be analysed. In the cash flow of ZAAO two sources of revenues are identified – the income from the waste management tariff and income from the biogas sales to “ZAAO Energija”. In the cash flow of “ZAAO Energija” the revenues are coming from the sales of electricity, but costs are related to the purchase of biogas which is supplied by ZAAO. In this appraisal the costs for the feedstock and revenues from the waste management are set to zero. In this way the biogas project is separated from the waste management part and the financial analysis is made only on the project base. The cash flow analysis for Valmiera is given in

3 Economic Feasibility of the Biogas Concept of Graz

The following evaluation is mainly based on documents [10], [11], [12] and [14]. The focus will be on document [14].

3.1 Available Feedstock and Client Base

Based on [10] the estimated potential of organic waste, which could be utilized in the biogas plant, accounts for approximately 48.000 t/a. It consists of 33.000 t/a organic waste from the brown organic waste bins and other biowastes according to the following table:

Table 8: Substrate mass flows (estimated potential of organic waste), biogas yields and volume flows for biogas plant Graz.[14]

Estimated potential of organic waste [t/a]	fresh matter (FM)	dry matter (DM)			biogas				methane content
	t/a	DM %	oDM % of DM	t/a	m³/t FM	m³/t DM	m³/a (based on DM)	m³/a (based on FM)	%
organic waste from organic waste bins	33.000	30%	72%	7.118	81	350	2.491.335	2.673.000	63%
food waste from restaurants, caterings and food industry	8.000	20%	93%	1.486	144,7	856	1.272.358	1.157.600	56%
expired food from supermarkets and suppliers	5.000	20%	93%	929	144,7	856	795.224	723.500	56%
old bread from bakeries	1.500	65%	97%	946	482	760	718.770	723.000	53%
total	**47.500**			**10.479**			**5.277.687**	**5.277.100**	**59%**

The table shows that about 2/3 of the estimated mass flow of substrates will be organic wastes from households but roughly 50 % of the calculated energy output is expected to be from other biowaste fractions. To ensure a sufficient security of supply - especially for substrates that don't come from the household collection - it's highly recommended to generate long-term delivery contracts for those substrate fractions.

3.2 Prospective Plant Location

According to [13] a new site selection took place in 2014.

According to [13] [16] [17] the framework conditions of this new site are similar to the formerly described one:

"Concerning the plant location there are very positive news from Graz: plant location should be cleared, it is a little bit outside from Graz (about [redacted] km from the city center), good connection to highway, very near to gas grid. Option agreement for the land site is in elaboration. …."

3.3 Financial Feasibility

According to [13] after the site selection in 2014 *Energie Steiermark* is currently preparing a complete recalculation of the project.

Based on the latest information, following comments will be given:

- Overall investment costs of ~ [redacted] € are realistic for a biogas plant of this substrate mass flow using mainly household biowastes and including biogas upgrading and grid injection. According to [15] also costs for infrastructure are included.
- Investment costs of [redacted] € for the biogas upgrading and grid injection plants seem to be not unrealistic. For the upgrading plant itself (estimated capacity of ~700 m³/h biogas) around [redacted] Mio € (may be a little bit less) can be calculated. Costs for grid injection stations mainly depend on national requirements (standards in the natural gas sector and legislative incentive systems) but [redacted] Mio € seem to be not unrealistic. Nevertheless these costs depend mainly on pressure levels and also on the length of the connection pipe to the natural gas grid.

- 8,500 operation hours per year related to full operation mode are expected to be very optimistic. Only for the upgrading plant availabilities of 96 % can be seen as realistic. Also technology providers can give the warranty for that. But 96 % corresponds to 8,410 h/a. 8,500 h/a can be also not unrealistic for the upgrading plant itself but not for the whole system-chain of biogas production – biogas upgrading – grid injection.
- Costs for maintenance and spare parts seem not unrealistic. Depending on the technology (provider) and the plant size full maintenance contracts can be expected roughly in a range of 2-4 % related to investment costs. These percentages are related to sites in Germany of German plant manufacturers and can be expected (if choosing a foreign plant manufacturer) to be a little bit increased for Austria.
- The electricity demand of 0.3 kWh_{el}/m^3 biomethane seems to be too low.
- [redacted] Cent/kWh biomethane seems to be realistic based on the assumptions made:
  - Especially the costs for biowaste from household collection are calculated conservatively what is basically advantageous. On the other hand especially revenues for this kind of feedstock fraction are very sensitive for the economic success of the project.
  - ~ [redacted] Cent/kWh for upgrading seems to be in a realistic scale.
  - ~ [redacted] Cent/kWh for grid injection could be too low, especially if gas conditioning (addition of LPG) is necessary to adapt heating value and Wobbe-Index.
  - Depending on the transfer point to the biomethane customer also further costs such as transport costs in the natural gas grid, accounting cost management costs, etc. can/will occur. This should be respected. It can be seen as relevant advantage that the gas grid operator is also partner of this project.

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Figure 7: Cost fractions as specific costs for Graz biogas plant [14]

3.4 Project Risks

3.4.1 Economic Risks

Basically it has to be stressed that the calculation and the financial modelling of the project had been done relatively conservative. Concerning the Capex there should be a sufficient financial buffer available to realize the project within the calculated budget.

Within [14] it had been stated that the market price for biomethane from waste would be [redacted] $Cent/kWh_{Hs}$. That would have meant that the production costs for biomethane, also without profit, were [redacted] $Cent/kWh_{Hs}$ higher compared to the current market price of biomethane from waste ([redacted] $Cent/kWh_{Hs}$). Furthermore tax was not included what would have caused a further difference of ~ [redacted] $Cent/kWh_{Hs}$. Finally there would have been a difference of around – [redacted] $Cent/kWh_{Hs}$ between costs and revenues.

This has been clarified within [18]. The formerly mentioned value for the market price of biomethane from waste ([redacted] $Cent/kWh_{Hs}$) is related to average production costs for biomethane from waste in Austria. According to [18] the current market price for biomethane from waste would be around 1 $Cent/kWh_{Hs}$ increased compared to average production costs. Therefore an economic success of the project would be possible.

The economic success of the project depends therefore mainly on two parameters:

- Specific revenues that can be received for biowaste from household collection. At the moment there are [redacted] €/t (including transport costs) calculated what seems to be

relatively conservative. 1 €/t increased revenues from biowaste (related to 33000 t/a) means decreased production costs of ca. 0.1 Cent/kWh_{Hs}.
- The price that can be generated for biomethane.

