Implementing Advanced Concepts for Biological Utilization of Waste

Report no: O 4.3

MIDTERM OUTPUT REPORT – PILOT B IN LITHUANIA

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1. Technical report

The technical report will deal with all aspects of on-site testing and the research on biogas potential of the different substrates used in the corresponding testing period. The experimental studies have been done in the pilot plant itself and in parallel studies in the Ostfalia laboratory. For detailed information on Pilot B operation see output report O.4.2.

1.1 Introduction, description of roadmap for report

First of all a short description will be given concerning the developed scenarios for Lithuanian case. Afterwards the issues of location, transportation and plant setup of Pilot B will be described.

1.1.1 Scenarios for Lithuanian case study

On the basis of regional specific availability of substrates, the following scenarios (as seen in Figure 1) have been developed. For the pilot plant two scenarios were in focus. The usage of locally available cow manure and bioethanol distillery waste and the usage of cow manure, food waste and algae. At the end of the Lithuanian operating period only manure was used in addition to the developed scenarios. Based on data gained from practical plant and laboratory works calculations on required fermenter dimensions are made.
The scenarios themselves must be understood as hypothetical approaches. They show how a concrete implementation concept would be handled. This may be part of further activities regarding biogas implementation in Lithuania.

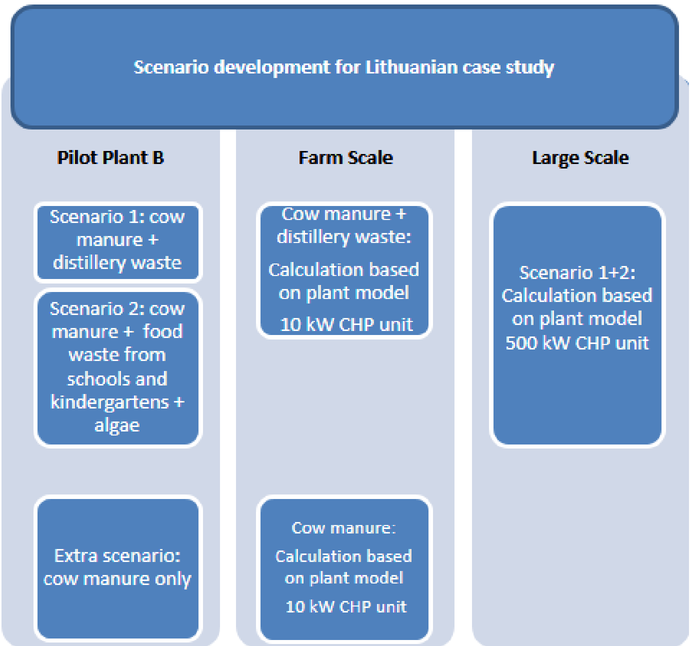


Figure 1: Overview on Lithuanian case study scenarios.

On the basis of these predetermined scenarios the single substrates, as well as the determined mixtures have been analysed under laboratory conditions and in the pilot plant to determine their suitability for full-scale biogas production. From this data calculations on required farm-/ and full scale plant size, substrate amounts, investment costs, etc. have been made (see Chapter 2.3).

1.1.2 Location

In preliminary talks, with potential candidates whose names have been provided by the Ministry of Economy of Lithuania, about possible locations for the implementation of a biogas plant in Western Lithuania it turned out that the family of one of the project partners' colleagues operates a farm. As many farmers from the region are interested in biogas but no one agreed to install the pilot plant on their farm, talks with the family continued. In discussions about this topic an interest on biogas technology awoke in the family. Especially the possible use of manure as a valuable material for biomethane production and its remaining suitability as a fertilizer were acceptable. After concerns regarding technical details of implementation and safety issues regarding the biogas production were allayed the decision had been made.

The plant was set up on a small farm in Šilininkų km. Švėkšnos sen. Šilutės raj. Lietuva (see Figure 2).

