Urban Waste for Biomethane Grid Injection and Transport in Urban Areas

Project No: IEE/10/251

Biogas & Biomethane Production in Valmiera, Latvia

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UrbanBiogas website: www.urbanbiogas.eu

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Contents

Abbreviations

AD	Anaerobic digestion
BG	biogas
CH_4	methane
CHP	combined heat and power (co-generation)
DM	Dry matter
FF	Fine fraction (of mechanically sorted organic waste)
FM	Fresh matter content
MSW	Municipal solid waste
PSA	Pressure Swing Adsorption – biogas upgrading technology
VS	Volatile solids content
WtB	Waste-to-Biomethane
WWT	Waste water treatment
Y_{gas}	Specific biogas yield [m^3_N/t_{VS}]
ZAAO	North Vidzeme Waste Management Company (partner of UrbanBiogas project)

Introduction

Biogas and biomethane production concept for Valmiera city and North Vidzeme Region is developed in the UrbanBiogas project, supported by the Intelligent Energy Europe program of the European Commission. The main objective of the biogas and biomethane production concept is to identify economical, organisational and technical solutions for biogas and biomethane production from waste in Valmiera city and North Vidzeme Region.

Report provides information about technical solution for biogas production, overview on legal requirements of using waste as feedstock, investigation of potential relevant national support schemes for biogas production, economical calculations of the suggested solution and provision about strategies to overcome legal and non-technical barriers for biogas project.

Biogas and biomethane production concept for Valmiera city is based on the Waste management concept that has been developed by ZAAO earlier in the UrbanBiogas project. In the waste management concept the selected option is collection of the unsorted municipal waste. It is concluded that until 2020 it is not economically and legally feasible to implement source separated organic waste collection in Valmiera city. The selected option foresees two scenarios:

1) Basic scenario – collection of unsorted waste, mechanical separation of organic fraction and composting (present practice);
2) Combined scenario – collection of unsorted municipal waste and separated food waste from companies, mechanical separation of organic fraction from MSW and dry fermentation.

Authors of this concept believes that collection of unsorted municipal waste and later mechanical separation of organic waste is not the best solution for the municipality since it does not fulfil the resource-efficiency requirements while a resource-efficient Europe is on of seven flagship initiatives under the Europe 2020 Strategy (COM (2011) 21, A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy). As it is stated in a position paper of the European municipal waste association (Municipal Waste Europe, 2011), resource-efficiency cannot be achieved without the engagement of municipalities and their waste management companies. Resources must be recovered in order to achieve overall sustainable use of resources, beginning with prevention and continuing with the retrieval of resources from the waste stream back into the production cycle or into re-use. The purity of the separated organic material after mechanical treatment is low and it can only be used in dry fermentation process. The sludge after fermentation can only be disposed in a landfill (used as a landfill cover material). Therefore in this technical solution nutrients are not recovered and the nutrient cycle is not closed.

Based on the above mentioned considerations, along with the solution proposed by ZAAO in the waste management concept the authors of this concept are proposing an alternative scenario that foresees a source separated waste collection and organic waste treatment in the wet anaerobic digestion process. The biogas and biomethane production concept is developed based on the following two scenarios:

1) Combined scenario – collection of unsorted municipal waste and separated food waste from companies, mechanical separation of organic fraction from MSW and dry fermentation;
2) Resource-efficiency scenario – introduction of source separated waste collection and wet fermentation with upgrading of biogas to biomethane.

1. Survey of available feedstock

The focus of the UrbanBiogas project is set on promoting the use of the untapped fraction of organic urban waste for biogas production in order to inject biomethane in the natural gas grid or use it in transport. Therefore in this concept the basic substrate to be used for biogas production is organic fraction of the municipal solid waste (MSW) and other organic waste (landscape management, kitchen waste, expired food and industrial waste) from gardening, restaurants, supermarkets, and from the food and beverage industry.

1.1. Municipal solid waste, organic in Valmiera and vicinity

The availability of municipal solid waste has been assessed in the Waste Management Concept for Valmiera City (Niklass M. et.al, 2012) and the draft North Vidzeme Regional Waste Management Development Plan 2014-2020 (ZAAO, 2013). According to the waste management concept, for the first scenario the amount of organic waste available for biogas production is given in Table 1 and Figure 1.

Table1. Available organic waste, [t] and forecast (2012-2020)

	2011	2012	2015	2018	2020
Biodegradable waste separated from MSW by mechanical treatment	8 920	5 785	7 213	8 140	8 486
Separately collected green waste	-	3 020	3 071	3 103	3 125
Waste water treatment sludge	2 016	3 886	3 951	3 993	4 021
TOTAL	10 936	12 691	14 235	15 236	15 632

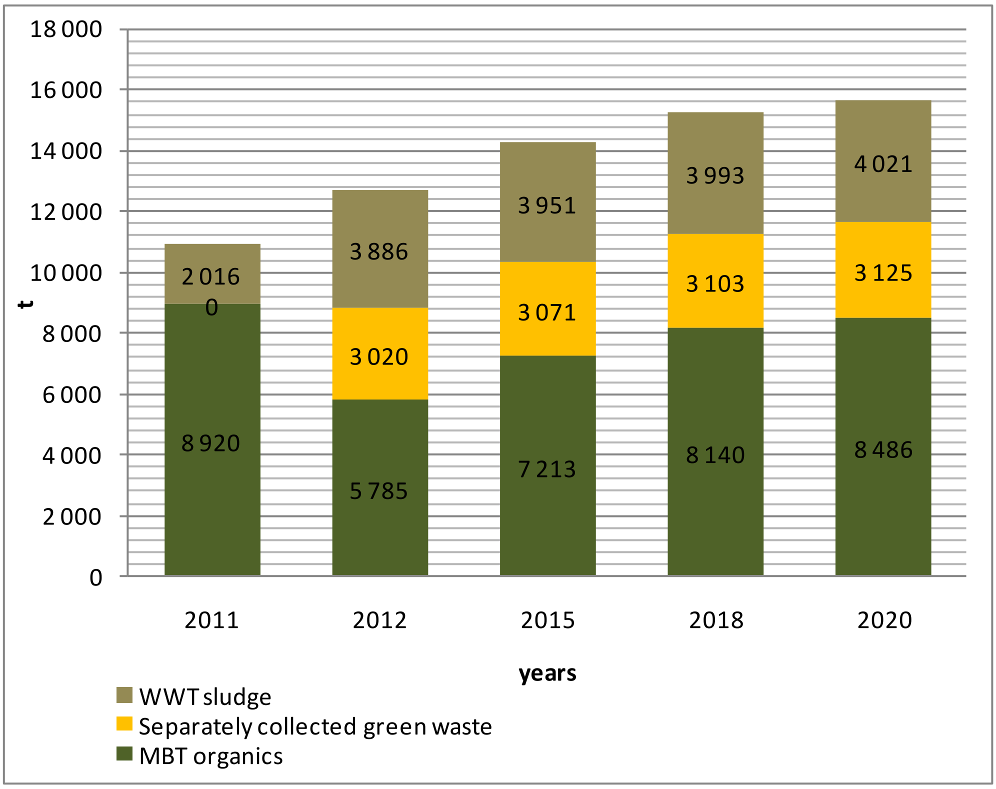

Figure 1: Availability of organic waste for biogas and biomethane production

According to this forecast, the amount of organic waste will gradually increase reaching 15.6 thousand tons in 2020. Authors of this concept have recalculated the availability of organic waste based on the latest forecast about amounts of unsorted municipal waste and other separately collected waste reported in the draft North Vidzeme Regional Waste Management Development Plan 2014-2020 (ZAAO, 2013). This has been done in order to be able to compare both proposed scenarios in this concept. The available organic waste according to this forecast is given in Figure 2.

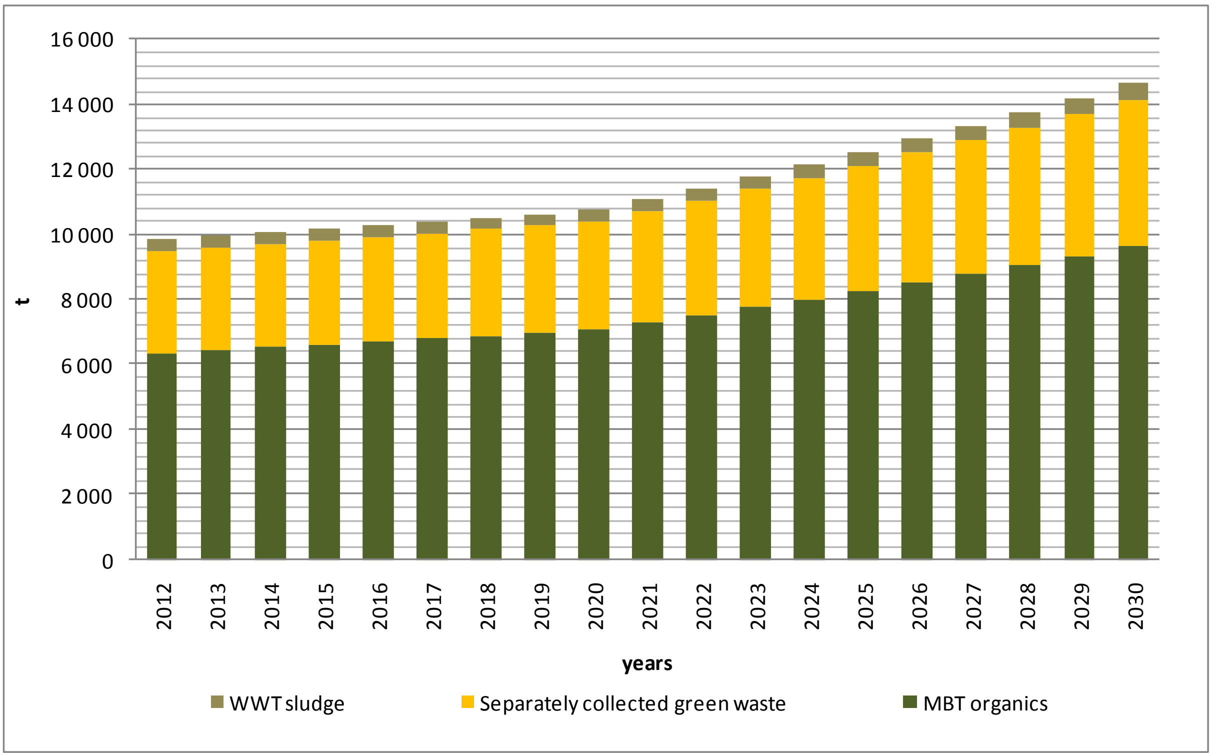

Figure 2: Availability of organic waste for biogas and biomethane production – updated forecast

The amount of available organic waste will increase from 9.86 thousand t in 2012 to 10.75 thousand t in 2020, and reaching 14.65 thousand t in 2030.

1.2. Industrial organic residues in Valmiera and vicinity

In North Vidzeme region there are several dairy processing plants, breweries and other food processing companies. Most of the dairy plants are technically advanced and do whey processing into powdered milk or into protein rich drinks. List of the largest food and beverage companies in the region and their organic waste amounts is given in the Table 2.

Majority of the organic waste from food and beverage industry is delivered to the farmers for feeding animals or fertilization of the fields. Some part of the waste goes to the biogas plants that belong to the farmers. Deliveries sometimes are based on a long term contracts and therefore it will be difficult to convert these organic waste flows to the potential biogas plant. Competition for the feedstock among biogas plants is very high. Information about existing biogas plants in the region is provided in the Chapter 2.3.

Most of the communal waste water treatment sludge in North Vidzeme region is generated in Valmiera city. Overview about WWT sludge in 2012 (2-Ūdens, 2012) is given in Table 3.

Table 2.Available industrial organic waste

Company	Type of company	Organic waste	Waste classification code	Amount, t (year)	Current form of disposal
JSC “Valmieras piens”	Dairy (milk products)	Waste water sludge	020502/ 190805	5 487	Farmers
Cooperative “Straupe”	Dairy	Whey	020599	3 130	Farmers
“Milda KM”, Ltd.	Preserved food	Biowaste	200201	3 (2010) 1.05 (2011) 1.2 (2012)	ZAAO
“Valmiermuižas alus”, Ltd.	Brewery	Brewer’s grains	020799	10	Farmers
JSC “Cēsu alus”	Brewery	Brewer’s grains	020799	6 800	Farmers
“Piebalgas alus”, Ltd.	Brewery	Brewer’s grains	200207	151	Farmers
JSC “Brīvais vilnis”	Fish processing	Waste from the fat traps	190810	435 (2010) 420 (2011) 420 (2012)	Mapeteks (fish meal and oil production plant)
“Matadors”, Ltd.	Meat processing	Animal waste	020102	5.3 (2012)	Reneta (animal waste processing plant)
“Aloja-Starkelsen”, Ltd.	Potato starch production	Organic waste Organic waste	200203 200201	2 660 8 535	Aloja Agro (potato growers)

Table 3.WWT sludge generation and flow in the region in 2012

Territory	Generated, t	Utilized, t	In agriculture, t	Composted, t	Landfilled, t	Temporarily stored, t	Recultivation of brown fields, t	Other purpose (biogas), t
Alojas novads	20	20	1	19	0	0	0	0
Balvu novads	24	24	0	0	0	23	1	0
Inčukalna novads	0	0	0	0	0	0	0	0
Jaunpiebalgas novads	23	23	0	0	0	23	0	0
Kocēnu novads	4	4	4	0	0	0	0	0
Krimuldas novads	17	17	6	0	0	12	0	0
Limbažu novads	34	37	0	28	0	0	0	9
Līgatnes novads	100	100	1	0	0	99	0	0
Mazsalacas novads	5	5	0	0	0	5	0	0
Naukšēnu novads	1	1	1	0	0	0	0	0
Priekuļu novads	27	25	6	0	0	19	0	0
Pārgaujas novads	355	355	355	0	0	0	0	0
Raunas novads	5	5	5	0	0	0	0	0

Territory	Generated, t	Utilized, t	In agriculture, t	Composted, t	Landfilled, t	Temporarily stored, t	Recultivation of brown fields, t	Other purpose (biogas), t
Rūjienas novads	6	6	4	0	0	0	0	2
Salacgrīvas novads	80	80	0	60	0	0	0	20
Siguldas novads	111	0	0	0	0	0	0	0
Smiltenes novads	23	23	0	21	0	0	0	2
Strenču novads	13	13	0	0	0	0	0	13
Sējas novads	3	3	0	3	0	0	0	0
Valkas novads	20	11	0	10	1	0	0	0
Valmiera	1 031	1 031	0	0	8	0	0	1 023
Vecpiebalgas novads	9	9	9	0	0	0	0	0
Viļakas novads	0	0	0	0	0	0	0	0
TOTAL:	**1 910**	**1 791**	**391**	**141**	**8**	**181**	**1**	**1 070**

1.3. Agricultural energy crops in vicinity of Valmiera (alternatively)

Potential use of agricultural energy crops in the biogas plant is limited due to the competition with other biogas plants that are located in the region. All together there are eight agricultural biogas plants operating in the North Vidzeme region. Information about the biogas plants located in the region is given in Table 4 and Figure 3.

Table 4.Biogas plants in vicinity of Valmiera

No	Biogas plant	Start of the operation	Address	Installed capacity, MWe
1	BIOPAB, SIA	2012.11.08	Sējas novads, "Jurku ferma"	0.6
2	BĒRZI BIO, SIA	2013.02.04	Mālpils novads, "Bērzi"	0.5
3	BP Energy, SIA	2012.02.02	Siguldas novads, Allažu pagasts, "Krastmalas"	0.25
4	EKORIMA, SIA	2012.01.10	Krimuldas novads, Lēdurgas pagasts, "Veckļaviņas"	0.95
5	Grow Energy, SIA	2012.01.24	Limbažu novads, Limbažu pagasts, "Gravas"	1.995
6	JAUNDZELVES, ZS	2011.08.10	Limbažu novads, Katvaru pagasts,	0.52
7	SIDGUNDAS BIO, SIA	2012.10.03	Mālpils novads, Sidgunda, "Niedras"	0.8
8	ZEMTURI ZS, SIA	2010.12.29	Burtnieku novads, Burtnieku pagasts, "Zemturi"	0.68
			TOTAL:	**6.295**

Figure 3: **Location of the agricultural biogas plants in the region**

In Figure 3 the eight green dots are agricultural biogas plants (see in Table 4). The location of the waste treatment centre and landfill gas collection plant in "Daibe" is marked with the red dots.