3.4.2 Organisational Risks

According to [15] LOIs by the city of Graz and Energie Steiermark are already available. As mentioned above “Option agreement for the land site is in elaboration.”.

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Figure 8: Sales concept and stakeholder structure of the produced biomethane (Source: GEA project presentation) [14]

According to [16] biomethane utilization is organized as follows:

Confidential data

This concept seems to be promising especially because of the chance of long-term delivery contracts without having an ongoing competition situation with market prices of biomethane.

3.4.3 Legal Risks

According to [15] caused by the selection of the new site legal risks concerning the planning and permission process are significantly reduced. By now there are no objections by the municipality.

A relevant financial risks is the tax to be paid when injecting biomethane into the natural gas grid. Currently there is a political discussion to exempt biomethane from this regulation. [15]

3.4.4 Social Risks

In the past risks caused by groups that were dealing critically with the plant site selection was significant.
At the current planning stage this risk seems to be reduced. The municipality where the new selected site will be located seems to support the project. [15]
Nevertheless it will be an ongoing process to inform authorities, politicians and especially citizens sufficiently about the project and to convince them about the need and advantages of the sustainability of such a project.

4 References

[1] Eggenreich S., Schinnerl D. (2012): „Städtische Abfallwirtschaft in Graz Municipal waste management in Graz", WP3 – Task 3.4 / D 3.3, July 2012.

[2] Eggenreich S., Meißner, E., Schinnerl D. (2013): „Biogas und Biomethan Produktion in Graz / Biogas & Biomethane Production in Graz", WP 4 – Task 4.3 / D 4.3, May 2013.

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[4] Meißner E. (2014): Personal communication (E-Mail Meißner E. to Beil M. and Rutz D.)

[5] Eggenreich S., Meißner, E., Schinnerl D. (2013): „Biogas & Biomethane Production in Graz", Draft V 2 CONFIDENTIAL, WP 4 – Task 4.3 / D 4.3, May 2013.

[6] Beil M., Meißner E. (2014): Personal communication

[7] Meißner E. (2014): Personal communication (E-Mails Meißner E. to Beil M. and Rutz D.)

[8] Meißner E. (2014): Personal communication (E-Mail Meißner E. to Hoffstede U.)

[9] Meißner E. (2014): Personal communication (E-Mail Meißner E. to Beil M. and Rutz D.)

Annex 01 to this document. The IRR for this project is 6% without investment subsidy.

5.1 Project Risks

5.1.1 Economic Risks

A long pay-back period is a general risk but the private economic risk is still outweighed by the positive environmental aspects.

As long as there are no promoting measures for the use of renewable fuels (tax exemptions e. g.) the use of biomethane in transport vehicles is almost impossible to develop. And there is always the competitor natural gas to be observed.

The minor availability of feedstock – here tendering the regional waste management – may be compensated with different feedstock from agriculture or industry or may be covered by long-term contracts.

Latvia provides less experience in the operation of biogas plants than Western Europe. There is only little knowledge about the suitability of Western Europe equipment in Latvian climate, its durability, maintenance efforts and costs, and therefore the annual full load hours.

Finally the competitive use of organic waste in waste incineration plants has to be assessed and taken into account.

5.1.2 Organisational Risks

Excellent expertise among the designers, manufacturers, assemblers and – last but not least – among the operators is a basis for the success of a biogas production and biomethane up-grading facility. Particularly the training of the latter group is essential.

5.1.3 Legal Risks

At present there are no legal problems with the treatment of the digestate, particularly in combination with the existing composting plant and the Daibe landfill.

The reliability of feed-in tariffs for electricity and biomethane is crucial for the investment in a project in Valmiera.

5.1.4 Social Risks

The risk of critical citizens is very low for this project because the plant location is in a remote area and far away from dwelling areas.

6 Economic Feasibility of the Biogas Concept of Zagreb

6.1 Available Feedstock and Client Base

The availability of feedstock suitable for anaerobic digestion (AD from hereon) in the capital city of Croatia – Zagreb - will greatly depend on the future actions in respect to the waste management and efforts to fulfil several goals stipulated as national obligations particularly related to the reduction of the biodegradable part of municipal solid waste (MSW). Namely, although the obligation demands a reduction of up to 65% of biodegradable waste based on the year 1997, this would equal to only ~20% of today's (actually existing) quantities, Landfill Directive and Renewables Directive being the foremost, by 2020. In any case, as the capital is also the largest city in Croatia, the City of Zagreb carries significant contribution in achieving overall national goals.

Diverting the biodegradable part of MSW from landfills is an overall EU task, where each member country has its mandates. For most of the member states, the percentage of biodegradable municipal waste (BMW) landfilled in each European country with derogation periods for fulfilling the BMW diversion targets of the EU Landfill Directive, are compared with the amount generated in 1995. The general derogation is a four year period implying that the countries have to fulfil the targets by 2010, 2013 and 2020 instead of by 2006, 2009 and 2016. Croatia must match the targets by 2013, 2016 and 2020 based on the year 1997 (Waste and material resources, 2013).

For the purpose of this study, the base quantity of calculating the share of the biodegradable fraction of municipal solid waste would be the quantity of waste landfilled on Prudinec – the landfilling site of the City of Zagreb in 1997 which is about 209,000 to (Croatian Environment Agency, 2006) Although it is true that the city's waste management company has collected 184,502 to of waste in that year, here it is assumed that all waste that was landfilled at the city's landfill falls under the Landfill Directive mandate.

Table 2: Collectable biodegradable waste in the city of Zagreb by the year 2020

Input	Dry Matter [%]	Amount [to/a]
biowaste from shopping centres and households	20	5,000
biowaste from kitchens and restaurants	20	10,000
market residues	20	3,000
industrial biodegradable waste (brewery, dairy, food processing)	20	1,500
expired milk and eggs	17	500
Total		**20,000**

This scenario is based on the Waste Management Concept delivered by Zagreb holding - branch Čistoća. It presents total estimated quantities of biowaste which might be collected in Zagreb and directed towards a biogas production by 2020. Its main subjects are:

· composition of the collectable biodegradable waste in the City of Zagreb (Table 2)

· dynamic of its implementation by 2020 (Table 3, Figure 4).