Figure 2: Pilot B location in Lithuania

The farm is operated by a family, producing mainly milk. In addition sometimes cattle is sold. The overall area of the farm is 34 hectares. The food for the cattle is produced on own fields, whereby no chemical fertilizers are used.
At the moment (17th of September 2013) the livestock of the farm consists of:
14 cows, 13 calves, 7 bulls and 5 pigs
The dairy cattle produces 280-300 liters of milk per day, which is collected by a dairy van on a daily basis. The payment is approx. 0.29 € per liter milk (Dauksys, 2013).

1.1.3 Transportation

Organizing transportation was more difficult than expected. After several calls had been made, only three German logistics companies (Hellmann East, DB Schenker and ISDB Logistik GmbH) could be identified to deal with our demands (loading the container in Germany, transportation to Lithuania and unloading at final destination). Finally the offer of "Hellmann East" had been accepted. A crane for loading the container in Germany had to be organized by WPL, unloading in Lithuania was organized by the logistics company.

Loading itself was difficult because the logistics company sent a truck with a so called Megatrailer, which made it impossible to load the container through the top of the trailer. The crane had to hover the container so that the truck could place the trailer underneath it.

Figure 3: Loading of Pilot B in Germany. Difficult procedure because the container didn´t fit through the top.

The lesson learned here is, that for the next transport to Estonia a trailer without truck superstructure was ordered. This made the loading procedure much easier.

Figure 4: Loading of the container in Lithuania for the transportation to Estonia.

Sanitation of the equipment was not necessary due to the fact that a complete service had been performed before the purchase. For further cross-border transports a sanitation of the fermenter will be performed by heating the cleaned fermenter with water at a temperature of 60°C for at least 24 h. Inner surfaces will be sanitized with a surface disinfectant.

1.1.4 Positioning

Apart from bad weather conditions, unloading and positioning of the container was not a big problem. Metal wire strengthened rubber mats have been positioned under the corners of the container in order to get a bigger supporting surface. The container was levelled with simple wooden boards.

Figure 5: Levelling of the container with wooden boards.

1.1.5 Electrical connection

Via a 30 m cable, the container has been connected to the local electricity grid. The local grid makes some problems during thunderstorms, as lightings striking the transmission lines cause fluctuating voltages. This led to some shutdowns of the pilot plant. To prevent this, additional emergency power supply kits have been installed.

Figure 6: Emergency power supply kits for control-computer and gas measurement system

1.1.6 Check-up

After setting up the equipment, an inventory check has been performed to make sure everything (lab equipment, additional tools, etc.) is in place.

1.1.7 Pilot B process technology

The operators' manual for Pilot B is part of output report O.4.2. It contains:

- General plant description
- Equipment description
- Program description
- Work instructions for Pilot B
- Troubleshooting advices

1.2 Materials and methods

1.2.1 Batch tests

- layout and test operation

The batch tests are performed in 5L Erlenmeyer flasks, with rubber plugs, valves, a Thesseraux® gas bag and some pipe devices. Before starting the batch fermentation it is necessary to define the ratio between substrate and sewage sludge. For a smooth process flow it is important, that all flasks are cleaned before using them for a bioreactor. Cleaning them with toxic or aggressive cleaning agents may cause process troubles. The next step is to fill the determined amounts of substrate into the flasks before filling them with sewage sludge to an overall amount of 3500g. The flasks are filled usually with sewage sludge also called inoculum. The atmosphere inside the flasks has to be inerted with pure nitrogen, because the methanogenic bacteria need anaerobic conditions. After inertisation the rubber plug has to be fitted without letting air inside the devices. At least the Thesseraux® gas bag is attached to the rubber plug and all valves are open now. Like shown in Figure 7, the batch reactors are placed under mesophilic conditions in heating cabinets at 42°C for 35 days.