Eight mentioned biogas plants use co-fermentation of agricultural feedstock (manure and energy crops) with industrial residues and WWT sludge (both communal and industrial). Information about feedstock the biogas plants are using is given in Table 5.

Table 5.Feedstock for the biogas plants in vicinity of Valmiera

No	Biogas plant	Maize silage, t	Grass silage, t	Cattle manure, t	Cattle slurry, t	Pig slurry, m3	Poultry manure, t	Whey, t	Grain, t	WWT sludge (Wet), t	WWT sludge (dry), t	Potato mash, t	Animal feed, t
1	BIOPAB, SIA	Information is not available											
2	BĒRZI BIO, SIA	4 290	5 950	7 026									
3	BP Energy, SIA					16 027							
4	EKORIMA, SIA	15 200	1 000	16 600									
5	Grow Energy, SIA		14 600	8 760			2 920	2 920					

No	Biogas plant	Maize silage, t	Grass silage, t	Cattle manure, t	Cattle slurry, t	Pig slurry, m3	Poultry manure, t	Whey, t	Grain, t	WWT sludge (Wet), t	WWT sludge (dry), t	Potato mash, t	Animal feed, t
6	JAUNDZELVES, ZS	7 200	286	1 950	360				550				
7	SIDGUNDAS BIO, SIA	Information is not available											
8	ZEMTURI ZS, SIA			7 300				14 600		5 220	4 821	1 095	1 278
	TOTAL:	**26 690**	**21 836**	**41 636**	**360**	**16 027**	**2 920**	**17 520**	**550**	**5 220**	**4 821**	**1 095**	**1 278**

According to the data from the statistical bureau of Latvia (Agricultural Census, 2010), in 2010 about 4% of the agricultural land in the region was un-used. All together this would make 16.5 thous.ha of land that is available for growing energy crops. However, lately there is a discussion among the Ministry of the Agriculture of Latvia, farmers and biogas plant owners about sustainability of growing energy crops. It is expected that in future the land where energy crops are cultivated will not be eligible for direct agricultural payments and fuel that is used for growing, harvesting, preparation and transportation of energy crops will no longer be excluded from the excise tax payment. Therefore it is unlikely that there will be huge plantations of energy crops in the region in years to come.

2. Product biomethane

2.1. Calculation of prospective biogas and biomethane yield

2.1.1. Combined scenario

In the first scenario all collected unsorted MSW are brought to the mechanical treatment facility in Daibe landfill. During the mechanical treatment, waste is separated in three fractions – coarse, medium and fine fraction – and separately some metal parts are removed (see Figure 4).

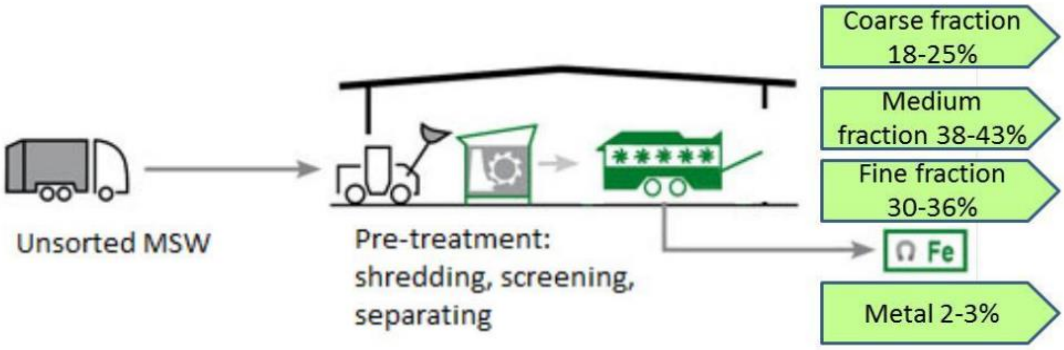

Figure 4: Mechanical treatment of waste in Daibe landfill (source: Arina D. et.al., 2012)

The fine fraction is 70% made of biologically degradable material and 27% is glass, ceramics and stones. Currently after the biological treatment (composting and stabilisation) the fine fraction is used as landfill cover material. The moisture content of the material is changing depending from the season – around 49% in summer and winter, 44% in autumn.

In addition to the mechanically treated organics, a source separated organic waste is collected from companies in very limited amounts. In 2011 only 112 m^3 (about 22 t) of organic waste were separately collected from companies.

Separately collected green waste includes leafs, grass, branches etc. Collection of green waste is a service provided by the waste management company ZAAO at additional cost that is lower than cost for collection of unsorted MSW.

2.1.2. Resource-efficiency scenario

The second scenario proposed in this concept foresees that until 2017 a source separated collection of organic waste from households is introduced. Waste management company ZAAO have estimated the impact on waste management tariff if source separated organic waste collection would be introduced. Current waste management tariff for residents is 8.13 Ls/m^3 (11.57 EUR/m^3), excluding VAT. Green wastes are collected for 7.26 Ls/m^3 (10.33 EUR/m^3) + VAT. ZAAO calculations show that tariff for residents would increase by 32% and instead of 8.13 Ls/m^3 the cost would be 10.70 Ls/m^3 (15.22 EUR/m^3).

According to the survey that has been implemented in Valmiera in the UrbanBiogas project (Dzene I., 2012), 80% of the respondents are already using the provided opportunity and separating plastic, glass and paper.

Most of the people evaluate current costs of waste management as very high. However about 12% of Valmiera inhabitants are not aware about how much they are paying for the waste management services. Others evaluated that they are paying more than 7 EUR/month (18%), 3-7 EUR/month (40%) and less than 3 EUR/month (30%). According to the results of survey 32% of people would agree to pay more for the introduction of source separated organic waste collection, but remaining 68% would need some financial incentive (decrease of waste management cost) to support source separated organic waste collection. Compared to other European countries where waste collection and recycling system is more developed, the cost for waste management in Latvia is very low.

2.1.3. Assumptions

Assumptions used for the calculation of prospective biogas and biomethane yield for both scenarios are given in Table 6.

Table 6.Assumptions for the calculation of biogas and biomethane yield

Parameter	Value	Unit
Fine fraction (FF) after mechanical treatment	35	%
Content of organic fraction after mechanical treatment	70	% (of FF)
Organic fraction of the MSW that can be collected by source separated collection	25	%
Dry matter (DM) content:		
mechanically treated organic MSW	35	% (of FM)
source separated organic MSW	16	% (of FM)
separately collected green waste	40	% (of FM)
waste water treatment sludge	25	% (of FM)
Volatile solids (VS) content:		
mechanically treated organic MSW	70	% (of DM)
source separated organic MSW	87	% (of DM)
separately collected green waste	50	% (of DM)
waste water treatment sludge	70	% (of DM)

Parameter	Value	Unit
Specific biogas yield:		
mechanically treated organic MSW	325	m^3_N/t_{VS}
source separated organic MSW	680	m^3_N/t_{VS}
separately collected green waste	615	m^3_N/t_{VS}
waste water treatment sludge	325	m^3_N/t_{VS}
Methane (CH_4) content:		
mechanically treated organic MSW	55	%
source separated organic MSW	60	%
separately collected green waste	60	%
waste water treatment sludge	55	%
landfill gas	55	%
Biogas upgrading efficiency	95	%

2.1.4. Calculation of indicative biogas and prospective biomethane yields

Indicative biogas and biomethane yields were calculated based on the assumptions given below and based on a forecast of available unsorted municipal waste. Detailed calculations are given in Annex 1 of this report. In the calculations the amounts of collected landfill gas has been taken into account. Calculation results are provided in Figure 5.

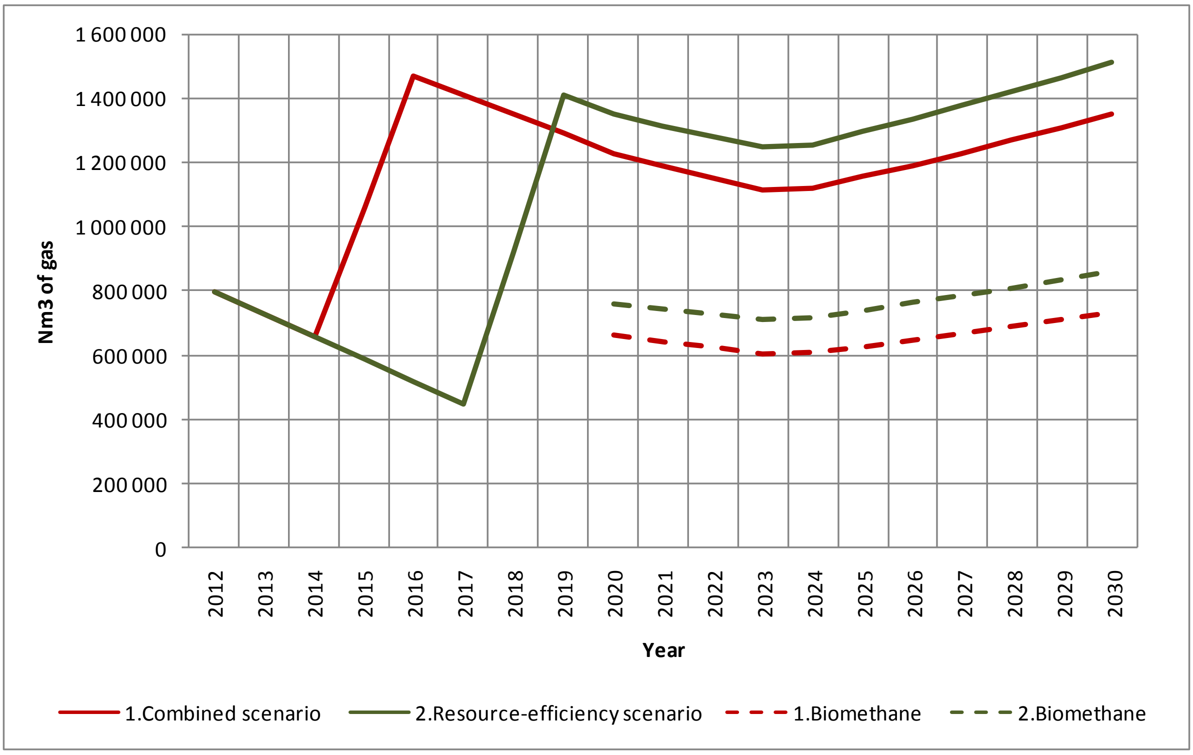

Figure 5: Calculated prospective biogas and biomethane yields, Nm^3

According to the calculation results, until 2014 there will be only landfill gas production that is gradually decreasing over the last years. In 2014 if combined scenario is introduced, the generation of biogas will increase due to the installation of dry fermentation unit and over the next years (until 2023) the total outcome of gas will decrease due to reduced yields of landfill gas production. Then around 2024 the total gas production will again start increasing because more organic waste will be generated from growing population and economical activity in the region.

In case of resource-efficiency scenario the change in existing trend will happen around 2017 when source separated organic waste collection should start. The new wet anaerobic digestion plant could be built in 2019. In wet fermentation process more biogas will be generated.

Biogas upgrading to biomethane most likely will not start before 2020. This assumption is made due to several reasons:

1) ZAAO has obtained rights to sell in biogas CHP generated electricity for a feed-in tariff and this decision is valid for at least 10 years (until 2019). Currently the amount of collected landfill gas is decreasing and company can not produce as much electricity as they are allowed to sell according to the decision of the Ministry. Biogas produced either in dry or wet fermentation until 2019 will be used for CHP.
2) There are no incentives to use biomethane in transport sector in Latvia.
3) Using biomethane for gas grid injection is not possible due to the monopoly situation in the natural gas market and the lack of the legislative framework and standards for biomethane injection.

In combined scenario 1.47 million Nm^3 of biogas will be generated in dry fermentation and collected from the landfill in 2016. The lowest generation point will be reached in 2023 when the total outcome of gas will be only 1.12 million Nm^3. After that the generation will gradually increase, reaching 1.35 million Nm^3 of gas in 2030. If starting from 2020 biogas would be upgraded to the biomethane, then 605-732 thous.Nm^3 of biomethane could be generated every year.

In resource-efficiency scenario 1.41 million Nm^3 of biogas will be generated in wet fermentation and collected from the landfill in 2019. The lowest generation point will be reached in 2023 when the total outcome of gas will be 1.25 million Nm^3, but it is more than in combined scenario. After 2023 the generation will gradually increase, reaching 1.51 million Nm^3 of gas in 2030. If starting from 2020 biogas would be upgraded to the biomethane, then 709-861 thous.Nm^3 of biomethane are generated every year.

3. Biogas Production and Upgrading Plant

3.1. Technology

3.1.1. Good practice examples

In both scenarios the amount of organic waste that is available for biogas production is around 10-15 thousand tons per year. Good practice examples described in UrbanBiogas project (Hahn.H., 2011) show that there are several good practice examples of small biogas and biomethane plants being set up and operated in Europe using organic municipal and industrial waste as feedstock.

Some examples of small scale waste biogas plants with upgrading units are given in Table 7.

Table 7.Good practice plants in Europe to be used as reference to Valmiera

Name of the plant	Country	Feedstock, t/year	Technology	Investment costs, € (year)
Biogas plant Västerås	Sweden	Household waste – 15 400 Grease trap removal – 2 150 Grass silage – 2 990 TOTAL: 20 550	Source separated household waste; Wet digestion, gas outcome 280 Nm^3/h; Water scrubber (700 Nm^3/h) – treating gas also from other plant	6 million (2005), without upgrading

Name of the plant	Country	Feedstock, t/year	Technology	Investment costs, € (year)
Biogas plant Rostock	Germany	Food waste – 4 000 Municipal waste – 36 000 TOTAL: 40 000	Source separated household waste; Wet digestion, gas outcome 1000 Nm³/h; Water scrubber (350 Nm³/h)	n/a (2010)
Biogas plant Altenstadt	Germany	Municipal waste (food waste, canteen waste, fats, slaughterhouse waste) – 40 000	Wet digestion, gas outcome 1200 Nm³/h; Water scrubber (690 Nm³/h)	4 million (2001), without upgrading
Biogas plant Bruck an der Leitha	Austria	Organic waste (green waste, kitchen debris, food waste, remains from food industry, expired food, beer malt, fat separator, residues from vegetable oil production) – 30 000	Wet digestion, gas outcome 650-800 Nm³/h; Membrane (180 Nm³/h)	6.5 million (2004), without upgrading

3.1.2. Dry fermentation (combined scenario)

Each biogas production process involves several steps (see Figure 6):

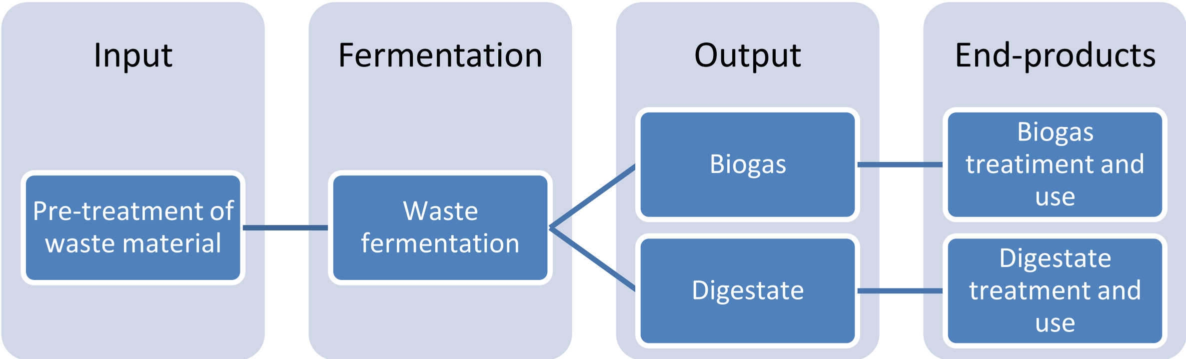

Figure 6: Waste-to-biogas process tree

In combined scenario the following waste material is available:

Organic MSW after mechanical treatment	6 370-9 640 t/year
Separately collected green waste	3 140 - 4 510 t/year
Waste water treatment sludge	340 - 490 t/year
TOTAL:	9 850 - 14 650 t/year

Before fermentation waste is mechanically treated. In dry fermentation the pre-treatment requirements are generally lower compared to wet fermentation technology. In dry fermentation separated organic fraction of MSW will be mixed together with green waste and WWT sludge.