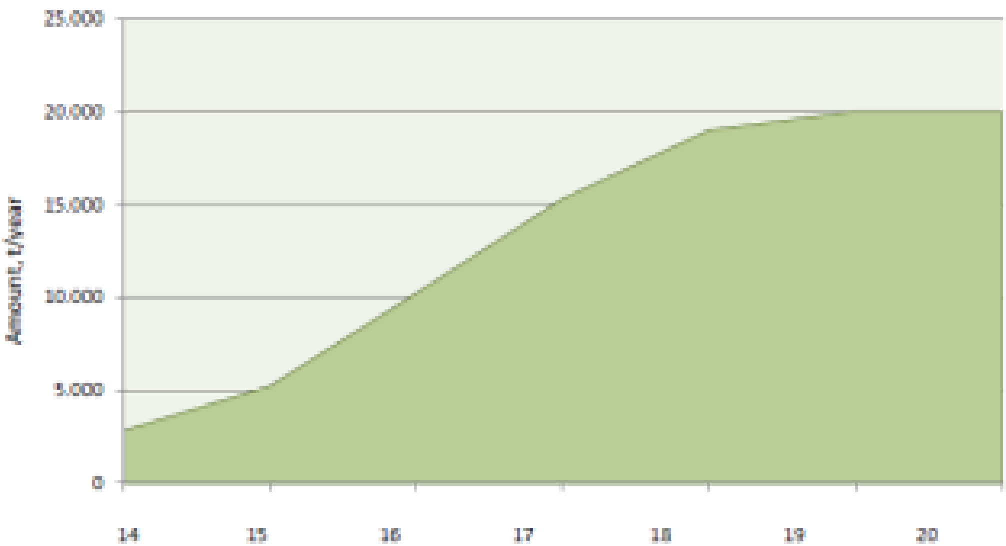

Figure 4: Estimate of the increase of separately collected biowaste in Zagreb (2014-2020)

The available amounts of biowaste for an AD project start with 1,500 t/a in 2011 and develop to 20,000 t/a in the year 2020 which is a conservative assessment.

Table 3: Total estimated quantities of biowaste in Zagreb [kto/a]

Type of waste	2011	2015	2017	2020
Biowaste from shopping centres and households	1.5	2.6	3.8	5.0
Biowaste from kitchens and restaurants	0	3.4	6.7	10.0
Market biowaste	0	1.0	2.0	3.0
Industrial biodegradable waste (brewery, dairy, food processing)	0	0.5	1.0	1.5
Expired milk & eggs	0	0.2	0.3	0.5
Total	**1.5**	**7.7**	**13.8**	**20.0**

Natural gas consumption in the City of Zagreb in 2011 totalled 12.63 PJ (371.6 million m³), which represents 26.1 % of the final energy consumption. Natural gas is mostly used by households (66%) followed by industry (27%) and the service sector (7%) and a very insignificant share of final energy consumption in transport. Namely, the final energy consumption in transport in the City of Zagreb in 2011 totalled up to 12.01 PJ. Natural gas consumption in the transport sector totalled up to only 0.027 PJ (0.8 mil. m³), which represents only 0.22 % of the total energy consumption in the transport sector in Zagreb in 2011.

Currently, the City of Zagreb runs 60 public transport busses powered by CNG which represents the existing demand for biomethane. Comparing the possible biogas/biomethane production (Table 4) for the year 2020, the assessment meets the existing demand for the existing public transport.

The biomethane production given in Table 4 will meet about 0.3% of the final consumption of natural gas in the City of Zagreb. On the other hand, the same production will surpass (39%) the existing demand for biomethane in the transport sector by eightfold. Based on this comparison, it can be concluded that there is potential to fully close waste-to-biomethane concept for the City of Zagreb where biomethane use will be aimed at injection into the natural gas grid instead of having a filling station on the production site. The local distribution gas network operator – Gradska plinara Zagreb - would be a potential client for taking over the produced biomethane into the gas grid. The local gas grid operator operates 3,709 km of gas pipes and delivered approximately 421 million cubic meters of natural gas in 2012.

Table 4: Biogas and biomethane production in Zagreb [10^6 m_N^3]

Parameter	2011	2015	2017	2020
Biogas production	0.19	1.07	1.41	2.04
Biomethane production	0.09	0.60	0.77	1.11

6.2 Prospective Plant Location

Resnik (see Figure 5) is considered mostly due to the already existing biogas plant and availability of existing facilities for treating the waste water after the wet AD process. It has limited road access for regular biowaste supply. Delivery would be through populated suburbs of Zagreb (nuisance due to increased traffic) but the plant itself is sufficiently remote from the settlement. The location has sufficient electrical power supply. Access to medium pressure natural gas grid is in a distance of about 0.5 km (Figure 6).

The main additional criterion for investigating this location is an operating waste water treatment plant – producing and using biogas from surplus sludge. There are numerous examples where biowaste and excess sludge from waste water treatment plants are combined in one biogas production plant. Examples are: Henriksdal biogas plant of Stockholm Vatten (Sweden), Linköping biogas plant of Svensk Biogas (Sweden) which also includes incineration plant, Borås biogas plant (Sweden) is connected with 7 km biogas pipeline with WWTP to combine upgrading; Grindsted Municipality Biogas Plant (Denmark).