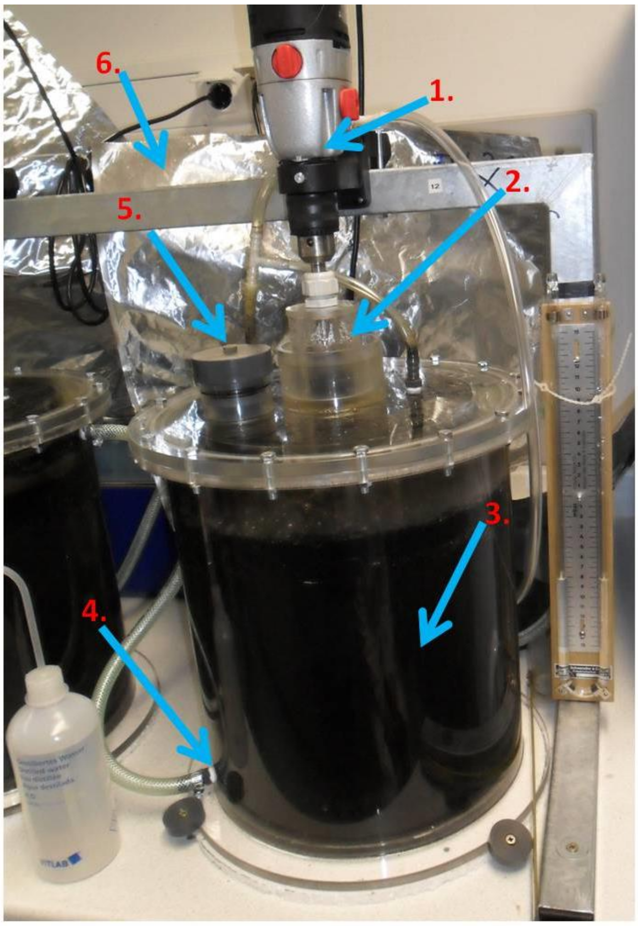
Figure 7: batch tests in heating cabinet

A continuous stirring device is not available, so the batch tests must be shaken every day manually to guarantee a sufficient mixing. While shaking the filling level of the gas bags is controlled and if there is a sufficient level, the gas bags can be measured on a gas measuring station. The gas measuring station can capture the amounts of methane CH_4, carbon dioxide CO_2, hydrogen sulfide H_2S, oxygen O_2 and gas volume. After gas measuring the bags are mounted again at the batch reactors and valves are opened. After 35 days fermentation time the tests are aborted, because after this period is guaranteed, that almost all biodegradable ingredients are digested. The batch tests are opened and weighted again to calculate the amount of mass loss.
(T. Ahrens, 2011)

1.2.2 Continuous tests

- Layout, devices

Before starting the continuous digestion tests it was necessary to mount the reactors. Therefore acryl glass reactors where used with a self-constructed stirring device. A modified drill machine was used for each reactor with a revolution of 100 rpm. On top of the reactor are several ports.



1. Stirring device
2. Water seal
3. Double walled heating coat
4. One of fourwater supply ports
5. Sampling connection
6. Gasbag with devices

Figure 8: continuous lab fermenter

The first port (number 2) on the middle is the water seal to guarantee a stirring without inserting air into the anaerobic process. Furthermore a water seal can prevent damage by overpressure inside the fermenter (also digester). The two smaller ports are for collecting the produced gas in special gasbags from Tesseraux®. The last port (numbered with 5.) is the sampling port, where samples were taken or substrate fed. To get an optimal temperature of 40-42°C for digestion the fermenter has a double walled heating coat. Water is heated by a water bath and pumped into the reactors heating coat.
(T. Ahrens, 2011)

1.3 Definition of general regional challenges regarding technical implementation of biogas technology

1.3.1 Transfer of knowledge concerning biogas technology

One main goal of Pilot B operation in Lithuania is to revive interest in the biogas technology. As knowledge about this technology and especially application of this technology is not yet wide spread in Lithuania, the pilot plant can be seen as a pioneer in this sector. With its possibilities it can be used as a training device for future plant operators as well as a demonstration object for interested people.

1.3.2 Lithuanian testing period substrates

The selection of the substrates was made due to their local availability and their suitability for fermentation (see 1.1.1).

All substrates which have been used during Lithuanian operating period will be shortly described. All of the substrates have been examined in batch tests to gather information on their biogas potential. Furthermore continuous tests have been operated with different substrate mixture to gain information about their long term behaviour in the biogas process. The methods used for this determination are described in chapter 0.

For easier comparability of the different substrates the axes in the following batch test figures are equally scaled. Each figure contains two curves for biogas- and methane amounts, called 1 and 2, which derives the two tests that have been set up per substrate.