In dry fermentation the mixture of waste is inoculated with digestate and fed in the digester. This is a batch process. Continuous inoculation with bacterial biomass occurs through recirculation of percolation liquid, which is sprayed over the substrate in the digester. Unlike wet digestion, dry digestion needs no stirring or mixing of the AD substrate during digestion. The temperature of the process and of percolation liquid are regulated by a built-in floor heating system, inside the digester, and by a heat exchanger, which acts as a reservoir for percolation liquid (Rutz, D. et.al., 2009).

Schematic design of the dry fermentation unit designed by company “Kompoferm” for treating 10 000 t of organic waste per year can be seen in Figure 7.

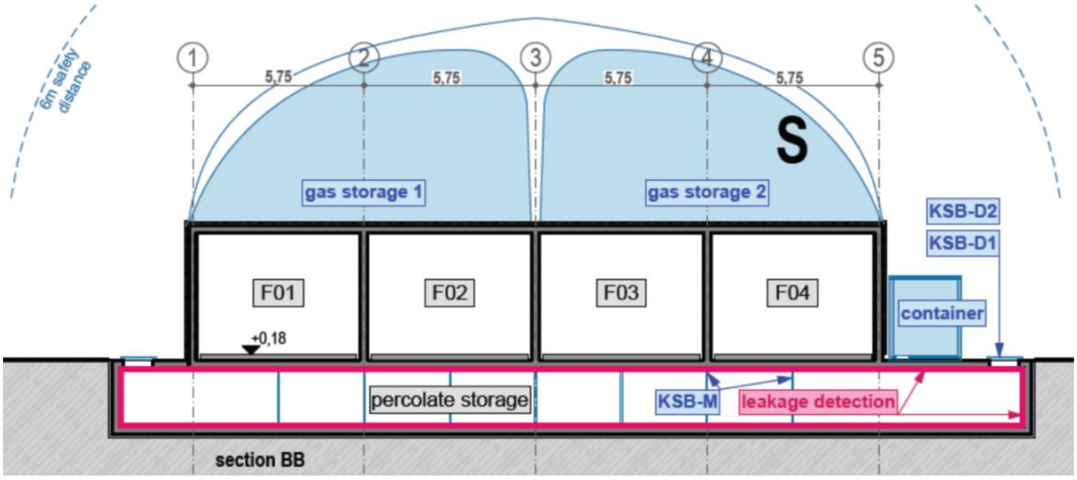

Figure 7: Design of the dry fermentation unit (ZAAO, 2012)

In this scenario the calculated biogas outcome is 105 – 150 Nm^3/h. The other product is the dry digestate (about 9 000 – 13 500 t/year). If biogas is used for CHP production process, gas cleaning and treatment requirements are lower than those for the biogas upgrading to biomethane. Basically desulphurisation and drying of the gas is required. If biogas is upgraded to biomethane, more sophisticated technologies are used (see Chapter 3.1.4).

Due to the low quality of the input material, the quality of digestate after the dry fermentation process is not appropriate for using it as fertilizer. It contains glass particles and other contaminants. In order to use digestate as fertilizer, it must be further processed. Currently it is not economically feasible because of the low demand in the local market for high quality compost. The solution proposed by waste management company ZAAO is to use digestate for daily cover of the landfill. However, as mentioned in the introduction part of this concept, this solution does not guarantee that nutrients are returned back to the soil.

3.1.3. Wet fermentation (resource efficiency scenario)

In resource efficiency scenario the following waste material is available:

Organic fraction of MSW	6 500 – 9 840 t/year
Separately collected green waste	3 140 – 4 510 t/year
Waste water treatment sludge	340 – 490 t/year
TOTAL:	9 990 – 14 850 t/year

In wet fermentation scenario it is assumed that separately collected waste will be delivered to the biogas plant. After the basic pre-treatment of the separately collected organic waste, the feedstock for the biogas production is on much better quality and can be used for wet fermentation. Continuous wet fermentation process gives higher biogas outcome compared to dry fermentation and is generally more effective.

Example of a single-stage wet fermentation process is given in Figure 8 (Waste-to-Energy Research and Technology Council, 2009). The complexity of the technology depends on the quality of the input material, design of the bioreactor and desired quality of the digestate.

In this scenario the calculated biogas outcome is 115 – 170 Nm^3/h. Biogas treatment requirements are not much different from the dry fermentation. Again desulphurisation and drying is needed if biogas will be used in CHP. To reach the biomethane quality, in addition the CO_2 must be removed (see Chapter 3.1.4.).

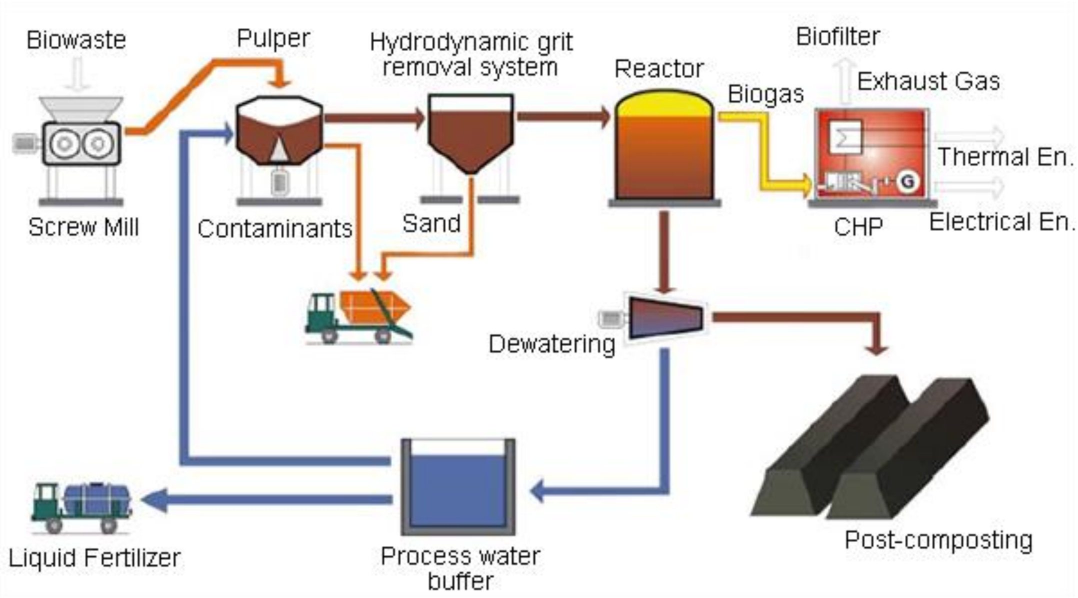

Figure 8: Process scheme of the BTA® Single-stage wet fermentation (Image: BTA International GmbH)

As can be seen in Figure 8, there are two options for the digestate treatment. It can be collected and used directly as a liquid fertilizer or additional treatment step can be applied. In this treatment step the solid and liquid part is separated having two products – liquid fertilizer and compost. This compost is much higher quality compared to the compost after the dry fermentation. In Figure 8 one important part of the municipal waste fermentation process is missing. In order to be able to use compost and fertilizer for the agricultural purposes, the sanitation of the waste is needed before pumping the feedstock into the bioreactor.

3.1.4. Biogas upgrading to biomethane

Several biogas upgrading technological solutions exists. Commercially available are 6 of them: pressure swing adsorption (PSA), water scrubber, physical absorption with organic solvents, and chemical absorption with organic solvents, high and low pressure membrane separation methods (see Figure 9).

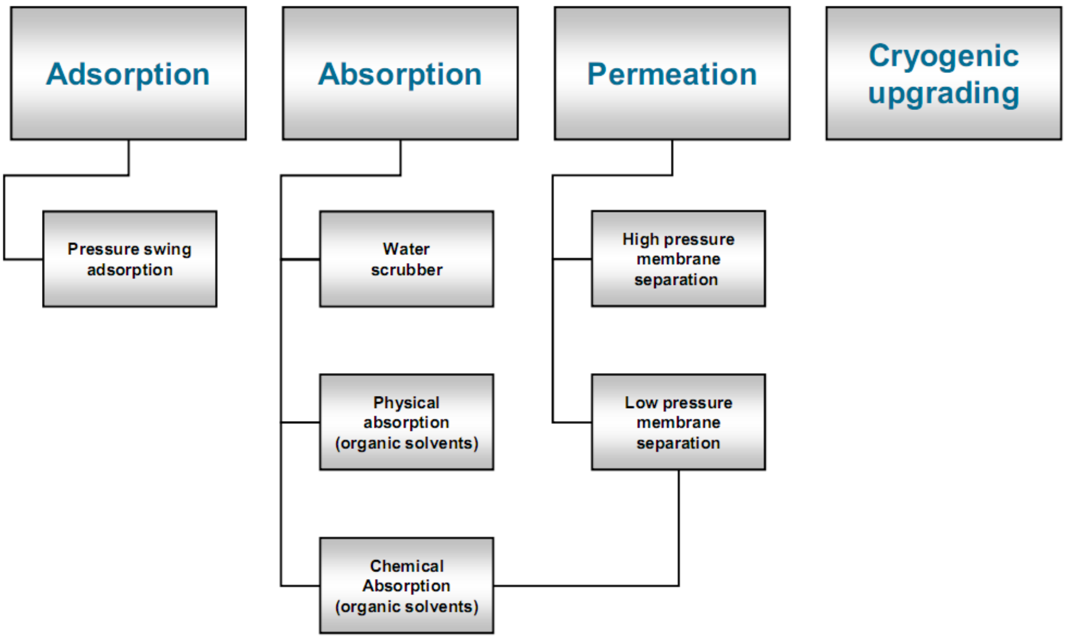

Figure 9: Biogas upgrading technology overview (Beil M., 2012)

Most commonly used are PSA, water scrubber and amine scrubber (chemical absorption) biogas upgrading systems. Currently in Latvia there are no biogas upgrading plant and no local upgrading technology suppliers. Therefore the services of the foreign supplier must be used.

Upgrading method should be selected based on the biogas characteristics and intended use of the biomethane. The best technology to choose is based on specific parameters at the plant, such as the availability of cheap heat and the electricity price. It should also be noted that it is often possible to lower the methane loss, but at the expense of a higher energy consumption (Petersson A., Wellinger A., 2009). The key parameters for upgrading technologies according to (Beil M., 2012) are summarized in the Table 8.

Table 8.Key parameters of upgrading technologies (Beil M.,2012)

Parameter	Unit	PSA	Water scrubber	Physical absorption (organic solvents)	Chemical absorption (organic solvents)	Membrane (high pressure, dry)	Cryogenic
Electricity demand	kWh/m^3_{BG}	~0.2-0.25	~0.2-0.3	0.23-0.33	>0.10	~0.25	0.18-0.33
Heat demand (temperature level)	^oC	No	No	55-80	~160	No	No
Operation pressure	bar	4-7	5-10	4-7	0.1	5-10	
Methane loss	%	1-5	0.5-2	1-4	0.1		0.5 (?)
Exhaust gas treatment suggested (methane loss >1%)		Yes	Yes	Yes	No	Yes	Yes
Precision desulphurization required		Yes	No	No	Yes	Suggested	Yes
Water demand		No	Yes	No	Yes	No	No
Demand on chemical substances		No	No	Yes	Yes	No	No

In order to recommend the technology for upgrading of gas in Valmiera biogas plant, further references were analyzed based on the list of upgrading plants given by Petersson A., Wellinger A., 2009. From the list it can be seen that also small scale biogas upgrading plants are installed and operating in Europe (see Table 9).

Table 9.List of relevant upgrading plants in Europe (after Petersson A., Wellinger A., 2009)

Country	Place	Substrate	Utilisation	CH_4 (%)	Technology	Plant capacity, Nm^3/h raw gas	In operation since
Austria	Margarethen am Moos	Energy crops & manure	Vehicle fuel	>95	Membrane	70	2007
Austria	Pucking	Manure	Gas grid	97	PSA	10	2005
Austria	Reitbach / Eugendorf	Energy crops	Gas grid, Vehicle fuel	97	PSA	150	2008
France	Lille Marquette				Water srubber	100	2009
Germany	Bottrop	Sewage sludge	Vehicle fuel		PSA	120	2008
Germany	Jameln	Manure & Energy crops	Gas grid, Vehicle fuel		Genosorb scrubber	160	2005
Germany	Utzensdorf	Biowaste	Gas grid	96	PSA	100	2009
Spain	Vacarisses (Barcelona)	Landfill gas	Vehicle fuel	>85	Chemical scrubber	100	2005
Sweden	Eslöv	Biowaste, sewage sludge	Vehicle fuel	97	Water scrubber	80	1999

Country	Place	Substrate	Utilisation	CH_4 (%)	Technology	Plant capacity, Nm^3/h raw gas	In operation since
Sweden	Katrineholm	Sewage sludge	Vehicle fuel	97	Water scrubber	80	2009
Sweden	Motala	Sewage sludge	Vehicle fuel	97	Water scrubber	80	2009
Sweden	Skövde	Sewage sludge, slaughter waste	Vehicle fuel	97	PSA	140	2002
Sweden	Ulricehamn	Sewage sludge	Vehicle fuel	97	PSA	20	2003
Sweden	Västervik	Sewage sludge	Vehicle fuel	97	Water scrubber	130	2009
Switzerland	Bachenbülach	Biowaste	Gas grid, Vehicle fuel	96	PSA	50	1996
Switzerland	Bischofszell	Sewage sludge	Gas grid	96	Genosorb scrubber	100	2007
Switzerland	Jona	Biowaste	Gas grid	96	Genosorb scrubber	55	2005
Switzerland	Lavigny	Biowaste	Gas grid	96	PSA	150	2009
Switzerland	Lucerne	Sewage sludge	Gas grid	96	PSA	75	2004
Switzerland	Obermeilen	Sewage sludge	Gas grid	96	Chemical scrubber	100	2008
Switzerland	Otelfingen	Biowaste	Vehicle fuel	96	PSA	50	1998
Switzerland	Romanshorn	Sewage sludge	Gas grid	96	Genosorb scrubber	100	2007
Switzerland	Rümlang	Biowaste	Vehicle fuel	96	PSA	30	1995
Switzerland	Samstagern	Biowaste	Gas grid	96	PSA	50	1998
Switzerland	Utzensdorf	Biowaste	Gas grid	96	PSA	100	2009
Switzerland	Widnau	Agricultural co-digestion	Gas grid	96	PSA	100	2007

It can be seen in Table 9 that among the small capacity upgrading plants (up to 170 Nm^3/h) in most cases PSA technology is used. In Switzerland and Germany PSA is used in particular in a small scale biowaste treatment plants. Therefore as a base scenario in this concept we assume that PSA technology for the upgrading of biogas will be used.

3.2. Plant location

For selection of the plant location site, in general three options are evaluated:

1) Biogas plant at Daibe landfill site
2) Biogas plant close to Valmiera city
3) Delivery of the waste to one of the existing biogas plants

3.2.1. Biogas plant at Daibe landfill site

One of the options is to use the advantage of Daibe location and to build the biogas plant in the territory of Daibe landfill. As it can be seen from the Figure 10, the Daibe landfill is located in the central part of the North Vidzeme region in Pargauja district.