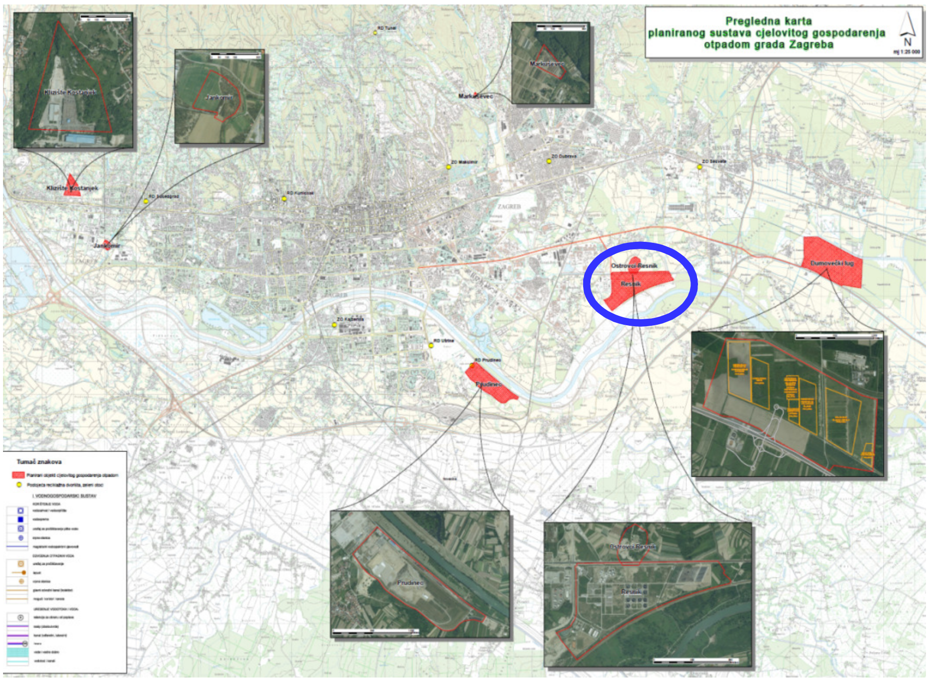

Figure 5: Resnik, joint areas of existing waste water management site and considered thermal waste processing plant

The Central WWTF has a biogas plant with an installed capacity of 2x1.5 MW_{el}. It uses biogas in a CHP where a part of the heat is used internally and electricity is sold to the grid. The current Feed-in tariff (FiT) system does not support preferential price for electricity from landfill gas and the electricity is purchased at average production price (0.53 HRK/kWh or 0.07 €/kWh).

This could motivate power plant management to consider entering the biomethane market by joining its existing biogas production with the new biowaste biogas (up-grading) facility.

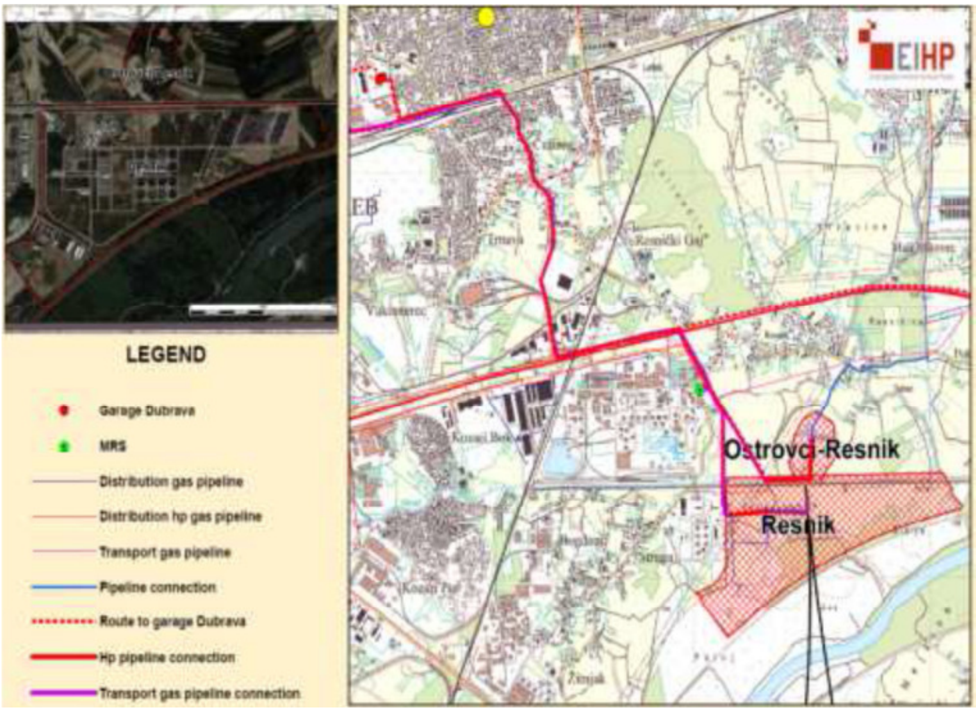

Figure 6: Resnik, access to the natural gas grid

The area of this location has sufficient space for biogas production and an up-grading plant. In addition, biogas production from biodegradable fraction of MSW could improve the efficiency of a prospective thermal waste treatment facility nearby. One technology of waste treatment (separation) could be installed for both facilities. Produced digestate could be dried and used as RDF.

As this area provides an already existing WWTP, it will require minimal spatial alterations for biogas/biomethane production and it fits well in the considered waste management concept. This location belongs to III. category of water protection zones (Limitation and Control Zone) which allows biogas production from biowaste only with special (additional) waste water management measures as described in decision on protection of water springs for the City of Zagreb.

Combining all above mentioned criteria, economic feasibility of the investment via maximisation of biogas production criteria, symbiosis with existing (biogas production, waste water treatment facility) and prospective (thermal waste treatment facility) facilities plus vicinity of natural gas grid access highlights this site for biogas/biomethane production.

6.3 Financial Feasibility

The biogas/biomethane plant on biowaste would be the first of its kind in Croatia and there is little information on the actual investment costs. However, using the average investment for plant of that type in developed waste-to-biomethane market and adapting it to the national situation would provide a sufficient approximation to start from.

The estimated price for a pre-treatment plant would be 1.67 mil. € or 84 €/t (including engineering, electrical equipment, montage...). Investment in a biogas plant running on biowaste would be the same as in a biogas plant running on agricultural feedstock. Currently, there are 8 agricultural biogas plants in Croatia where 7 of them are of 1 MW_{el} installed capacity. The average investment is 4,500 €/kW which is some 60% higher than its counterpart investment in Germany. This will lead to an investment of 6.2 mil. € for the AD installation. For the up-grading plant, the biogas yield from biowaste was taken (biogas yield in 2020) to which existing biogas production (~500 Nm3/h) was added. The desired methane content in biomethane was set to 97% (Table 5).

Table 5: Parameters for the investment in biogas up-grading

Plant availability	98%
Depreciation life	15 years
Interest rate	6%
Electricity price	0.15 EUR/kWh

These assumptions lead to investment costs as given in the following table.