Cow manure

Figure 9: Cow manure as used in Pilot B and for laboratory analysis (Picture taken at local stable)

Cow manure is a mixture of urine and faeces from cattle. On the farm the manure is collected in a channel in the stable as shown in Figure 9. The manure is then used as a fertilizer on the farms fields. On the farm no antibiotics are used. These could be problematic when the manure should be used for biogas production, because they would affect the abundance and diversity of the bacteria.

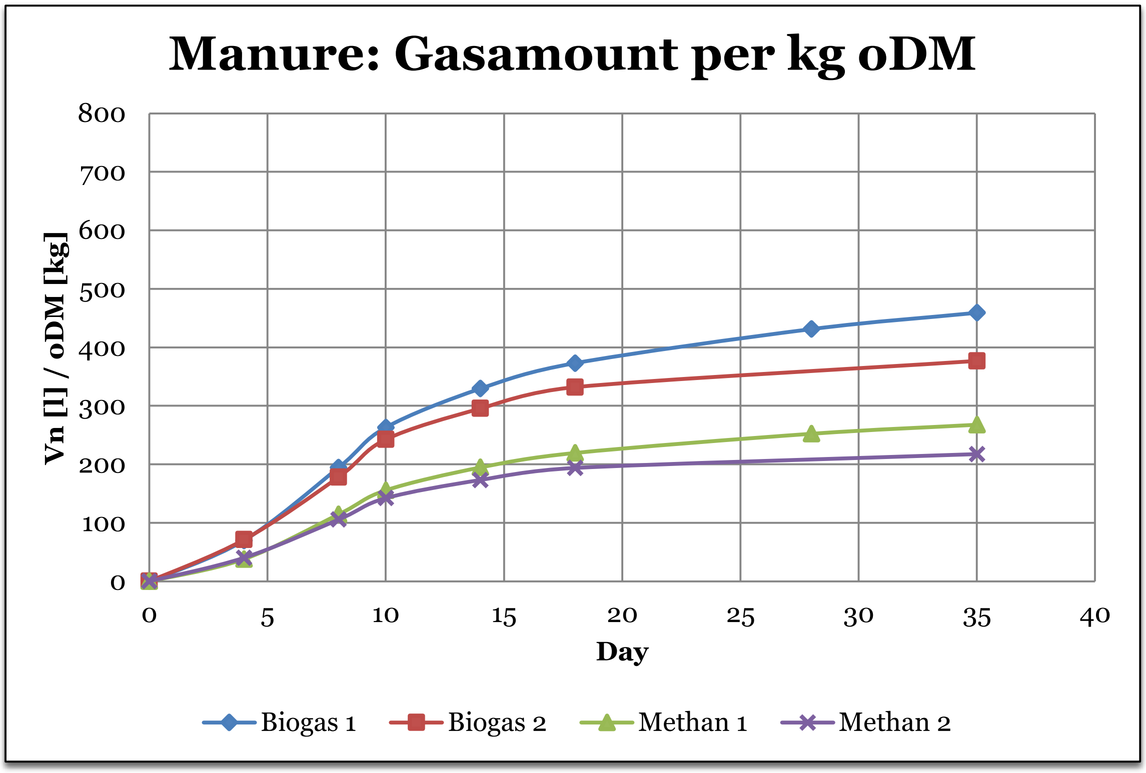


Figure 10: manure, Lithuania, August 2013, cumulative gas amounts; biogas/methane 1+2 derive from twofold test for each substrate, test duration was 35 days

Figure 10 shows the cumulative gas amounts produced during the batch test. Both tests show a slightly weak starting of the gas production in comparison to regular curves. The difference between both tests may be explained by different amounts of biodegradable matter.
Table 1 gives an overview on relevant substrate parameters.