Daibe landfill is located in rather remote area and it has a potential to extend the territory, so the potential biogas plant could be located very close to the landfill. The area is connected with the 20 kV power line. Pargauja district is crossed by the major state road A3 and Daibe landfill is located approximately 7km from the main road A3 (see Figure 11). 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 provided.

Figure 10: Location of Daibe landfill (source: http://www.zaao.lv/public/lat/par_sia_zaao/**)**

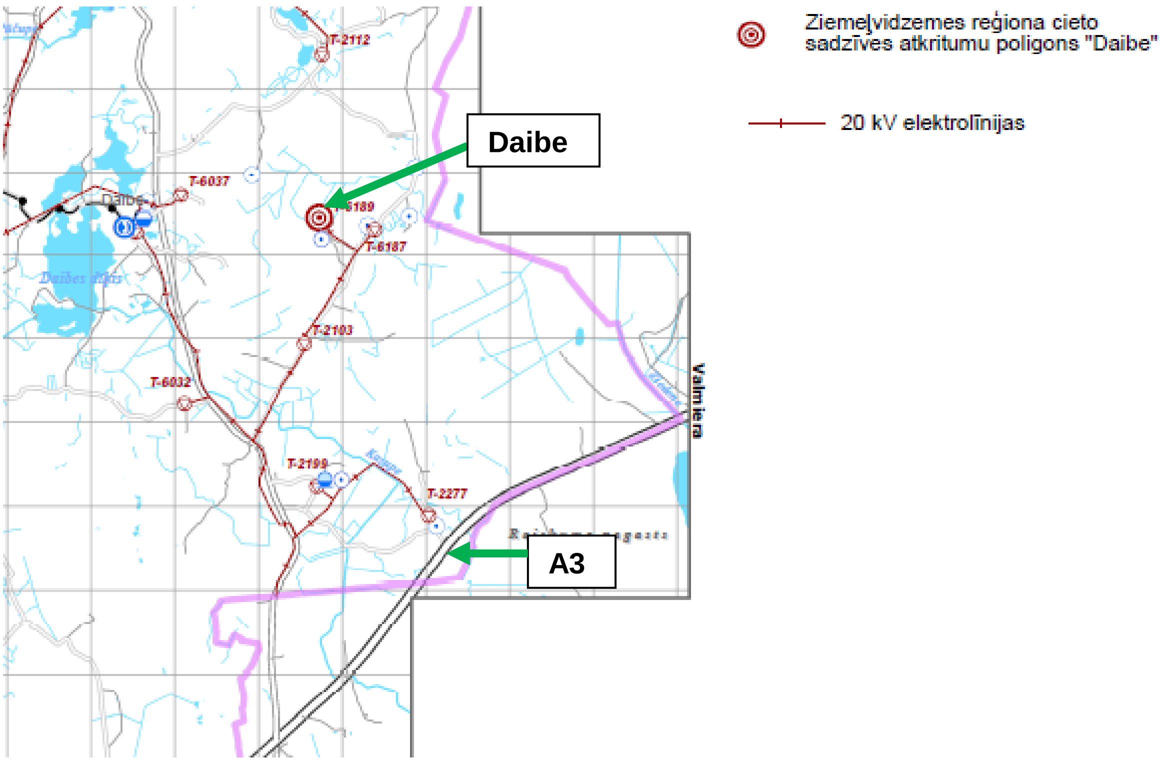

Figure 11: Location of Daibe landfill (source: http://www.pargaujasnovads.lv/lv/pargaujas-novada-teritorijas-planojuma-2013.-2024.gadam-galiga-redakcija---/**)**

Around the landfill there are no major residential areas or industrial or commercial areas. And also there are no historical sites are around the area.

In 2009 the project on landfill gas extraction and use in CHP has started. The capacity of the CHP unit was 175 kW_e 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 installation of additional CHP unit. Electricity generated in the CHP is sold for the feed-in tariff. If the intended biogas is located in Daibe landfill, then biogas plant could be connected to the existing CHP plant. The capacity of the plant allows combustion of more biogas since the amount of landfill gas that is collected is decreasing over the years.

3.2.2. New biogas plant close to Valmiera city

Since the main organic waste producers are located in and around Valmiera city, one of the considered options is to build the biogas plant next to Valmiera.

Currently organic waste in Valmiera is not source separated. Location of the biogas plant in Valmiera might be economically feasible in case if source separated organic waste are collected and delivered to the biogas plant near the city. This would allow to save on the transportation costs compared to the scenario if biogas plant is located in Daibe landfill.

Another advantage of locating the biogas plant in Valmiera is access to the existing natural gas pipeline. The main gas line with several distribution points is crossing the Eastern part of the city (see Figure 12).

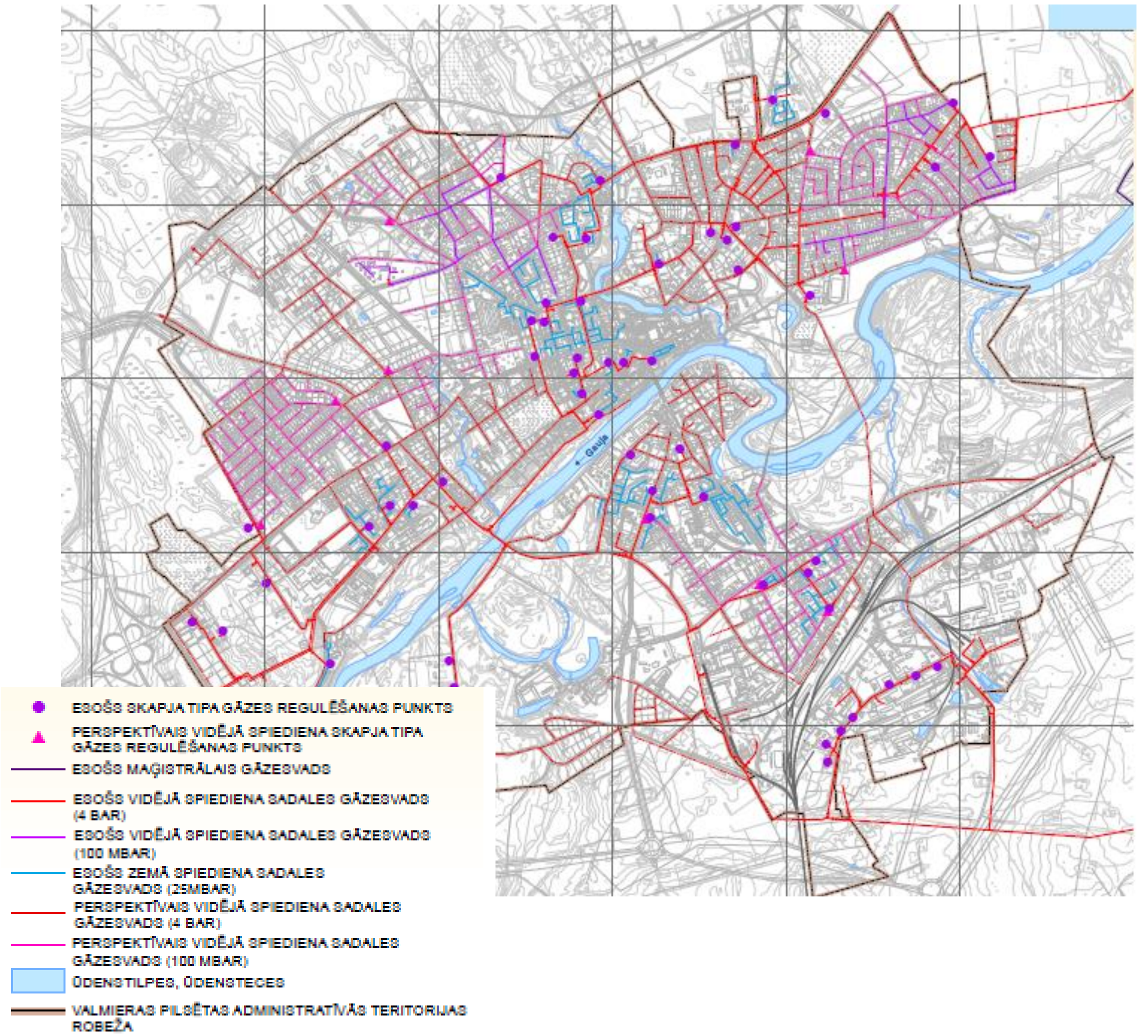

Figure 12: Gas supply network in Valmiera city

Road infrastructure is well developed and Valmiera has sufficient electrical power supply.

The main problem when considering building the biogas plant next to the city is selection of particular area and potential impact on the neighbourhood. The results of the survey (Dzene I., 2012) show that 80% of the survey participants supported UrbanBiogas idea and project activities, however many of them were concerned about building the biogas plant close to the city and about odour and noise problem that it might create. The inhabitants of Valmiera are very sensitive to the odour issue because of the historically bad experience they had with some of the food processing companies located in the city. However when it happened years ago the environmental performance requirements were much lower than it is in our days for a new plants.

3.2.3. New biogas plant as the part of some existing biogas plant

According to the Figure 3, there are 8 biogas plants in North Vidzeme area and the closest one to Valmiera city is biogas plant "Zemturi" (see Figure 13).

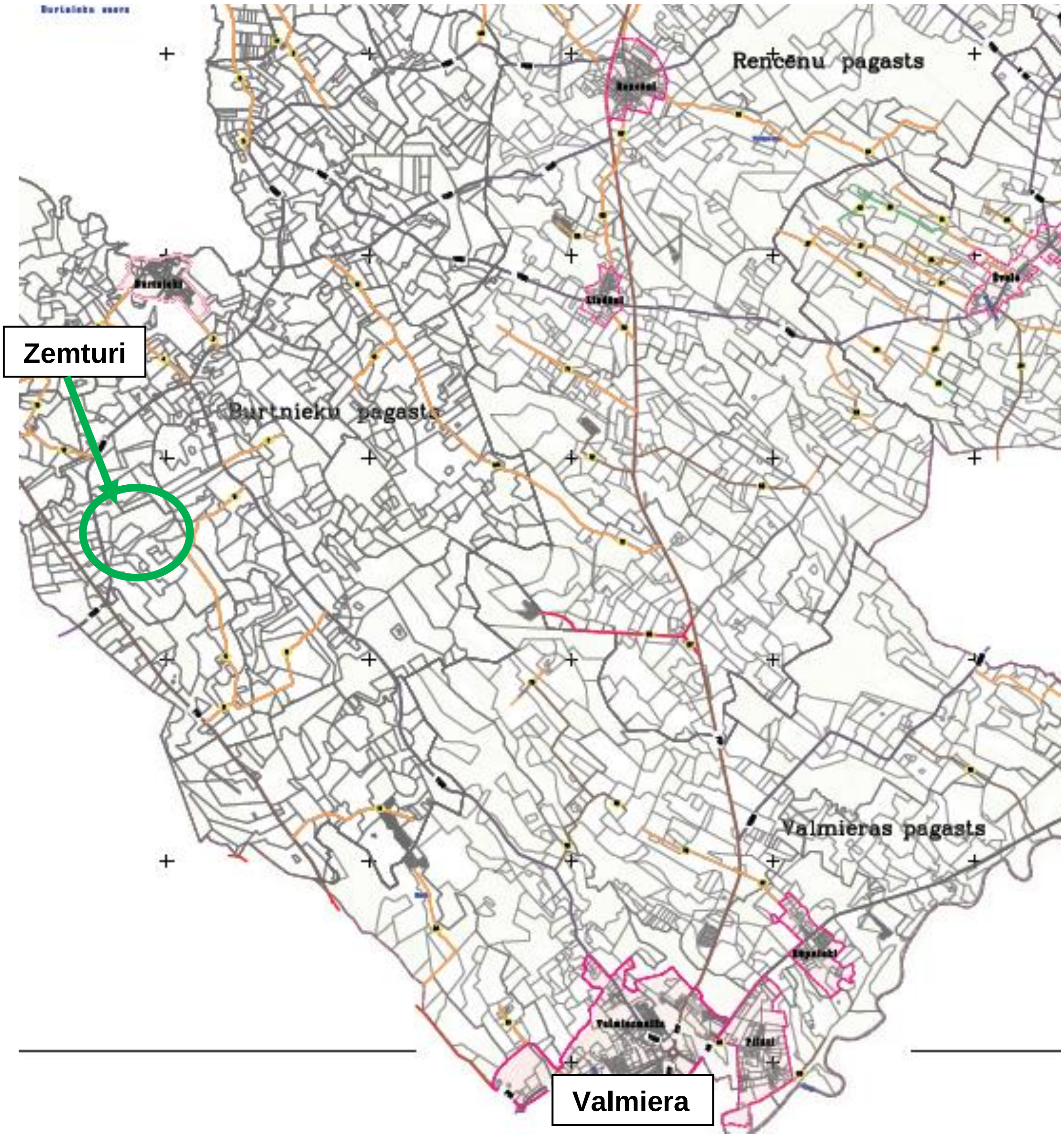

Figure 13: Location of "Zemturi" farm (source: http://www.burtniekunovads.lv/teritorijas-planojums)

Biogas plant is located in a remote area, approx. 16 km from Valmiera. The closest residential areas are located about 6 km away from the farm. The biogas plant is located in the territory of North Vidzeme Biosphere National Park; however this particular area does not have any limitations for economical activity since it is not a part of Natura 2000.

Disadvantage for this location is the lack of the natural gas grid in Burtnieki parish, where the biogas plant is located.

If this option for biogas plant location is selected, the role of ZAAO will be collection, transportation and treatment of organic waste and selling it as biogas feedstock to the “Zemturi” biogas plant. The advantage of this option is the fact that distance to Valmiera city is shorter than to Daibe landfill. This would significantly reduce the transportation costs. Another advantage is suitability of the location for the biogas plant. All the necessary permits and infrastructure for biogas production is already there. In this case the source separated organic waste collection system in Valmiera must be introduced.

3.3. Economy

3.3.1. Dry fermentation

Evaluation of the investment cost for the dry fermentation garage type biogas plant is based on the offer provided by company “Kompoferm” upon ZAAO call for quotations in 2012 (see Table 10).

Table 10.Investment costs for 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
Margin of the unforeseen expenses (5%)	51 349	73 063
TOTAL:	1 078 321	1 534 321

The batch digestion has a number of advantages compared to other systems, in terms of lower costs of the process and of the mechanical technology behind it. This in turn has an adverse effect on process energy consumption and on maintenance costs (Rutz, D. et.al., 2009). Operation and maintenance costs are assumed as 5% from the total investment – 76 716 EUR/year. Operation and maintenance costs include regular maintenances of biogas plant, staff costs, administration costs, energy (electricity) cost and insurance costs. Depreciation costs are equally distributed over the first 10 years.

The economical evaluation of this scenario was done by using a cash flow analysis. Two alternative solutions were investigated:

- Dry fermentation + CHP
- Dry fermentation + CHP + biogas upgrading

Alternative 1: Dry fermentation + CHP

In the first alternative the income is generated from 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. In 2030 it is assumed that electricity will be sold at the market price that at that time could be around 103 EUR/MWh. Assumption is made by taking the electricity market price in 2012 in Latvia with an escalation rate of 4.5% per year.

The waste management tariff in Latvia is calculated based on the following equation:

$$T_{wm} = \frac{C_T + C_A + C_L + K + N}{W_L} \times R$$

Where

T_{wm} – waste management tariff [LVL/t or LVL/m^3]

C_T – transportation costs [LVL/year]

C_A – administration costs [LVL/year]

C_L – landfilling costs [LVL/year]

K – long term loans [LVL/year]

N – taxes and fees [LVL/year]

W_L – amount of treated waste per year [t/year or m^3/year]

R – profit margin [%]

The profit margin for the waste management companies is limited. If costs for the long-term loan are included in the tariff costs, then profit margin is limited to 3.5%. If cost for the long-term loan is included in the tariff, the depreciation of the equipment, that has been purchased using the loan, can not be included in the tariff costs. Otherwise the profit margin is limited to 7%.