Table 6: techno-economic characteristics of biomethane production

Increased biogas flow	PSA	Water Scrubber
Volume flow [m^3/h]	765	765
Methane content [vol %]	58.1	58.1
Upper heating value Hs [kWh/m^3]	6.41	6.41
Methane slip [%]	2	2
Volume flow of biomethane [m^3/h]	449.0	449.0
Upper heating value of biomethane Hs [kWh/m^3]	10.7	10.7
Investment costs [EUR]	1 589 003	1 545 384
Annual overall costs [EUR/year]	458 881	453 971
Specific cost per m^3 biomethane [ct/m^3]	11.90	11.78
Specific cost per kWh methane in biomethane (Hs) [ct/kWh]	1.11	1.10

Regarding the access to the natural gas distribution grid of the chosen location (Resnik), the shortest distance from the medium pressure network (4 bar, 160 mm) is 457 m and from the high pressure network (6 bar) it is 779 m. The distance to the nearest by transport gas pipeline connection is 1,848 m (MRS Zg East, 50 bar, 250-300 mm). The distance from the nearest ZET garage (planned CNG filling station) is 6,666 m (Dubrava). Access to natural gas grid of chosen location is presented in Figure 6. The length of the gas pipes and the estimated necessary investments for a connection to the gas distribution and gas transmission system is shown below in Table 7.

Table 7: Connection to the gas distribution network - length and investments

LOCATION	Gas distribution network			Investment (EUR)			Total (EUR)	
	Middle/low pressure		High pressure	Middle/low pressure	High pressure	Connection	Middle/low pressure	High pressure
	length, m	diameter, mm	length, m					
Prudinec	4 324	225	5 215	432 400	778 320	140 000	572 400	918 320
Resnik	457	160	779	45 700	82 260	140 000	185 700	222 260
Markusevec	365	225	837	36 500	65 700	140 000	176 500	205 700
Dumovecki lug	5 380	110	2 908	538 000	968 400	140 000	678 000	1 108 400

Considering that the difference between the terminal at medium/low pressure and high pressure gas distribution system is not significant, and that biomethane by injection into a high pressure distribution gas network will be available throughout the city, injection of biomethane into a high pressure gas distribution network is proposed (6 bars). Water scrubber or PSA technology with the working pressure above 6 bars is proposed as the technology for upgrading of biogas to biomethane.

Annex 2 shows the cash flow analysis of the scheduled plant. With an initial gate fee of 25 €/t, a price for biomethane starting with 0.27 €/m³ in 2015 and a pay-back period of 15 years it is obvious that this system is only profitable by a strong support of the local waste management and a national support for the production and use of biomethane regarding both tariff systems (gate fee and gas feed-in). Crucial is also the negotiation with the sewage treatment plant on the price of their biogas and respective escalation clauses. In this cash-flow analysis the AD and the up-grading facility was built for the full capacity which – according to the studies of the Zagreb waste management – is true only from 2020 onward;

meaning the AD and biomethane plants are operated with partial load only which reduces the profitability. Investments in 2 phases (2014 and 2017 e. g.) might relieve the financial burden.

6.4 Project Risks

6.4.1 Economic Risks

A very long pay-back period is a general risk but the economic risk is still outweighed by the positive environmental aspects which are maybe not that important for private companies but are for municipalities.

As long as there are no promoting measures for the use of renewable fuels (tax exemptions, feed-in tariffs e. g.) the use of biomethane in transport vehicles is almost impossible to develop. And there is always the competitor natural gas to be observed.

The availability of feedstock seems to be safe in Zagreb but the up-grading of the biogas from the neighboured WWTP has to be negotiated thoroughly and covered by long-term contracts. And the figures for the organic fraction of the MSW (input) have to be checked systematically with respect to the percentage of usable organic fraction (impurities, sieve overflow) since this influences the output of biogas significantly.

Croatia provides less experience in the operation of biogas plants than Western Europe. There is only little knowledge about the durability, maintenance efforts and costs, and therefore the annual full load hours.

Finally the competitive use of organic waste in waste incineration plants has to be assessed and taken into account politically.

6.4.2 Organisational Risks

Excellent expertise among the designers, manufacturers, assemblers and – last but not least – among the operators is a basis for the success of a biogas production and biomethane up-grading facility. Particularly the training of the latter group is essential.

6.4.3 Legal Risks

At present there are no legal problems with the treatment of the digestate, particularly in combination with the existing WWTP plant in Zagreb.

The existence and reliability of feed-in tariffs for (electricity and) biomethane is crucial for the investment in a project in Zagreb.

6.4.4 Social Risks

The risk of critical citizens is very high for this project because the plant location is surrounded by dwelling areas and the citizens showed a NIMBY attitude (not in my backyard!) in former times with other projects.

7 Economic Feasibility of the Biogas Concept of Graz

The following evaluation is mainly based on documents [10], [11], [12] and [14]. The focus will be on document [14].

7.1 Available Feedstock and Client Base

Based on [10] the estimated potential of organic waste, which could be utilized in the biogas plant, accounts for approximately 48.000 t/a. It consists of 33.000 t/a organic waste from the brown organic waste bins and other biowastes according to the following table:

Table 8: Substrate mass flows (estimated potential of organic waste), biogas yields and volume flows for biogas plant Graz.[14]

Estimated potential of organic waste [t/a]	fresh matter (FM)	dry matter (DM)			biogas				methane content
	t/a	DM %	oDM % of DM	t/a	m³/t FM	m³/t DM	m³/a (based on DM)	m³/a (based on FM)	%
organic waste from organic waste bins	33.000	30%	72%	7.118	81	350	2.491.335	2.673.000	63%
food waste from restaurants, caterings and food industry	8.000	20%	93%	1.486	144,7	856	1.272.358	1.157.600	56%
expired food from supermarkets and suppliers	5.000	20%	93%	929	144,7	856	795.224	723.500	56%
old bread from bakeries	1.500	65%	97%	946	482	760	718.770	723.000	53%
total	**47.500**			**10.479**			**5.277.687**	**5.277.100**	**59%**

The table shows that about 2/3 of the estimated mass flow of substrates will be organic wastes from households but roughly 50 % of the calculated energy output is expected to be from other biowaste fractions. To ensure a sufficient security of supply - especially for substrates that don't come from the household collection - it's highly recommended to generate long-term delivery contracts for those substrate fractions.

7.2 Prospective Plant Location

According to [13] a new site selection took place in 2014.

According to [13] [16] [17] the framework conditions of this new site are similar to the formerly described one:

"Concerning the plant location there are very positive news from Graz: plant location should be cleared, it is a little bit outside from Graz (about [redacted] km from the city center), good connection to highway, very near to gas grid. Option agreement for the land site is in elaboration. …."

7.3 Financial Feasibility

According to [13] after the site selection in 2014 *Energie Steiermark* is currently preparing a complete recalculation of the project.