Table 1: Cow manure, Lithuania, August 2013; DM, oDM and estimated biogas/methane yields

	Unit	Results
Dry matter content (DM)	% (FM)	24.05
Organic dry matter content (oDM)	% (FM)	10.66
Average methane concentration	Vol. %	57
Estimated biogas production - **per Mg fresh matter** - **per Mg organic dry matter**	 Nm³/Mg (FM) Nm³/Mg (oDM)	 29.69 315.22
Estimated methane production - **per Mg fresh matter** - **per Mg organic dry matter**	 Nm³/Mg (FM) Nm³/Mg (oDM)	 19.34 205.30

Distillery leftovers

Figure 11: Distillery leftovers from local distillery located in Šilutė, Lithuania, August 2013

The distillery leftovers (Figure 11) have been collected in a bioethanol factory in Šilutė (AB Biofuture, Šilo g. 4, LT-99149, Šilutė). The company sells these leftovers to local farmers which use them to feed the cattle and as a fertilizer on the fields. The distillery uses wheat and triticale. (biofuture, 2013)

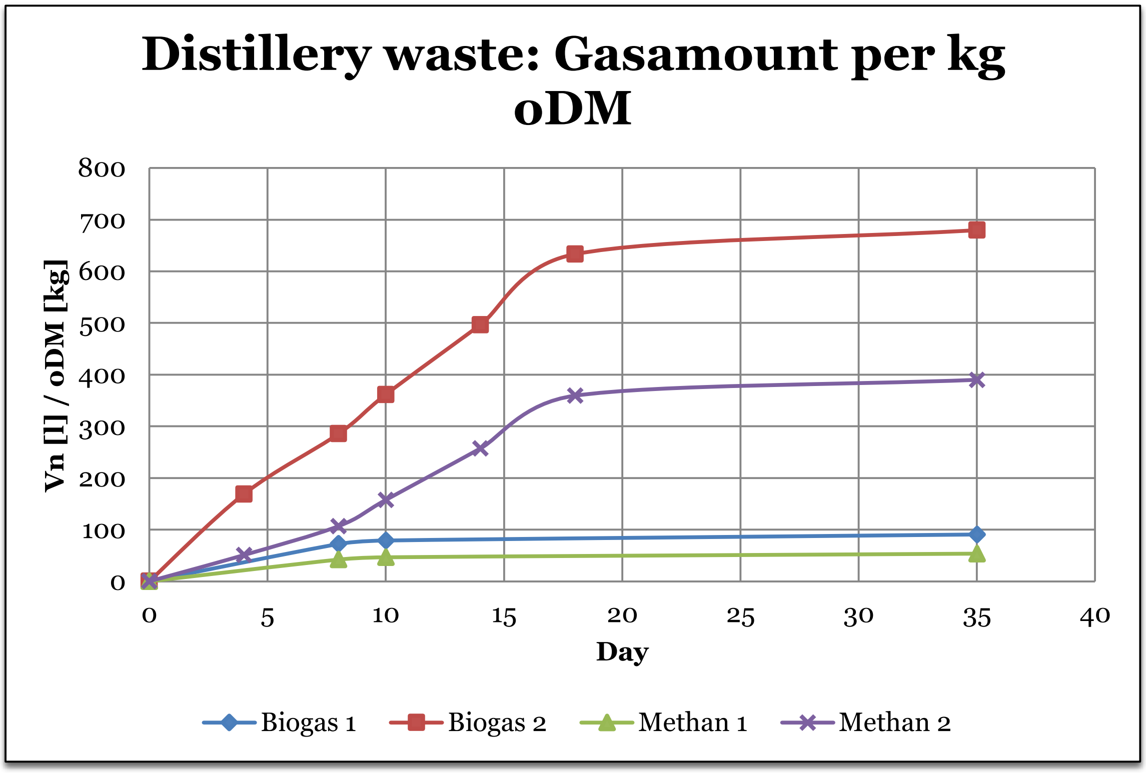


Figure 12: Distillery waste, Lithuania, August 2013, cumulative gas amounts; biogas/methane 1+2 derive from twofold test for each substrate, test duration was 35 days

Figure **12** shows the cumulative gas amounts produced in the batch tests. The difference in the two tests can be explained by leakage with occurred in test 1. Table 2 gives an overview on relevant substrate parameters.