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 plant 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 that is supplied by ZAAO.

In this cash flow analysis the cost for the feedstock and revenues from the waste management are assumed zero. In this way the biogas project is separated from the waste management part and cost analysis are made only on the project base. The cash flow analysis for this alternative scenario is given in Annex 2. The IRR for this project is 26% without investment subsidy.

Alternative 2: Dry fermentation + CHP + biogas upgrading

In the second alternative it is assumed that biogas from dry fermentation will be used in CHP until 2019 and in 2020 the biogas upgrading will start. In this case the income will be generated by electricity sales until 2019 and by biomethane sales after that. Investment costs for the dry fermentation plant are assumed the same as given in the Table 10. However in this scenario another investment is made in 2019 for the installation of biogas upgrading plant.

Investment costs for the biogas upgrading plant are assumed based on the specific costs curve given by Hahn, H. and Hoffstede, U. (2011) – see Figure 14.

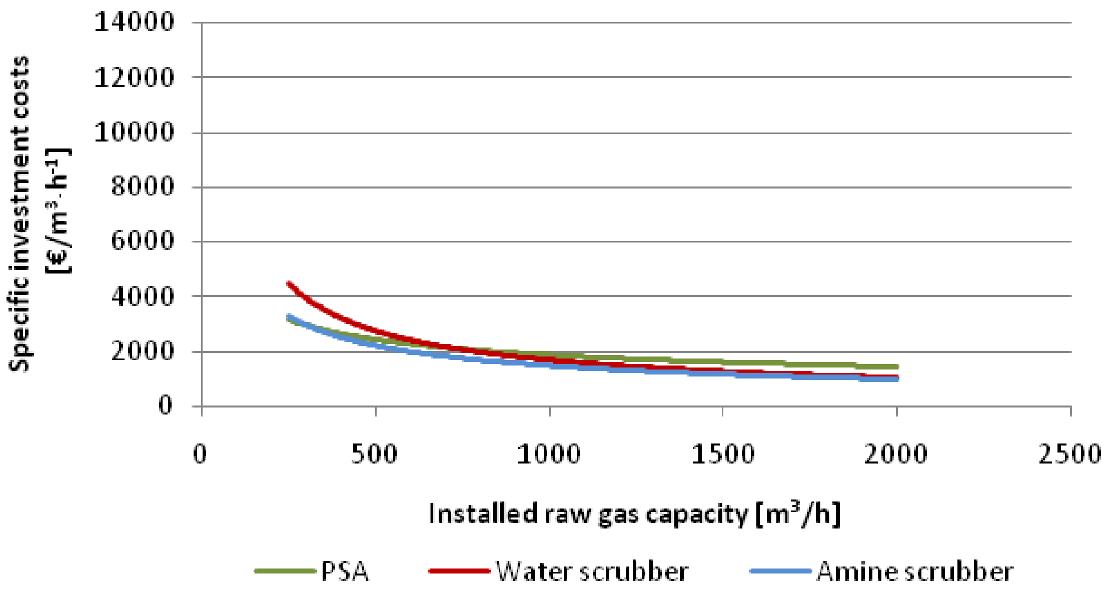

Figure 14: Specific Investment costs of upgrading plants (Hahn H., Hoffstede U., 2011)

It is assumed that biogas upgrading plant will treat 120 Nm^3 of raw biogas per hour. Specific cost for this scale of plant is 4 207 $EUR/m^3 \cdot h^{-1}$. By this assumption the total investment cost would be about 0.5 million EUR. Previous studies about agricultural biogas plants in Latvia show that actual costs in the market are at least 20% above the reference capital costs from Western-European countries. Therefore 20% more to the reference costs are added to adapt them to the local market situation. Additional 5% are added as unforeseen expenses. The summary of the investment costs for biogas upgrading plant is given in Table 11.

Table 11.Investment costs for biogas upgrading plant

Reference Investments	504 850	EUR
Investment costs adapted to the Latvian market (+20%)	605 821	EUR
Margin of the unforeseen expenses (+5%)	30 291	EUR
Total Investment costs	636 112	EUR

Biogas upgrading plant operation costs are assumed to make 7% from the investment costs. Operation and maintenance costs for dry fermentation plant in 2020 are reduced by 50% because of shutting down the CHP part.

Like in alternative 1, also in this cash flow analysis the cost for the feedstock and revenues from the waste management are assumed zero. In order to get the cash flow positive, the revenues from selling biomethane should be at least 0.35 EUR/Nm^3 with annual increase of 3% due to the inflation. The cash flow of this alternative is enclosed to the Annex 3.

3.3.2. Wet fermentation

Evaluation of the investment cost for the wet fermentation biogas plant is based on the cost reference values given in the study (ARCADIS, 2009). According to this study, the country specific CAPEX for Latvia for the waste anaerobic digestion (AD) plant with upgrading to biomethane is 342 EUR/t of treated waste.

In this scenario it is calculated that in average 12 500 t of waste will be treated. This results to the total investment cost of 4.275 million EUR.

The economical evaluation of this scenario was done by using a cash flow analysis. Two alternative solutions were investigated:

- Wet fermentation + CHP
- Wet fermentation + CHP + biogas upgrading

Alternative 3: Wet fermentation + CHP

In the first alternative the income is generated only from sales of electricity according to the feed-in tariff. The guaranteed feed-in tariff for company “ZAAO Energija” is 212.64 EUR/MWh until 2019 and 170.11 EUR/MWh until 2029. In 2030 it is assumed that electricity will be sold at the market price that at that time could be around 103 EUR/MWh. Assumption is made by taking the electricity market price in 2012 in Latvia with an escalation rate of 4.5% per year.

In this case the investment costs are reduced because they do not include installation of the biogas upgrading unit. The investment cost for biogas upgrading plant is calculated based on the same specific investment curve that have been used in the 1.scenario (see Figure 14). It is assumed that biogas upgrading plant will treat 135 Nm^3 of raw biogas per hour. Specific cost for this scale of plant is 4 023 $EUR/m^3 \cdot h^{-1}$. By this assumption the total investment cost would be about 0.54 million EUR. Previous studies about agricultural biogas plants in Latvia show that actual costs in the market are at least 20% above the reference capital costs from Western-European countries. Therefore 20% more to the reference costs are added to adapt them to the local market situation. Additional 5% are added as unforeseen expenses. The summary of the investment costs for biogas upgrading plant is given in Table 12.

Table 12.Investment costs for biogas upgrading plant

Reference Investments	543 097	EUR
Investment costs adapted to the Latvian market (+20%)	651 716	EUR
Margin of the unforeseen expenses (+5%)	32 586	EUR
Total Investment costs	684 302	EUR

The investment cost for the wet fermentation plant only is calculated as total investment cost of 4.275 million EUR minus 684 302 EUR.

Operational costs

If the cost for the feedstock and revenues from the waste management are assumed zero, the cash flow is negative and project is not economically feasible (see Annex 4). The project may pay back in two ways:

- If part of the investment costs are covered by the subsidy
- If additional revenues from the waste management are received (the waste management tariff is increased).

The second option could be replaced by the gate fee, which is currently not applicable in Latvia.

In order to have the project IRR = 7%, at least 71% of the investment costs must be covered by the subsidy (see Annex 4). If more revenues are intended from increasing the waste management tariff, then existing waste management tariff must be increased by 1.88 EUR/m^3 to get the project IRR = 7% (see Annex 4).

Alternative 4: Wet fermentation + CHP + biogas upgrading

In the second alternative it is assumed that biogas from wet fermentation will be used in CHP until 2019 and in 2020 the biogas upgrading will start. In this case the income will be generated by electricity sales until 2019 and by biomethane sales after that. The investment costs for the wet fermentation plant are assumed the same as for alternative 3. Additional investment is made in 2019 for the installation of biogas upgrading plant at the cost that is calculated in Table 12.

Operation and maintenance costs for operating the wet AD plant are assumed at 7% from the investment costs. Biogas upgrading plant operation costs are assumed to make 7% from the investment costs into the biogas upgrading plant. Operation and maintenance costs for AD plant in 2020 are reduced by 50% because of shutting down the CHP part.

The cost for the feedstock and revenues from the waste management are assumed zero. In order to get the cash flow positive, the revenues from selling biomethane should be at least 0.74 EUR/Nm^3 with annual increase of 3% due to the inflation. The cash flow of this alternative is enclosed to the Annex 5.

If the biomethane sale price is equal to the price given in Alternative 2 (0.35 EUR/Nm^3), then investment cost subsidy or additional revenues from the waste management tariff is needed. The project IRR=7% if 63% of the investment into the AD plant investment is covered by the subsidy (see Annex 5). Alternatively the project IRR=7% if existing waste management tariff will be increased by 1.66 EUR/m^3 starting from 2018 (see Annex 5).

4. Stakeholders

Economical calculations of several waste-to-biomethane scenarios show that implementation of the full waste-to-biomethane chain is not always economically feasible. Either public subsidy or/and increase of waste management tariff is needed. Increasing the waste management tariff requires strong political will and explanatory work with society.

The main responsibility on making this political decision lies is on the city council that is responsible for organisation of the waste management services in the city. Other stakeholders that are involved in the WtB chain are:

- Public services:
    - Valmieras Namsaimnieks (house management, green areas management)
    - VTU-Valmiera (public transport company)
    - Valmieras ūdens (water and wastewater management company)
- Waste management company ZAAO
- Company “ZAAO Enerģija”
- Other existing and planned biogas plants in the region
- Environmental protection organisations (Regional Environmental Board, environmental NGOs)
- Society and inhabitants of Valmiera city
- Industrial companies

4.1. Combined scenario (unsorted waste + dry fermentation)

In combined scenario the main investor in the WtB concept will be ZAAO. In this scenario ZAAO will invest into the dry fermentation unit, probably with a support from public funds. The need for the public funding will be justified by the fact that ZAAO and “ZAAO Energija” are legally two separate companies and investments into the dry fermentation unit might not be covered by the income from sales of biogas. Otherwise the price for the biogas that is now agreed between ZAAO and ZAAO Energija must be increased, that, however, is not favourable for both companies. ZAAO profit margin is limited by the waste management tariff, and income of ZAAO Energija depends directly on the biogas price.

Nevertheless combined scenario is not the best from the environmental and resource efficiency point of view, both ZAAO and ZAAO Energija are very much interested in the unsorted waste – dry fermentation scenario. This is because ZAAO will be able to operate and pay back the investments of the mechanical waste treatment centre and ZAAO Energija will get more biogas and will be able to produce more electricity to fill the feed-in tariff allowance and maximize the income from electricity sales. Valmiera city council supports this scenario because it does not affect the current waste management system and the waste management tariff. Tariffs are always very sensitive issue in communication with society. Municipality is rarely supportive to un-popular decisions, like increasing waste management tariffs, especially before elections.

The organisational model of the combined scenario is provided in Figure 15.

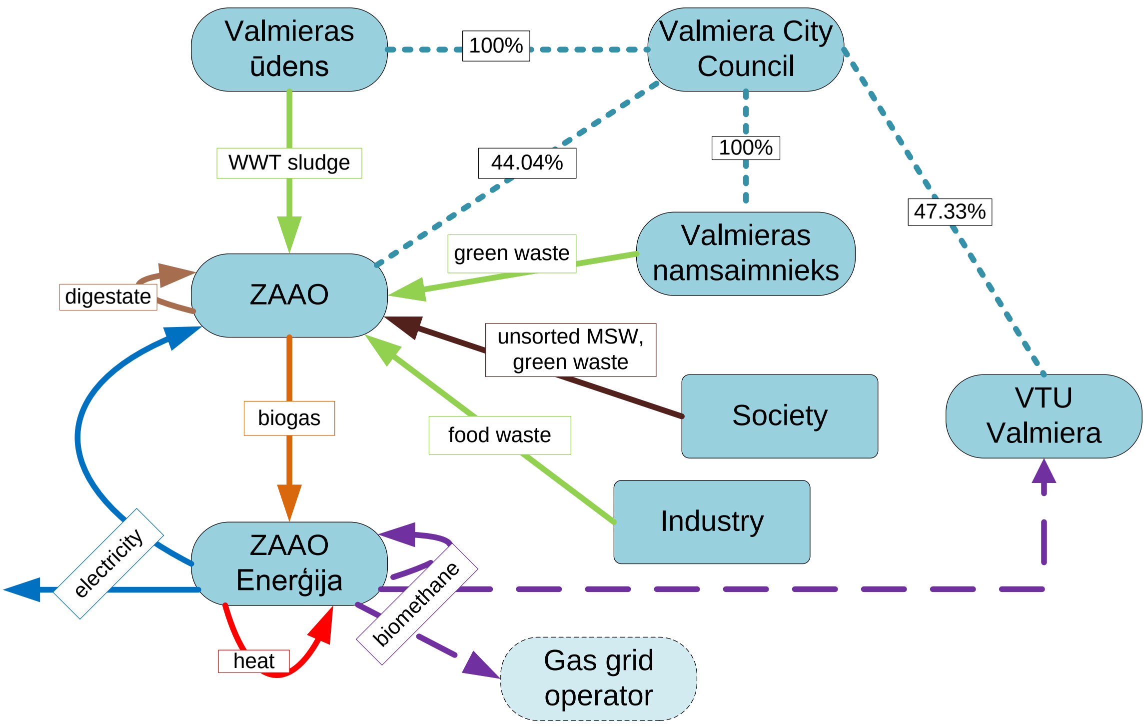

Figure 15: Organisational model of the combined scenario (unsorted MSW and dry fermentation)

4.2. Resource-efficiency scenario (source separated waste + wet fermentation)

In order to realize the resource-efficiency scenario, the strong political decision and strong support from the environmental organisations is needed. In this scenario the location of potential WtB plant should be selected based on economical criteria. It should not become necessarily a part of ZAAO. The biogas production facility might be jointly owned by the city council, ZAAO, private investors and/or even some industry. One of the options for organisational model of the resource-efficiency scenario is provided in Figure 16.

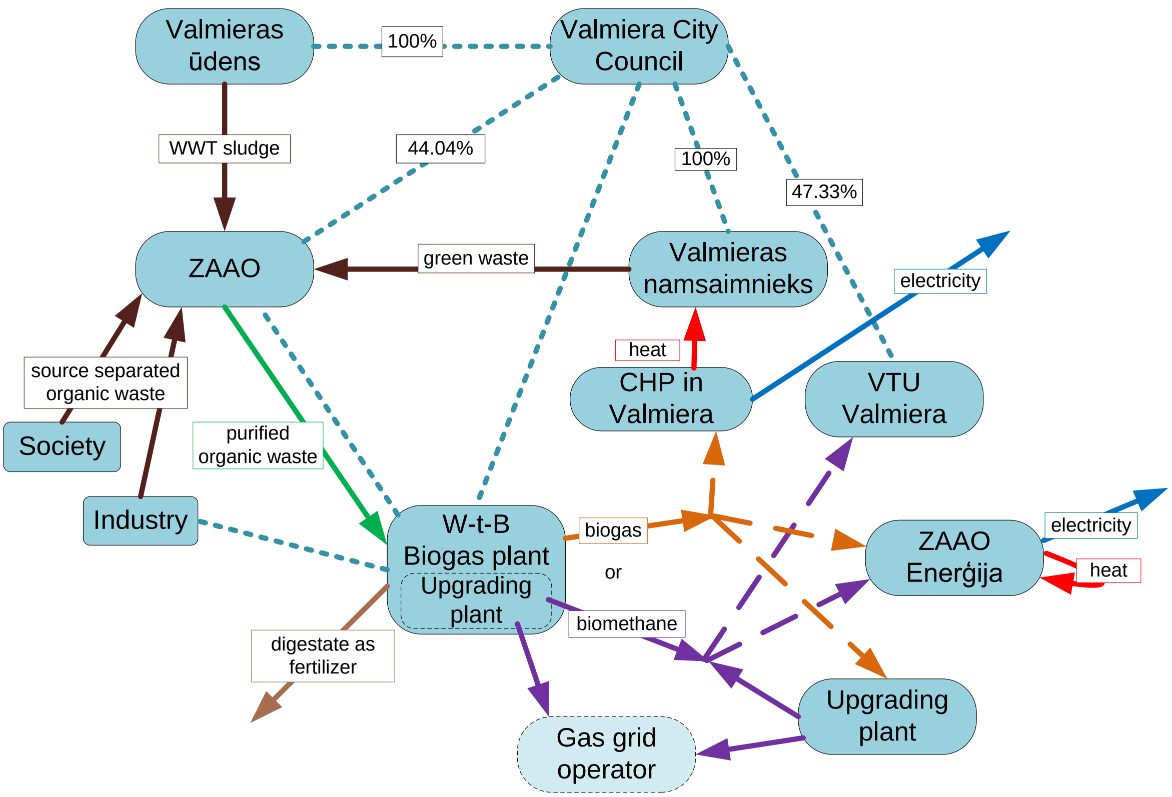

Figure 16: Organisational model of the resource-efficiency scenario (source separated organic waste collection and wet fermentation)

5. Proposal of preferable solution of biomethane production in Valmiera

Preferable WtB solution in Valmiera is a source separated organic waste collection, delivery of the waste to a wet anaerobic digestion plant located near Valmiera (in order to reduce the transportation costs and allow collection and delivery of other organic waste (e.g. from the industry) to the plant), biogas upgrading to the biomethane and using biomethane for the public transport of the city. This solution is the most beneficial for society and for environment in the long term perspective. Society and inhabitants of Valmiera will benefit from improved environmental quality, from more sustainable transport in the city and reduced odour disturbances from existing waste water treatment plants.