Based on the latest information, following comments will be given:

- Overall investment costs of ~ [redacted] € are realistic for a biogas plant of this substrate mass flow using mainly household biowastes and including biogas upgrading and grid injection. According to [15] also costs for infrastructure are included.
- Investment costs of [redacted] € for the biogas upgrading and grid injection plants seem to be not unrealistic. For the upgrading plant itself (estimated capacity of ~700 m³/h biogas) around [redacted] Mio € (may be a little bit less) can be calculated. Costs for grid injection stations mainly depend on national requirements (standards in the natural gas sector and legislative incentive systems) but [redacted] Mio € seem to be not unrealistic. Nevertheless these costs depend mainly on pressure levels and also on the length of the connection pipe to the natural gas grid.

- 8,500 operation hours per year related to full operation mode are expected to be very optimistic. Only for the upgrading plant availabilities of 96 % can be seen as realistic. Also technology providers can give the warranty for that. But 96 % corresponds to 8,410 h/a. 8,500 h/a can be also not unrealistic for the upgrading plant itself but not for the whole system-chain of biogas production – biogas upgrading – grid injection.
- Costs for maintenance and spare parts seem not unrealistic. Depending on the technology (provider) and the plant size full maintenance contracts can be expected roughly in a range of 2-4 % related to investment costs. These percentages are related to sites in Germany of German plant manufacturers and can be expected (if choosing a foreign plant manufacturer) to be a little bit increased for Austria.
- The electricity demand of 0.3 kWh_{el}/m^3 biomethane seems to be too low.
- [redacted] Cent/kWh biomethane seems to be realistic based on the assumptions made:
  - Especially the costs for biowaste from household collection are calculated conservatively what is basically advantageous. On the other hand especially revenues for this kind of feedstock fraction are very sensitive for the economic success of the project.
  - ~ [redacted] Cent/kWh for upgrading seems to be in a realistic scale.
  - ~ [redacted] Cent/kWh for grid injection could be too low, especially if gas conditioning (addition of LPG) is necessary to adapt heating value and Wobbe-Index.
  - Depending on the transfer point to the biomethane customer also further costs such as transport costs in the natural gas grid, accounting cost management costs, etc. can/will occur. This should be respected. It can be seen as relevant advantage that the gas grid operator is also partner of this project.

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Figure 7: Cost fractions as specific costs for Graz biogas plant [14]

7.4 Project Risks

7.4.1 Economic Risks

Basically it has to be stressed that the calculation and the financial modelling of the project had been done relatively conservative. Concerning the Capex there should be a sufficient financial buffer available to realize the project within the calculated budget.

Within [14] it had been stated that the market price for biomethane from waste would be [redacted] $Cent/kWh_{Hs}$. That would have meant that the production costs for biomethane, also without profit, were [redacted] $Cent/kWh_{Hs}$ higher compared to the current market price of biomethane from waste ([redacted] $Cent/kWh_{Hs}$). Furthermore tax was not included what would have caused a further difference of ~ [redacted] $Cent/kWh_{Hs}$. Finally there would have been a difference of around – [redacted] $Cent/kWh_{Hs}$ between costs and revenues.

This has been clarified within [18]. The formerly mentioned value for the market price of biomethane from waste ([redacted] $Cent/kWh_{Hs}$) is related to average production costs for biomethane from waste in Austria. According to [18] the current market price for biomethane from waste would be around 1 $Cent/kWh_{Hs}$ increased compared to average production costs. Therefore an economic success of the project would be possible.

The economic success of the project depends therefore mainly on two parameters:

- Specific revenues that can be received for biowaste from household collection. At the moment there are [redacted] €/t (including transport costs) calculated what seems to be relatively conservative. 1 €/t increased revenues from biowaste (related to 33000 t/a) means decreased production costs of ca. 0.1 Cent/kWh_{Hs}.

- The price that can be generated for biomethane.

7.4.2 Organisational Risks

According to [15] LOIs by the city of Graz and Energie Steiermark are already available. As mentioned above "Option agreement for the land site is in elaboration.".

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Figure 8: Sales concept and stakeholder structure of the produced biomethane (Source: GEA project presentation) [14]

According to [16] biomethane utilization is organized as follows:

Confidential data

This concept seems to be promising especially because of the chance of long-term delivery contracts without having an ongoing competition situation with market prices of biomethane.

7.4.3 Legal Risks

According to [15] caused by the selection of the new site legal risks concerning the planning and permission process are significantly reduced. By now there are no objections by the municipality.

A relevant financial risks is the tax to be paid when injecting biomethane into the natural gas grid. Currently there is a political discussion to exempt biomethane from this regulation. [15]

7.4.4 Social Risks

In the past risks caused by groups that were dealing critically with the plant site selection was significant.
At the current planning stage this risk seems to be reduced. The municipality where the new selected site will be located seems to support the project. [15]
Nevertheless it will be an ongoing process to inform authorities, politicians and especially citizens sufficiently about the project and to convince them about the need and advantages of the sustainability of such a project.

8 References

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[12] Eggenreich S., Meißner, E., Schinnerl D., Stadtschreiber E. (2013): „Biomethannutzung: Netzeinspeiszung und Transport in Graz (Österreich) / Biomethane use for cities: grid injection & transport in Graz (Austria) Final, WP 5 – Task 5.2/5.3 / D 5.2/5.3, July 2013.

[13] Meißner E. (2014): Personal communication (E-Mail Meißner E. to Beil M. and Rutz D.)

[14] Eggenreich S., Meißner, E., Schinnerl D. (2013): „Biogas & Biomethane Production in Graz", Draft V 2 CONFIDENTIAL, WP 4 – Task 4.3 / D 4.3, May 2013.

[15] Beil M., Meißner E. (2014): Personal communication

[16] Meißner E. (2014): Personal communication (E-Mails Meißner E. to Beil M. and Rutz D.)

[17] Meißner E. (2014): Personal communication (E-Mail Meißner E. to Hoffstede U.)

[18] Meißner E. (2014): Personal communication (E-Mail Meißner E. to Beil M. and Rutz D.)

Annex 01

1.Combined Scenario (Biomethane) - Cash Flow

Investments	EURO
Investment Dry Fermentation Unit	1.534.321
Investment Biogas Upgrading Facility	636.112
Subsidy Dry Fermentation Unit	0
Subsidy Biogas Upgrading Facility	0
Investment (minus) subsidy 1	1.534.321
Investment (minus) subsidy 2	636.112

Post-Financing	EURO
Debt Capital 75,0%	1.150.741
Debt Capital 75,0%	477.084
Equity Capital 25,0%	383.580
Equity Capital 25,0%	159.028
Total 1	1.534.321
Total 2	636.112

Debt term (years)	10
Interest rate:	6%
Subsidy 1	0%
Subsidy 2	0%

Biomethane price	0,35 € /Nm3
Electricity feed-in tariff (year 1-10)	212,64 € /MWh
Electricity feed-in tariff (after year 10)	170,11 € /MWh

Cash Flow Model, EUR	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
Year of contract in exploitation		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Energy sale																		
Energy price inflation, %			4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	4,5%	
General price inflation, %			3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	
Feedstock price inflation, %			2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	
Electricity sale		**194.295**	**392.609**	**396.606**	**400.717**	**404.845**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1.789.072**
Heat sale		**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Income from waste management tariff		**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Biomethane sale		**0**	0	0	0	0	241.151	241.284	241.405	241.525	239.599	254.536	270.405	287.262	305.171	324.196	344.407	**2.990.941**
Income		**194.295**	**392.609**	**396.606**	**400.717**	**404.845**	**241.151**	**241.284**	**241.405**	**241.525**	**239.599**	**254.536**	**270.405**	**287.262**	**305.171**	**324.196**	**344.407**	**4.780.012**
Cost for the feedstock		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
O&M cost		-76.716	-79.018	-81.388	-83.830	-86.345	-45.763	-47.136	-48.550	-50.006	-51.506	-53.051	-54.643	-56.282	-57.971	-59.710	-61.501	**-993.415**
O&M cost upgrading plant		0	0	0	0	0	-44.528	-45.864	-47.240	-48.657	-50.116	-51.620	-53.169	-54.764	-56.407	-58.099	-59.842	**-570.303**
Corporate income tax 15,0%		0	-15.268	-16.289	-17.361	-18.468	0	0	0	0	0	-20.681	-22.823	-25.105	-27.538	-30.131	-42.436	**-236.100**
Operational Cashflow		**117.579**	**298.323**	**298.928**	**299.527**	**300.032**	**150.860**	**148.285**	**145.616**	**142.862**	**137.977**	**129.184**	**139.771**	**151.111**	**163.255**	**176.256**	**180.628**	**2.980.194**
Investment and Financing																		
Investment	-1.534.321					-636.112												**-2.170.433**
Debt financing	1.150.741					477.084												**1.627.825**
Subsidy	0					0												**0**
Pre-subsidy debt cost																		**0**
Return of subsidy to bank																		**0**
Debt service 1		-152.666	-152.666	-152.666	-152.666	-152.666	-152.666	-152.666	-152.666	-152.666	-152.666							**-1.526.662**
Debt service 2							-63.294	-63.294	-63.294	-63.294	-63.294	-63.294	-63.294	-63.294	-63.294	-63.294		**-632.936**
Own financing	383.580					159.028												**542.608**
FREE CASH FLOW	**0**	**-35.088**	**145.657**	**146.262**	**146.861**	**147.366**	**-65.100**	**-67.675**	**-70.344**	**-73.097**	**-77.983**	**65.890**	**76.477**	**87.817**	**99.961**	**112.962**	**180.628**	**820.595**
Annual return on investment:																		
Oper. Cash Flow/ Debt payment:		**0,77**	**1,95**	**1,96**	**1,96**	**1,97**	**0,70**	**0,69**	**0,67**	**0,66**	**0,64**	**2,04**	**2,21**	**2,39**	**2,58**	**2,78**	**#DIV/0!**	**1,20**
ROI		7,7%	19,4%	19,5%	19,5%	19,6%	7,0%	6,8%	6,7%	6,6%	6,4%	20,3%	22,0%	23,8%	25,7%	27,7%	28,4%	
NPV - 16 years @6.4%	-Ls 55.867,03																	
IRR	6%																	
Debt Capital payments		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Annual loan repayment 1		**152.666**	**152.666**	**152.666**	**152.666**	**152.666**	**152.666**	**152.666**	**152.666**	**152.666**	**152.666**	**0**	**0**	**0**	**0**	**0**	**0**	**1.526.662**
Interest payment		*63.291*	*58.375*	*53.189*	*47.718*	*41.946*	*35.856*	*29.431*	*22.654*	*15.503*	*7.959*	*0*	*0*	*0*	*0*	*0*	*0*	***375.921***
Payment on principal		*89.375*	*94.291*	*99.477*	*104.948*	*110.721*	*116.810*	*123.235*	*130.013*	*137.163*	*144.707*	*0*	*0*	*0*	*0*	*0*	*0*	***1.150.741***
Balance		1.061.365	967.074	867.597	762.649	651.928	535.118	411.883	281.871	144.707	0	0	0	0	0	0	0	**1.150.741**
Annual loan repayment 2							**63.294**	**63.294**	**63.294**	**63.294**	**63.294**	**63.294**	**63.294**	**63.294**	**63.294**	**63.294**	**0**	**632.936**
Interest payment							*26.240*	*24.202*	*22.052*	*19.783*	*17.390*	*14.865*	*12.202*	*9.392*	*6.427*	*3.300*	*0*	***155.853***
Payment on principal							*37.054*	*39.092*	*41.242*	*43.510*	*45.903*	*48.428*	*51.092*	*53.902*	*56.866*	*59.994*	*0*	***477.084***
Balance							440.030	400.938	359.696	316.185	270.282	221.854	170.762	116.860	59.994	0	0	**477.084**
Corporate Income tax		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	**16 years**
Part of Investment Expensed in Year 1, %																		
Part of Investment Depreciated over years		100%																
Taxable income		54.288	255.216	262.028	269.170	276.555	159.532	164.717	170.202	176.016	180.134	201.485	215.762	230.980	247.200	264.486	282.905	3.410.676
Investment expensed		0																
Investment depreciated 1		-153.432	-153.432	-153.432	-153.432	-153.432	-153.432	-153.432	-153.432	-153.432	-153.432							-1.534.321
Investment depreciated 2							-63.611	-63.611	-63.611	-63.611	-63.611	-63.611	-63.611	-63.611	-63.611	-63.611		-636.112
Subsidy 1		0	0	0	0	0	0	0	0	0	0							0
Subsidy 2							0	0	0	0	0	0	0	0	0	0		0
Accumulated Taxable income		-99.144	101.784	108.596	115.738	123.123	-57.511	-52.326	-46.841	-41.027	-36.909	137.874	152.150	167.369	183.589	200.875	282.905	1.240.243
Corporate income tax 15,0%		0	-15.268	-16.289	-17.361	-18.468	0	0	0	0	0	-20.681	-22.823	-25.105	-27.538	-30.131	-42.436	-236.100
Rec																		
	-383.580	-35.088	145.657	146.262	146.861	-11.662	-65.100	-67.675	-70.344	-73.097	-77.983	65.890	76.477	87.817	99.961	112.962	180.628	
Biomethane price							0,35 €	0,36 €	0,37 €	0,38 €	0,39 €	0,41 €	0,42 €	0,43 €	0,44 €	0,46 €	0,47 €	