However in reality because of the reasons described in Chapter 4.1, the solution proposed by ZAAO in combined scenario will be implemented.

6. Strategies for a successful biomethane production in Valmiera

6.1. Creating and maintaining a sustainable demand for biomethane

Currently there is no demand for biomethane in Valmiera city. First it is because of the absence of the biomethane infrastructure. In order to create the demand for compressed biomethane in the transport, the gradual change of existing vehicles to CNG/CBG vehicles is needed. Discussions with Valmiera city council regarding the transition of the public transport fleet has started during the biomethane task force meetings.

This issue will be more discussed in the biomethane use concept for Valmiera city.

6.2. Inspiring investors

Investors will be inspired if they see a clear economical benefit for making the investment. However, at this stage of the project, it is not quite clear who will be investor in the proposed resource efficiency solution. In case of implementation of the dry fermentation plant, external investors are not needed.

6.3. Convincing authorities and oppositional groups

If the city council and ZAAO will decide to go for the first option – dry fermentation plant, there will not be much opposition. The only groups to oppose for this scenario must be the environmental protection groups and NGOs that in case of Valmiera are not very eager to act against the policy of the local waste management company.

If the other scenario is proposed, there are two main challenges:

1) Increase of the waste management tariff
2) Building the biogas plant near the city

Oppositional groups might be convinced with a strong and targeted information campaign, including public discussions and demonstration of the good practice examples. However, to raise awareness of the society, a strong commitment from all involved parties – the city council, waste management company, environmental board, NGOs – is needed. Currently because of the reasons mentioned in this concept, the commitment is lacking in all parts of the system.

6.4. Safeguarding a sound plant operation

At this point it is difficult to give recommendations and develop a strategy regarding the plant operation. In general the plant operation is successful if continuous feedstock (waste) flow is provided and there is a sustainable demand for the end-products (biogas or biomethane and digestate). The owner or the main shareholder of the biogas plant will be responsible for the sound plant operation.

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Annexes

Annex 1: Calculation of prospective biogas and biomethane yield

years	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Amount of unsorted MSW in the region	26 009	26 330	26 681	27 036	27 397	27 762	28 132	28 507	28 887	29 794	30 730	31 694	32 690	33 716	34 775	35 867	36 993	38 155	39 353
Landfill gas generation, m3	800 000	730 000	660 000	590 000	520 000	450 000	380 000	310 000	240 000	170 000	100 000	30 000	0	0	0	0	0	0	0
1.Combined scenario																			
1. Feedstock, t (FM):																			
Biodegradable waste separated from MSW by mechanical treatment	6 372	6 451	6 537	6 624	6 712	6 802	6 892	6 984	7 077	7 300	7 529	7 765	8 009	8 260	8 520	8 787	9 063	9 348	9 641
Separately collected green waste	3 143	3 162	3 183	3 204	3 226	3 247	3 269	3 291	3 313	3 417	3 524	3 635	3 749	3 867	3 988	4 113	4 243	4 376	4 513
Waste water treatment sludge	343	345	347	350	352	354	357	359	362	373	385	397	410	423	436	449	464	478	493
2. Biogas, Nm3	0	0	0																
Biodegradable waste separated from MSW by mechanical treatment	507 387	513 649	520 496	527 422	534 464	541 585	548 803	556 118	563 531	581 226	599 477	618 300	637 715	657 739	678 392	699 694	721 664	744 324	767 696
Separately collected green waste	386 589	388 926	391 509	394 092	396 798	399 381	402 087	404 793	407 499	420 294	433 492	447 103	461 142	475 622	490 557	505 960	521 847	538 233	555 134
Waste water treatment sludge	19 508	19 622	19 736	19 906	20 020	20 134	20 304	20 418	20 589	21 235	21 902	22 590	23 299	24 031	24 785	25 563	26 366	27 194	28 048
3. Methane, Nm3																			
Biodegradable waste separated from MSW by mechanical treatment	279 063	282 507	286 273	290 082	293 955	297 872	301 841	305 865	309 942	319 674	329 712	340 065	350 743	361 756	373 116	384 831	396 915	409 378	422 233
Separately collected green waste	231 953	233 356	234 905	236 455	238 079	239 629	241 252	242 876	244 499	252 177	260 095	268 262	276 685	285 373	294 334	303 576	313 108	322 940	333 080
Waste water treatment sludge	10 729	10 792	10 855	10 948	11 011	11 074	11 167	11 230	11 324	11 679	12 046	12 424	12 814	13 217	13 632	14 060	14 501	14 957	15 426
Methane TOTAL, Nm3	*521 746*	*526 655*	*532 033*	*537 486*	*543 045*	*548 574*	*554 261*	*559 971*	*565 765*	*583 530*	*601 853*	*620 751*	*640 243*	*660 347*	*681 082*	*702 468*	*724 525*	*747 275*	*770 740*
Biogas outcome for CHP, Nm3	800 000	730 000	660 000	1 060 710	1 471 282	1 411 099	1 351 194	1 291 329	1 231 619	1 192 756	1 154 870	1 117 993	1 122 156	1 157 392	1 193 734	1 231 217	1 269 878	1 309 752	1 350 878
Biomethane, Nm3									*662 877*	*643 179*	*624 011*	*605 389*	*608 231*	*627 329*	*647 027*	*667 344*	*688 299*	*709 911*	*732 203*
2.Resource-efficiency scenario																			
1. Feedstock, t (FM):																			
Organic fraction of MSW	6 502	6 583	6 670	6 759	6 849	6 941	7 033	7 127	7 222	7 449	7 682	7 924	8 172	8 429	8 694	8 967	9 248	9 539	9 838
Separately collected green waste	3 143	3 162	3 183	3 204	3 226	3 247	3 269	3 291	3 313	3 417	3 524	3 635	3 749	3 867	3 988	4 113	4 243	4 376	4 513
Waste water treatment sludge	343	345	347	350	352	354	357	359	362	373	385	397	410	423	436	449	464	478	493
2. Biogas, Nm3																			
Organic fraction of MSW	615 477	623 073	631 379	639 780	648 323	656 960	665 716	674 590	683 582	705 046	727 185	750 019	773 569	797 859	822 912	848 751	875 402	902 890	931 241
Separately collected green waste	386 589	388 926	391 509	394 092	396 798	399 381	402 087	404 793	407 499	420 294	433 492	447 103	461 142	475 622	490 557	505 960	521 847	538 233	555 134
Waste water treatment sludge	19 508	19 622	19 736	19 906	20 020	20 134	20 304	20 418	20 589	21 235	21 902	22 590	23 299	24 031	24 785	25 563	26 366	27 194	28 048
3. Methane, Nm3																			
Organic fraction of MSW	369 286	373 844	378 828	383 868	388 994	394 176	399 429	404 754	410 149	423 028	436 311	450 011	464 141	478 715	493 747	509 251	525 241	541 734	558 744
Separately collected green waste	231 953	233 356	234 905	236 455	238 079	239 629	241 252	242 876	244 499	252 177	260 095	268 262	276 685	285 373	294 334	303 576	313 108	322 940	333 080
Waste water treatment sludge	10 729	10 792	10 855	10 948	11 011	11 074	11 167	11 230	11 324	11 679	12 046	12 424	12 814	13 217	13 632	14 060	14 501	14 957	15 426
Methane TOTAL , Nm3	*611 969*	*617 992*	*624 588*	*631 272*	*638 083*	*644 878*	*651 849*	*658 860*	*665 972*	*686 884*	*708 452*	*730 697*	*753 641*	*777 306*	*801 713*	*826 887*	*852 851*	*879 631*	*907 251*
Biogas outcome for CHP, Nm3	*800 000*	*730 000*	*660 000*	*590 000*	*520 000*	*450 000*	*924 054*	*1 409 801*	*1 351 670*	*1 316 576*	*1 282 579*	*1 249 712*	*1 258 011*	*1 297 512*	*1 338 254*	*1 380 275*	*1 423 616*	*1 468 317*	*1 514 422*
Biomethane, Nm3									*758 074*	*741 365*	*725 279*	*709 838*	*715 959*	*738 440*	*761 627*	*785 543*	*810 209*	*835 649*	*861 889*

Annex 2: Cash flow analysis – dry fermentation + CHP

1.Combined Scenario (Biogas CHP) - Cash Flow

Investments	EURO
Investment Dry Fermentation Unit	1 534 321
Subsidy	0
Investment (minus) subsidy	**1 534 321**

Post-Financing	EURO
Debt Capital 75.0%	1 150 741
Equity Capital 25.0%	383 580
Total	**1 534 321**

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

Electricity feed-in tariff (year 1-10)	**212.64 € /MWh**
Electricity feed-in tariff (after year 10)	**170.11 € /MWh**
Market price (after 20 years)	**103.07 € /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**	**327 228**	**337 503**	**348 100**	**359 031**	**370 304**	**381 932**	**393 925**	**406 294**	**419 051**	**432 210**	**270 098**	**5 834 747**
Heat sale		**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	
Income		**194 295**	**392 609**	**396 606**	**400 717**	**404 845**	**327 228**	**337 503**	**348 100**	**359 031**	**370 304**	**381 932**	**393 925**	**406 294**	**419 051**	**432 210**	**270 098**	**5 834 747**
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	-88 935	-91 603	-94 351	-97 182	-100 097	-103 100	-106 193	-109 379	-112 660	-116 040	-119 521	**-1 546 357**
Corporate income tax 15.0%		0	-15 268	-16 289	-17 361	-18 468	-7 351	-9 455	-11 650	-13 937	-16 322	-41 825	-43 160	-44 537	-45 959	-47 425	-22 587	**-371 594**
Operational Cashflow		**117 579**	**298 323**	**298 928**	**299 527**	**300 032**	**230 942**	**236 444**	**242 100**	**247 912**	**253 885**	**237 007**	**244 572**	**252 378**	**260 433**	**268 744**	**127 991**	**3 916 796**
Investment and Financing																		
Investment	-1 534 321																	**-1 534 321**
Debt financing	1 150 741																	**1 150 741**
Subsidy	0																	**0**
Pre-subsidy debt cost																		**0**
Return of subsidy to bank																		**0**
Debt service		-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**
Own financing	383 580																	**383 580**
FREE CASH FLOW	**0**	**-35 088**	**145 657**	**146 262**	**146 861**	**147 366**	**78 276**	**83 778**	**89 434**	**95 246**	**101 219**	**237 007**	**244 572**	**252 378**	**260 433**	**268 744**	**127 991**	**2 390 134**
Annual return on investment:																		
Oper. Cash Flow/ Debt payment:		**0.77**	**1.95**	**1.96**	**1.96**	**1.97**	**1.51**	**1.55**	**1.59**	**1.62**	**1.66**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**1.65**
ROI		7.7%	19.4%	19.5%	19.5%	19.6%	15.1%	15.4%	15.8%	16.2%	16.5%	15.4%	15.9%	16.4%	17.0%	17.5%	8.3%	
NPV - 16 years @6.4%	Ls 939 088.32																	
IRR	26%																	

Debt Capital payments	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Annual loan repayment	**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**

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	202 437	216 468	231 096	246 346	262 248	278 832	287 732	296 915	306 391	316 170	150 577	3 912 469
Investment expensed	0																
Investment depreciated	-153 432	-153 432	-153 432	-153 432	-153 432	-153 432	-153 432	-153 432	-153 432	-153 432							-1 534 321
Subsidy	0	0	0	0	0	0	0	0	0	0							0
Accumultated Taxable income	-99 144	101 784	108 596	115 738	123 123	49 005	63 036	77 664	92 914	108 816	278 832	287 732	296 915	306 391	316 170	150 577	2 378 148
Corporate income tax 15.0%	0	-15 268	-16 289	-17 361	-18 468	-7 351	-9 455	-11 650	-13 937	-16 322	-41 825	-43 160	-44 537	-45 959	-47 425	-22 587	-371 594

Annex 3: Cash flow analysis – dry fermentation + CHP + upgrading

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
Accumultated 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 4: Cash flow analysis – wet fermentation + CHP

2.Resource-efficiency Scenario (Biogas CHP) - Cash Flow

Investments	EURO
Investment waste separation and wet digestion	3 590 698
Subsidy	0
Investment (minus) subsidy	**3 590 698**

Post-Financing	EURO
Debt Capital 75.0%	2 693 023
Equity Capital 25.0%	897 674
Total	**3 590 698**

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

Electricity feed-in tariff (year 1-10)	**212.64 € /MWh**
Electricity feed-in tariff (after year 10)	**170.11 € /MWh**
Market price (after 20 years)	**103.07 € /MWh**

Cash Flow Model, EUR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	
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		**235 636**	**476 340**	**385 186**	**397 280**	**409 755**	**422 621**	**435 892**	**449 579**	**463 695**	**478 256**	**493 273**	**508 761**	**317 937**	**0**	**0**	**0**	**5 474 211**
Heat sale		**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**	
Income		**235 636**	**476 340**	**385 186**	**397 280**	**409 755**	**422 621**	**435 892**	**449 579**	**463 695**	**478 256**	**493 273**	**508 761**	**317 937**	**0**	**0**	**0**	**5 474 211**
Cost for the feedstock		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
O&M cost		-251 349	-258 889	-266 656	-274 656	-282 895	-291 382	-300 124	-309 127	-318 401	-327 953	-337 792	-347 926	-358 363	0	0	0	**-3 925 514**
Corporate income tax 15.0%		0	0	0	0	0	0	0	0	0	0	-23 322	-24 125	0	-0	-0	-0	**-47 448**
Operational Cashflow		**-15 713**	**217 450**	**118 530**	**122 625**	**126 860**	**131 239**	**135 768**	**140 451**	**145 294**	**150 302**	**132 159**	**136 711**	**-40 426**	**-0**	**-0**	**-0**	**1 501 250**
Investment and Financing																		
Investment	-3 590 698																	**-3 590 698**
Debt financing	2 693 023																	**2 693 023**
Subsidy	0																	**0**
Pre-subsidy debt cost																		**0**
Return of subsidy to bank																		**0**
Debt service		-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	0	0	0	0	0	0	**-3 572 774**
Own financing	897 674																	**897 674**
FREE CASH FLOW	**0**	**-372 991**	**-139 827**	**-238 748**	**-234 653**	**-230 418**	**-226 038**	**-221 509**	**-216 826**	**-211 983**	**-206 975**	**132 159**	**136 711**	**-40 426**	**-0**	**-0**	**-0**	**-2 071 524**
Annual return on investment:																		
Oper. Cash Flow/ Debt payment:		**-0.04**	**0.61**	**0.33**	**0.34**	**0.36**	**0.37**	**0.38**	**0.39**	**0.41**	**0.42**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**0.36**
ROI		-0.4%	6.1%	3.3%	3.4%	3.5%	3.7%	3.8%	3.9%	4.0%	4.2%	3.7%	3.8%	-1.1%	0.0%	0.0%	0.0%	
NPV - 16 years @6.4%	-Ls 2 472 181.92																	
IRR	#DIV/0!																	