Annex 02

Combined Scenario (WWTP + org. MSW) - Cash Flow

Investments	EURO
Investment pre-treat + AD	7.870.000
Investment up-grading+ grid injection	1.767.000
Subsidy AD	0
Subsidy Biogas Upgrading Facility	0
Investment (minus) subsidy 1	**7.870.000**
Investment (minus) subsidy 2	**1.767.000**

Post-Financing	EURO
Debt Capital 75,0%	7.227.750
Debt Capital 75,0%	
Equity Capital 25,0%	2.409.250
Equity Capital 25,0%	
Total 1	**9.637.000**
Total 2	**0**

Debt term (years)	**15**
Interest rate:	**6%**
Subsidy 1	0%
Subsidy 2	0%

Biomethane price 2020	**0,31 € /Nm3**
Electricity feed-in tariff (year 1-10)	**/MWh**
Electricity feed-in tariff (after year 10)	**/MWh**

Cash Flow Model, EUR	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
Year of contract in exploitation		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	
Energy sale																		
Energy price inflation, %			*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	*4,5%*	
General price inflation, %			*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	*3,0%*	
Feedstock price inflation, %			*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	*2,0%*	
Electricity sale		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Heat sale		**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Income from waste management tariff		**192.500**	**276.813**	**366.011**	**433.539**	**504.791**	**579.637**	**597.026**	**614.937**	**633.385**	**652.387**	**671.958**	**692.117**	**712.880**	**734.267**	**756.295**	**778.984**	**9.197.526**
Biomethane sale		**645.287**	**689.744**	**756.908**	**827.283**	**877.662**	**930.366**	**992.346**	**1.057.208**	**1.125.068**	**1.158.820**	**1.193.585**	**1.229.392**	**1.266.274**	**1.304.262**	**1.343.390**	**1.383.692**	**16.781.288**
Income		**837.787**	**966.556**	**1.122.918**	**1.260.823**	**1.382.453**	**1.510.003**	**1.589.372**	**1.672.145**	**1.758.453**	**1.811.207**	**1.865.543**	**1.921.509**	**1.979.155**	**2.038.529**	**2.099.685**	**2.162.676**	**25.978.814**
Cost for the WWTP gas		-478.350	-478.350	-493.145	-508.396	-524.120	-540.330	-556.540	-573.236	-590.433	-608.146	-626.391	-645.182	-664.538	-684.474	-705.008	-726.158	**-9.402.798**
O&M cost AD		-600.000	-618.000	-636.540	-655.636	-675.305	-695.564	-716.431	-737.924	-760.062	-782.864	-806.350	-830.540	-855.457	-881.120	-907.554	-934.780	**-12.094.129**
O&M cost upgrading plant		-108.150	-111.395	-114.736	-118.178	-121.724	-125.375	-129.137	-133.011	-137.001	-141.111	-145.345	-149.705	-154.196	-158.822	-163.587	-168.494	**-2.179.967**
Operational Cashflow		**-348.713**	**-241.189**	**-121.503**	**-21.388**	**61.304**	**148.733**	**187.264**	**227.974**	**270.957**	**279.086**	**287.458**	**296.082**	**304.964**	**314.113**	**323.537**	**333.243**	**2.301.921**
Investment and Financing																		
Investment	-9.637.000																	**-9.637.000**
Debt financing	7.227.750																	**7.227.750**
Subsidy	0					0												**0**
Pre-subsidy debt cost																		**0**
Return of subsidy to bank																		**0**
Debt service 1		-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	-744.189	0	**-11.162.837**
Debt service 2							0	0	0	0	0	0	0	0	0	0		**0**
Own financing	2.409.250																	**2.409.250**
FREE CASH FLOW	**0**	**-1.092.902**	**-985.378**	**-865.692**	**-765.577**	**-682.885**	**-595.456**	**-556.925**	**-516.216**	**-473.232**	**-465.104**	**-456.731**	**-448.107**	**-439.225**	**-430.076**	**-420.652**	**333.243**	**-8.860.916**
Annual return on investment:																		
Oper. Cash Flow/ Debt payment:		**-0,47**	**-0,32**	**-0,16**	**-0,03**	**0,08**	**0,20**	**0,25**	**0,31**	**0,36**	**0,38**	**0,39**	**0,40**	**0,41**	**0,42**	**0,43**	**#DIV/0!**	**0,06**
ROI		-4,4%	-3,1%	-1,5%	-0,3%	0,8%	1,5%	1,9%	2,4%	2,8%	2,9%	16,3%	16,8%	17,3%	17,8%	18,3%	18,9%	**0,00**
Debt Capital payments		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Annual loan repayment 1		**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**744.189**	**0**	**11.162.837**
Interest payment		*433.665*	*415.034*	*395.284*	*374.350*	*352.160*	*328.638*	*303.705*	*277.276*	*249.261*	*219.565*	*188.088*	*154.722*	*119.354*	*81.863*	*42.124*	*0*	***3.935.087***
Payment on principal		*310.524*	*329.156*	*348.905*	*369.839*	*392.030*	*415.551*	*440.484*	*466.913*	*494.928*	*524.624*	*556.101*	*589.467*	*624.836*	*662.326*	*702.065*	*0*	***7.227.750***
Balance		6.917.226	6.588.070	6.239.165	5.869.326	5.477.297	5.061.745	4.621.261	4.154.348	3.659.419	3.134.795	2.578.694	1.989.226	1.364.391	702.065	0	0	**7.227.750**