Debt Capital payments		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Annual loan repayment		**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**0**	**0**	**0**	**0**	**0**	**0**	**3 572 774**
Interest payment		*148 116*	*136 612*	*124 476*	*111 672*	*98 163*	*83 912*	*68 877*	*53 015*	*36 281*	*18 626*	*0*	*0*	*0*	*0*	*0*	*0*	***879 751***
Payment on principal		*209 161*	*220 665*	*232 802*	*245 606*	*259 114*	*273 365*	*288 400*	*304 262*	*320 997*	*338 652*	*0*	*0*	*0*	*0*	*0*	*0*	***2 693 023***
Balance		2 483 862	2 263 197	2 030 396	1 784 790	1 525 676	1 252 311	963 911	659 648	338 652	0	0	0	0	0	0	0	**2 693 023**

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		-163 830	80 838	-5 946	10 953	28 696	47 327	66 891	87 436	109 014	131 676	155 481	160 836	-40 426	0	0	0	668 947
Investment expensed		0																
Investment depreciated		-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070							-3 590 698
Subsidy		0	0	0	0	0	0	0	0	0	0							0
Accumultated Taxable income		-522 899	-278 232	-365 016	-348 117	-330 374	-311 743	-292 179	-271 634	-250 056	-227 393	155 481	160 836	-40 426	0	0	0	-2 921 751
Corporate income tax 15.0%		0	0	0	0	0	0	0	0	0	0	-23 322	-24 125	0	-0	-0	-0	-47 448
Rec																		
	-897 674	-372 991	-139 827	-238 748	-234 653	-230 418	-226 038	-221 509	-216 826	-211 983	-206 975	132 159	136 711	-40 426	-0	-0	-0	

Electricity price in energy market, 2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
32.80	34.28	35.82	37.43	39.11	40.87	42.71	44.64	46.64	48.74	50.94	53.23	55.62	58.13	60.74	63.48	66.33	69.32	72.44
46.67	48.77	50.97	53.26	55.66	58.16	60.78	63.51	66.37	69.36	72.48	75.74	79.15	82.71	86.43	90.32	94.38	98.63	103.07

With subsidy

2.Resource-efficiency Scenario (Biogas CHP) - Cash Flow

Investments	EURO
Investment waste separation and wet digestion	3 590 698
Subsidy	2 566 330
Investment (minus) subsidy	**1 024 368**

Post-Financing	EURO
Debt Capital 75.0%	768 276
Equity Capital 25.0%	256 092
Total	**1 024 368**

Debt term (years)	**10**
Interest rate:	**6%**
Subsidy	71%

Electricity feed-in tariff (year 1-10)	**212.64 € /MWh**
Electricity feed-in tariff (after year 10)	**170.11 € /MWh**
Market price (after 20 years)	**103.07 € /MWh**
Increase in the waste management tariff	**0.00 € /m3**

Cash Flow Model, EUR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	
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		**235 636**	**476 340**	**385 186**	**397 280**	**409 755**	**422 621**	**435 892**	**449 579**	**463 695**	**478 256**	**493 273**	**508 761**	**317 937**	**0**	**0**	**0**	**5 474 211**
Heat sale		**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**	
Income		**235 636**	**476 340**	**385 186**	**397 280**	**409 755**	**422 621**	**435 892**	**449 579**	**463 695**	**478 256**	**493 273**	**508 761**	**317 937**	**0**	**0**	**0**	**5 474 211**
Cost for the feedstock		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
O&M cost		-251 349	-258 889	-266 656	-274 656	-282 895	-291 382	-300 124	-309 127	-318 401	-327 953	-337 792	-347 926	-358 363	0	0	0	**-3 925 514**
Corporate income tax 15.0%		0	0	0	0	0	0	0	0	0	0	-23 322	-24 125	0	-0	-0	-0	**-47 448**
Operational Cashflow		**-15 713**	**217 450**	**118 530**	**122 625**	**126 860**	**131 239**	**135 768**	**140 451**	**145 294**	**150 302**	**132 159**	**136 711**	**-40 426**	**-0**	**-0**	**-0**	**1 501 250**
Investment and Financing																		
Investment	-3 590 698																	**-3 590 698**
Debt financing	768 276																	**768 276**
Subsidy	2 566 330																	**2 566 330**
Pre-subsidy debt cost																		**0**
Return of subsidy to bank																		**0**
Debt service		-101 925	-101 925	-101 925	-101 925	-101 925	-101 925	-101 925	-101 925	-101 925	-101 925	0	0	0	0	0	0	**-1 019 254**
Own financing	256 092																	**256 092**
FREE CASH FLOW	**-0**	**-117 639**	**115 525**	**16 604**	**20 699**	**24 934**	**29 314**	**33 843**	**38 526**	**43 369**	**48 377**	**132 159**	**136 711**	**-40 426**	**-0**	**-0**	**-0**	**481 995**
Annual return on investment:																		
Oper. Cash Flow/ Debt payment:		**-0.15**	**2.13**	**1.16**	**1.20**	**1.24**	**1.29**	**1.33**	**1.38**	**1.43**	**1.47**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**1.25**
ROI		-1.5%	21.2%	11.6%	12.0%	12.4%	12.8%	13.3%	13.7%	14.2%	14.7%	12.9%	13.3%	-3.9%	0.0%	0.0%	0.0%	
NPV - 16 years @6.4%	Ls 13 703.67																	
IRR	7%																	
Debt Capital payments		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Annual loan repayment		**101 925**	**101 925**	**101 925**	**101 925**	**101 925**	**101 925**	**101 925**	**101 925**	**101 925**	**101 925**	**0**	**0**	**0**	**0**	**0**	**0**	**1 019 254**
Interest payment		*42 255*	*38 973*	*35 511*	*31 858*	*28 004*	*23 939*	*19 650*	*15 124*	*10 350*	*5 314*	*0*	*0*	*0*	*0*	*0*	*0*	***250 979***
Payment on principal		*59 670*	*62 952*	*66 415*	*70 067*	*73 921*	*77 987*	*82 276*	*86 801*	*91 575*	*96 612*	*0*	*0*	*0*	*0*	*0*	*0*	***768 276***
Balance		708 606	645 653	579 239	509 172	435 251	357 264	274 988	188 187	96 612	0	0	0	0	0	0	0	**768 276**
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		-57 968	178 477	83 019	90 767	98 855	107 300	116 119	125 327	134 944	144 989	155 481	160 836	-40 426	0	0	0	1 297 719
Investment expensed		0																
Investment depreciated		-102 437	-102 437	-102 437	-102 437	-102 437	-102 437	-102 437	-102 437	-102 437	-102 437							-1 024 368
Subsidy		-256 633	-256 633	-256 633	-256 633	-256 633	-256 633	-256 633	-256 633	-256 633	-256 633							-2 566 330
Accumultated Taxable income		-417 038	-180 593	-276 051	-268 303	-260 214	-251 769	-242 951	-233 743	-224 126	-214 081	155 481	160 836	-40 426	0	0	0	-2 292 979
Corporate income tax 15.0%		0	0	0	0	0	0	0	0	0	0	-23 322	-24 125	0	-0	-0	-0	-47 448
Rec																		
	-256 092	-117 639	115 525	16 604	20 699	24 934	29 314	33 843	38 526	43 369	48 377	132 159	136 711	-40 426	-0	-0	-0	

With increased waste management tariff

2.Resource-efficiency Scenario (Biogas CHP) - Cash Flow

Investments	EURO
Investment waste separation and wet digestion	3 590 698
Subsidy	0
Investment (minus) **subsidy**	**3 590 698**

Post-Financing	EURO
Debt Capital 75.0%	2 693 023
Equity Capital 25.0%	897 674
Total	**3 590 698**

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

Electricity feed-in tariff (year 1-10)	**212.64 € /MWh**
Electricity feed-in tariff (after year 10)	**170.11 € /MWh**
Market price (after 20 years)	**103.07 € /MWh**
Increase in the waste management tariff	**1.88 € /m3**

Cash Flow Model, EUR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	
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		**235 636**	**476 340**	**385 186**	**397 280**	**409 755**	**422 621**	**435 892**	**449 579**	**463 695**	**478 256**	**493 273**	**508 761**	**317 937**	**0**	**0**	**0**	**5 474 211**
Heat sale		**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Income from waste management tariff		**264 454**	**267 979**	**271 551**	**280 078**	**288 873**	**297 943**	**307 299**	**316 948**	**326 900**	**337 165**	**347 752**	**358 671**	**369 933**	**0**	**0**	**0**	
Income		**500 090**	**744 319**	**656 737**	**677 359**	**698 628**	**720 565**	**743 190**	**766 526**	**790 595**	**815 420**	**841 024**	**867 432**	**687 871**	**0**	**0**	**0**	**9 509 756**
Cost for the feedstock		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
O&M cost		-251 349	-258 889	-266 656	-274 656	-282 895	-291 382	-300 124	-309 127	-318 401	-327 953	-337 792	-347 926	-358 363	0	0	0	**-3 925 514**
Corporate income tax 15.0%		0	0	0	0	0	0	-2 268	-6 797	-11 527	-16 466	-75 485	-77 926	-49 426	-0	-0	-0	**-239 894**
Operational Cashflow		**248 741**	**485 430**	**390 081**	**402 703**	**415 732**	**429 182**	**440 799**	**450 602**	**460 668**	**471 001**	**427 748**	**441 581**	**280 081**	**-0**	**-0**	**-0**	**5 344 348**
Investment and Financing																		
Investment	-3 590 698																	**-3 590 698**
Debt financing	2 693 023																	**2 693 023**
Subsidy	0																	**0**
Pre-subsidy debt cost																		**0**
Return of subsidy to bank																		**0**
Debt service		-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	0	0	0	0	0	0	**-3 572 774**
Own financing	897 674																	**897 674**
FREE CASH FLOW	**0**	**-108 537**	**128 152**	**32 804**	**45 425**	**58 455**	**71 905**	**83 521**	**93 325**	**103 390**	**113 724**	**427 748**	**441 581**	**280 081**	**-0**	**-0**	**-0**	**1 771 574**
Annual return on investment:																		
Oper. Cash Flow/ Debt payment:		**0.70**	**1.36**	**1.09**	**1.13**	**1.16**	**1.20**	**1.23**	**1.26**	**1.29**	**1.32**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**1.17**
ROI		6.9%	13.5%	10.9%	11.2%	11.6%	12.0%	12.3%	12.5%	12.8%	13.1%	11.9%	12.3%	7.8%	0.0%	0.0%	0.0%	
NPV - 16 years @6.4%	Ls 50 823.76																	
IRR	7%																	

Debt Capital payments		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Annual loan repayment		**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**0**	**0**	**0**	**0**	**0**	**0**	**3 572 774**
Interest payment		*148 116*	*136 612*	*124 476*	*111 672*	*98 163*	*83 912*	*68 877*	*53 015*	*36 281*	*18 626*	*0*	*0*	*0*	*0*	*0*	*0*	***879 751***
Payment on principal		*209 161*	*220 665*	*232 802*	*245 606*	*259 114*	*273 365*	*288 400*	*304 262*	*320 997*	*338 652*	*0*	*0*	*0*	*0*	*0*	*0*	***2 693 023***
Balance		2 483 862	2 263 197	2 030 396	1 784 790	1 525 676	1 252 311	963 911	659 648	338 652	0	0	0	0	0	0	0	**2 693 023**

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		100 624	348 817	265 605	291 031	317 569	345 270	374 189	404 384	435 914	468 841	503 232	519 507	329 507	0	0	0	4 704 491
Investment expensed		0																
Investment depreciated		-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070							-3 590 698
Subsidy		0	0	0	0	0	0	0	0	0	0							0
Accumultated Taxable income		-258 445	-10 253	-93 465	-68 039	-41 501	-13 800	15 120	45 314	76 844	109 771	503 232	519 507	329 507	0	0	0	1 113 793
Corporate income tax 15.0%		0	0	0	0	0	0	-2 268	-6 797	-11 527	-16 466	-75 485	-77 926	-49 426	-0	-0	-0	-239 894
Rec																		
	-897 674	-108 537	128 152	32 804	45 425	58 455	71 905	83 521	93 325	103 390	113 724	427 748	441 581	280 081	-0	-0	-0	

Annex 5: Cash flow analysis – wet fermentation + CHP + biogas upgrading

2.Resource-efficiency Scenario (Biomethane) - Cash Flow

Investments	EURO
Investment Wet Fermentation Unit	3 590 698
Investment Biogas Upgrading Facility	684 302
Subsidy Wet AD plant	0
Subsidy Biogas Upgrading Facility	0
Investment (minus) **subsidy 1**	**3 590 698**
Investment (minus) **subsidy 2**	**684 302**

Post-Financing	EURO
Debt Capital 75.0%	2 693 023
Debt Capital 75.0%	513 227
Equity Capital 25.0%	897 674
Equity Capital 25.0%	171 076
Total 1	**3 590 698**
Total 2	**684 302**

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

Biomethane price	**0.74 € /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	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	
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**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**586 903**
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	581 613	586 297	591 229	596 452	597 647	634 906	674 487	716 536	761 206	808 662	859 075	0	0	0	**7 408 111**
Income		**194 295**	**392 609**	**581 613**	**586 297**	**591 229**	**596 452**	**597 647**	**634 906**	**674 487**	**716 536**	**761 206**	**808 662**	**859 075**	**0**	**0**	**0**	**7 995 014**
Cost for the feedstock		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	0	0	0	**-814 233**
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	0	0	0	**-395 956**
Corporate income tax 15.0%		0	0	-2 502	-4 759	-7 148	-5 892	-8 120	-15 876	-24 105	-32 836	-95 959	-102 838	-110 154	0	0	-0	**-410 189**
Operational Cashflow		**117 579**	**313 591**	**497 723**	**497 708**	**497 737**	**500 270**	**496 528**	**523 241**	**551 719**	**582 078**	**560 576**	**598 012**	**637 875**	**0**	**0**	**-0**	**6 374 637**
Investment and Financing																		
Investment	-3 590 698					-684 302												**-4 275 000**
Debt financing	2 693 023					513 227												**3 206 250**
Subsidy	0					0												**0**
Pre-subsidy debt cost																		**0**
Return of subsidy to bank																		**0**
Debt service 1		-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277							**-3 572 774**
Debt service 2							-81 020	-81 020	-81 020	-81 020	-81 020	-81 020	-81 020	-81 020	0	0		**-648 160**
Own financing	897 674					171 076												**1 068 750**
FREE CASH FLOW	**0**	**-239 699**	**-43 686**	**140 446**	**140 431**	**140 460**	**61 972**	**58 231**	**84 943**	**113 422**	**143 780**	**479 556**	**516 992**	**556 855**	**0**	**0**	**-0**	**2 153 703**
Annual return on investment:																		
Oper. Cash Flow/ Debt payment:		**0.33**	**0.88**	**1.39**	**1.39**	**1.39**	**1.14**	**1.13**	**1.19**	**1.26**	**1.33**	**6.92**	**7.38**	**7.87**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**1.14**
ROI		3.3%	8.7%	13.9%	13.9%	13.9%	11.7%	11.6%	12.2%	12.9%	13.6%	81.9%	87.4%	93.2%	0.0%	0.0%	0.0%	
NPV - 16 years @6.4%	Ls 7 453.68																	
IRR	7%																	
Debt Capital payments		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Annual loan repayment 1		**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**0**	**0**	**0**	**0**	**0**	**0**	**3 572 774**
Interest payment		*148 116*	*136 612*	*124 476*	*111 672*	*98 163*	*83 912*	*68 877*	*53 015*	*36 281*	*18 626*	*0*	*0*	*0*	*0*	*0*	*0*	***879 751***
Payment on principal		*209 161*	*220 665*	*232 802*	*245 606*	*259 114*	*273 365*	*288 400*	*304 262*	*320 997*	*338 652*	*0*	*0*	*0*	*0*	*0*	*0*	***2 693 023***
Balance		2 483 862	2 263 197	2 030 396	1 784 790	1 525 676	1 252 311	963 911	659 648	338 652	0	0	0	0	0	0	0	**2 693 023**
Annual loan repayment 2							**81 020**	**81 020**	**81 020**	**81 020**	**81 020**	**81 020**	**81 020**	**81 020**	**0**	**0**	**0**	**648 160**
Interest payment							*28 227*	*25 324*	*22 261*	*19 029*	*15 619*	*12 022*	*8 227*	*4 224*	*0*	*0*	*0*	***134 933***
Payment on principal							*52 793*	*55 696*	*58 759*	*61 991*	*65 401*	*68 998*	*72 793*	*76 796*	*0*	*0*	*0*	***513 227***
Balance							460 434	404 738	345 978	283 987	218 587	149 589	76 796	0	0	0	0	**513 227**
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		-30 538	176 979	375 749	390 795	406 721	466 777	481 635	533 341	588 201	646 404	708 155	754 019	802 793	0	0	0	6 301 031
Investment expensed		0																
Investment depreciated 1		-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070							-3 590 698
Investment depreciated 2							-68 430	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430		-684 302
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
Accumultated Taxable income		-389 608	-182 091	16 679	31 726	47 652	39 277	54 135	105 841	160 701	218 904	639 725	685 588	734 363	-68 430	-68 430	0	2 026 031
Corporate income tax 15.0%		0	0	-2 502	-4 759	-7 148	-5 892	-8 120	-15 876	-24 105	-32 836	-95 959	-102 838	-110 154	0	0	-0	-410 189
Rec																		
	-897 674	-239 699	-43 686	140 446	140 431	-30 616	61 972	58 231	84 943	113 422	143 780	479 556	516 992	556 855	0	0	-0	
Biomethane price				0.74	0.76 €	0.79 €	0.81 €	0.83 €	0.86 €	0.89 €	0.91 €	0.94 €	0.97 €	1.00 €				

With subsidy

2.Resource-efficiency Scenario (Biomethane) - Cash Flow

Investments	EURO
Investment Wet Fermentation Unit	3 590 698
Investment Biogas Upgrading Facility	684 302
Subsidy Wet AD plant	2247194
Subsidy Biogas Upgrading Facility	0
Investment (minus) **subsidy 1**	**1 343 504**
Investment (minus) **subsidy 2**	**684 302**

Post-Financing	EURO
Debt Capital 75.0%	1 007 628
Debt Capital 75.0%	513 227
Equity Capital 25.0%	335 876
Equity Capital 25.0%	171 076
Total 1	**1 343 504**
Total 2	**684 302**

Debt term (years)	**10**
Interest rate:	**6%**
Subsidy 1	63%
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	2017	2018	2019	2020	2021	2022	2023	2024	2025
Year of contract in exploitation		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Energy sale									
Energy price inflation, %			*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%*
Feedstock price inflation, %			*2.0%*	*2.0%*	*2.0%*	*2.0%*	*2.0%*	*2.0%*	*2.0%*
Electricity sale		**194 295**	**392 609**	**0**	**0**	**0**	**0**	**0**	**0**
Heat sale		**0**	0	0	0	0	0	0	0
Income from waste management tariff		**0**	0	0	0	0	0	0	0
Biomethane sale		**0**	0	274 470	276 680	279 008	281 472	282 036	299 619
Income		**194 295**	**392 609**	**274 470**	**276 680**	**279 008**	**281 472**	**282 036**	**299 619**
Cost for the feedstock		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
O&M cost upgrading plant		0	0	0	0	0	-44 528	-45 864	-47 240
Corporate income tax 15.0%		0	0	0	0	0	0	0	0
Operational Cashflow		**117 579**	**313 591**	**193 081**	**192 850**	**192 663**	**191 182**	**189 037**	**203 830**
Investment and Financing									
Investment	-3 590 698					-684 302			
Debt financing	1 007 628					513 227			
Subsidy	2 247 194					0			
Pre-subsidy debt cost									
Return of subsidy to bank									
Debt service 1		-133 680	-133 680	-133 680	-133 680	-133 680	-133 680	-133 680	-133 680
Debt service 2							-81 020	-81 020	-81 020
Own financing	335 876					171 076			
FREE CASH FLOW	**0**	**-16 101**	**179 911**	**59 402**	**59 171**	**58 983**	**-23 518**	**-25 662**	**-10 870**
Annual return on investment:									
Oper. Cash Flow/ Debt payment:		**0.88**	**2.35**	**1.44**	**1.44**	**1.44**	**0.89**	**0.88**	**0.95**
ROI		8.8%	23.3%	14.4%	14.4%	14.3%	9.4%	9.3%	10.1%
NPV - 16 years @6.4%	-Ls 30 042.00								
IRR	7%								
Debt Capital payments		1	2	3	4	5	6	7	8
Annual loan repayment 1		**133 680**	**133 680**	**133 680**	**133 680**	**133 680**	**133 680**	**133 680**	**133 680**
Interest payment		*55 420*	*51 115*	*46 574*	*41 783*	*36 729*	*31 397*	*25 771*	*19 836*
Payment on principal		*78 260*	*82 565*	*87 106*	*91 896*	*96 951*	*102 283*	*107 909*	*113 843*
Balance		929 368	846 803	759 697	667 801	570 850	468 567	360 659	246 816
Annual loan repayment 2							**81 020**	**81 020**	**81 020**
Interest payment							*28 227*	*25 324*	*22 261*
Payment on principal							*52 793*	*55 696*	*58 759*
Balance							460 434	404 738	345 978
Corporate Income tax		1	2	3	4	5	6	7	8
Part of Investment Expensed in Year 1, %									
Part of Investment Depreciated over years		100%							
Taxable income		62 159	262 476	146 507	151 067	155 934	204 313	209 130	231 233
Investment expensed		0							
Investment depreciated 1		-134 350	-134 350	-134 350	-134 350	-134 350	-134 350	-134 350	-134 350
Investment depreciated 2							-68 430	-68 430	-68 430
Subsidy 1		-224 719	-224 719	-224 719	-224 719	-224 719	-224 719	-224 719	-224 719
Subsidy 2							0	0	0
Accumultated Taxable income		-296 911	-96 594	-212 562	-208 003	-203 136	-223 187	-218 370	-196 267
Corporate income tax 15.0%		0	0	0	0	0	0	0	0

Cash Flow Model, EUR	2026	2027	2028	2029	2030	2031	2032	2033	
Year of contract in exploitation	*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%*	
General price inflation, %	*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%*	
Electricity sale	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**586 903**
Heat sale	0	0	0	0	0	0	0	0	**0**
Income from waste management tariff	0	0	0	0	0	0	0	0	**0**
Biomethane sale	318 298	338 141	359 222	381 616	405 407	0	0	0	**3 495 970**
Income	**318 298**	**338 141**	**359 222**	**381 616**	**405 407**	**0**	**0**	**0**	**4 082 873**
Cost for the feedstock	0	0	0	0	0	0	0		**0**
O&M cost	-50 006	-51 506	-53 051	-54 643	-56 282	0	0	0	**-814 233**
O&M cost upgrading plant	-48 657	-50 116	-51 620	-53 169	-54 764	0	0	0	**-395 956**
Corporate income tax 15.0%	0	0	-35 661	-38 781	-42 104	0	0	-0	**-116 547**
Operational Cashflow	**219 635**	**236 519**	**218 889**	**235 023**	**252 257**	**0**	**0**	**-0**	**2 756 137**
Investment and Financing									
Investment									**-4 275 000**
Debt financing									**1 520 854**
Subsidy									**2 247 194**
Pre-subsidy debt cost									**0**
Return of subsidy to bank									**0**
Debt service 1	-133 680	-133 680							**-1 336 797**
Debt service 2	-81 020	-81 020	-81 020	-81 020	-81 020	0	0		**-648 160**
Own financing									**506 951**
FREE CASH FLOW	**4 936**	**21 819**	**137 869**	**154 003**	**171 237**	**0**	**0**	**-0**	**771 180**
Annual return on investment:									
Oper. Cash Flow/ Debt payment:	**1.02**	**1.10**	**2.70**	**2.90**	**3.11**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**1.24**
ROI	10.8%	11.7%	32.0%	34.3%	36.9%	0.0%	0.0%	0.0%	
NPV - 16 years @6.4%									
IRR									
Debt Capital payments	9	10	11	12	13	14	15	16	
Annual loan repayment 1	**133 680**	**133 680**	**0**	**0**	**0**	**0**	**0**	**0**	**1 336 797**
Interest payment	*13 575*	*6 969*	*0*	*0*	*0*	*0*	*0*	*0*	***329 169***
Payment on principal	*120 105*	*126 711*	*0*	*0*	*0*	*0*	*0*	*0*	***1 007 628***
Balance	126 711	0	0	0	0	0	0	0	**1 007 628**
Annual loan repayment 2	**81 020**	**81 020**	**81 020**	**81 020**	**81 020**	**0**	**0**	**0**	**648 160**
Interest payment	*19 029*	*15 619*	*12 022*	*8 227*	*4 224*	*0*	*0*	*0*	***134 933***
Payment on principal	*61 991*	*65 401*	*68 998*	*72 793*	*76 796*	*0*	*0*	*0*	***513 227***
Balance	283 987	218 587	149 589	76 796	0	0	0	0	**513 227**
Corporate Income tax	9	10	11	12	13	14	15	16	**16 years**
Part of Investment Expensed in Year 1, %									
Part of Investment Depreciated over years									
Taxable income	254 717	279 666	306 170	326 973	349 125	0	0	0	2 939 471
Investment expensed									
Investment depreciated 1	-134 350	-134 350							-1 343 504
Investment depreciated 2	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430		-684 302
Subsidy 1	-224 719	-224 719							-2 247 194
Subsidy 2	0	0	0	0	0	0	0		0
Accumultated Taxable income	-172 783	-147 834	237 740	258 543	280 695	-68 430	-68 430	0	-1 335 529
Corporate income tax 15.0%	0	0	-35 661	-38 781	-42 104	0	0	-0	-116 547

With increased waste management tariff

2.Resource-efficiency Scenario (Biomethane) - Cash Flow

Investments	EURO
Investment Wet Fermentation Unit	3 590 698
Investment Biogas Upgrading Facility	684 302
Subsidy Wet AD plant	0
Subsidy Biogas Upgrading Facility	0
Investment (minus) **subsidy 1**	**3 590 698**
Investment (minus) **subsidy 2**	**684 302**

Post-Financing	EURO
Debt Capital 75.0%	2 693 023
Debt Capital 75.0%	513 227
Equity Capital 25.0%	897 674
Equity Capital 25.0%	171 076
Total 1	**3 590 698**
Total 2	**684 302**

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**
Increase in the waste management tariff	**1.66 € /m3**

Cash Flow Model, EUR	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	
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**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**586 903**
Heat sale		**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Income from waste management tariff		**232 915**	**236 019**	**239 166**	**246 675**	**254 421**	**262 410**	**270 649**	**279 148**	**287 913**	**296 954**	**306 278**	**315 895**	**325 814**	0	0	0	**3 554 256**
Biomethane sale		**0**	0	274 470	276 680	279 008	281 472	282 036	299 619	318 298	338 141	359 222	381 616	405 407	0	0	0	**3 495 970**
Income		**427 209**	**628 628**	**513 635**	**523 355**	**533 429**	**543 882**	**552 686**	**578 767**	**606 211**	**635 095**	**665 500**	**697 511**	**731 221**	**0**	**0**	**0**	**7 637 129**
Cost for the feedstock		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	0	0	0	**-814 233**
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	0	0	0	**-395 956**
Corporate income tax 15.0%		0	-8 089	0	0	0	0	-1 376	-7 455	-13 864	-20 619	-81 603	-86 166	-90 976	0	0	-0	**-310 148**
Operational Cashflow		**350 493**	**541 521**	**432 247**	**439 526**	**447 084**	**453 591**	**458 311**	**475 523**	**493 685**	**512 853**	**479 226**	**503 534**	**529 199**	**0**	**0**	**-0**	**6 116 792**
Investment and Financing																		
Investment	-3 590 698					-684 302												**-4 275 000**
Debt financing	2 693 023					513 227												**3 206 250**
Subsidy	0					0												**0**
Pre-subsidy debt cost																		**0**
Return of subsidy to bank																		**0**
Debt service 1		-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277	-357 277							**-3 572 774**
Debt service 2							-81 020	-81 020	-81 020	-81 020	-81 020	-81 020	-81 020	-81 020	0	0		**-648 160**
Own financing	897 674					171 076												**1 068 750**
FREE CASH FLOW	**0**	**-6 784**	**184 244**	**74 970**	**82 248**	**89 807**	**15 294**	**20 013**	**37 225**	**55 387**	**74 555**	**398 206**	**422 514**	**448 179**	**0**	**0**	**-0**	**1 895 858**
Annual return on investment:																		
Oper. Cash Flow/ Debt payment:		**0.98**	**1.52**	**1.21**	**1.23**	**1.25**	**1.03**	**1.05**	**1.08**	**1.13**	**1.17**	**5.91**	**6.21**	**6.53**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**1.17**
ROI		9.8%	15.1%	12.0%	12.2%	12.5%	10.6%	10.7%	11.1%	11.5%	12.0%	70.0%	73.6%	77.3%	0.0%	0.0%	0.0%	
NPV - 16 years @6.4%	-Ls 124.11																	
IRR	7%																	
Debt Capital payments		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Annual loan repayment 1		**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**357 277**	**0**	**0**	**0**	**0**	**0**	**0**	**3 572 774**
Interest payment		*148 116*	*136 612*	*124 476*	*111 672*	*98 163*	*83 912*	*68 877*	*53 015*	*36 281*	*18 626*	*0*	*0*	*0*	*0*	*0*	*0*	***879 751***
Payment on principal		*209 161*	*220 665*	*232 802*	*245 606*	*259 114*	*273 365*	*288 400*	*304 262*	*320 997*	*338 652*	*0*	*0*	*0*	*0*	*0*	*0*	***2 693 023***
Balance		2 483 862	2 263 197	2 030 396	1 784 790	1 525 676	1 252 311	963 911	659 648	338 652	0	0	0	0	0	0	0	**2 693 023**
Annual loan repayment 2							**81 020**	**81 020**	**81 020**	**81 020**	**81 020**	**81 020**	**81 020**	**81 020**	**0**	**0**	**0**	**648 160**
Interest payment							*28 227*	*25 324*	*22 261*	*19 029*	*15 619*	*12 022*	*8 227*	*4 224*	*0*	*0*	*0*	***134 933***
Payment on principal							*52 793*	*55 696*	*58 759*	*61 991*	*65 401*	*68 998*	*72 793*	*76 796*	*0*	*0*	*0*	***513 227***
Balance							460 434	404 738	345 978	283 987	218 587	149 589	76 796	0	0	0	0	**513 227**
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		202 377	412 998	307 771	327 854	348 921	414 207	436 673	477 202	519 924	564 963	612 448	642 868	674 939	0	0	0	5 943 146
Investment expensed		0																
Investment depreciated 1		-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070	-359 070							-3 590 698
Investment depreciated 2							-68 430	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430	-68 430		-684 302
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
Accumultated Taxable income		-156 693	53 928	-51 299	-31 216	-10 149	-13 293	9 173	49 702	92 424	137 463	544 018	574 438	606 509	-68 430	-68 430	0	1 668 146
Corporate income tax 15.0%		0	-8 089	0	0	0	0	-1 376	-7 455	-13 864	-20 619	-81 603	-86 166	-90 976	0	0	-0	-310 148