Table 2: Distillery waste, Lithuania, August 2013, DM, oDM and estimated biogas/methane yields

	Unit	Results
Dry matter content (DM)	%	12.28
Organic dry matter content (oDM)	%	11.52
Methane content	%	57
Estimated biogas production		
- **per Mg fresh matter**	Nm³/Mg (FM)	71.06
- **per Mg organic dry matter**	Nm³/Mg (oDM)	616.86
Estimated methane production		
- **per Mg fresh matter**	Nm³/Mg (FM)	40,54
- **per Mg organic dry matter**	Nm³/Mg (oDM)	351.95

Food waste

Figure 13: Food waste collected in three Kindergartens in Klaipeda, Lithuania, August 2013 (left to right: food waste as collected, after homogenization, after sterilization in pressure cooker)

The food waste as shown in Figure 13 has been collected in three different kindergartens in Klaipeda. Main components (visual impression) are potatoes, rice, bread and vegetables. Small amounts of meat and fish have also been present. For homogenization the waste samples have been mixed using a household blender.

Before using the food waste for the fermentation, the waste was sterilized using a pressure cooker. The food waste was boiled for at least 15 minutes in saturated steam atmosphere.

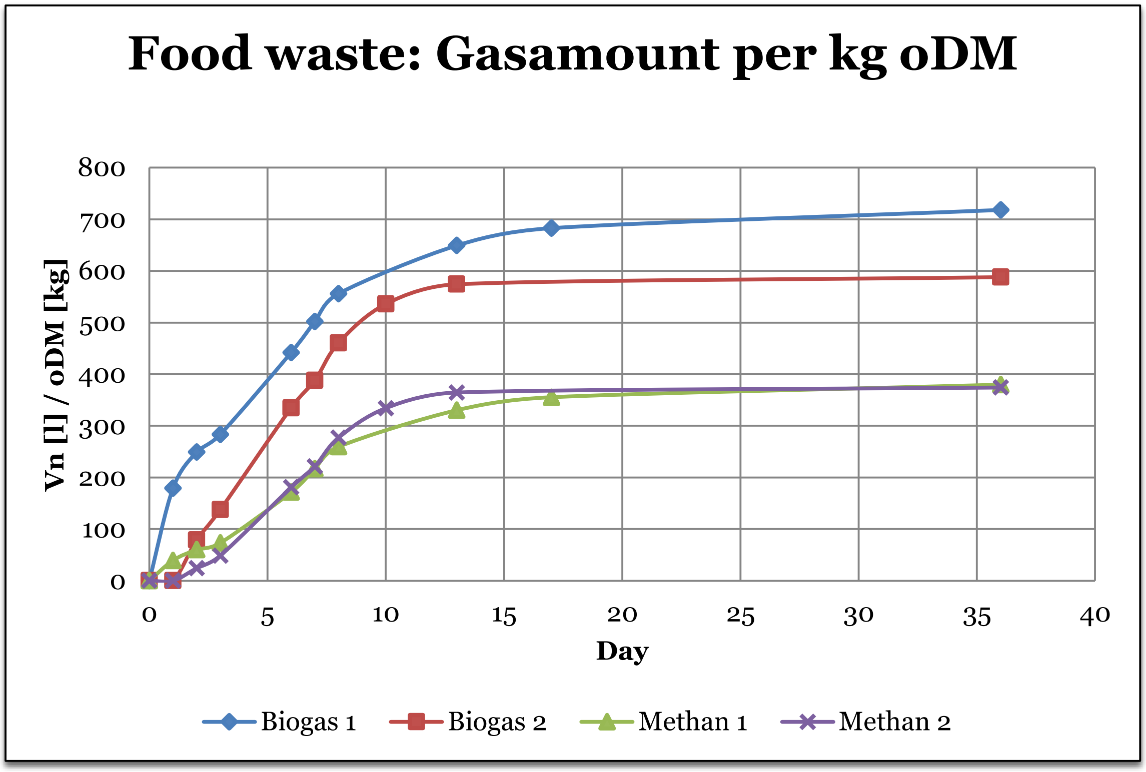


Figure 14: Food waste, Lithuania, August 2013, cumulative gas amounts; biogas/methane 1+2 derive from twofold test for each substrate, test duration was 35 days

Figure 14 shows the results of the batch tests performed with the food waste. Both show the typical curve for anaerobic batch fermentation. The little deviation of test 2 is a result of a leaking gas bag. That bag has been replaced after one day of testing. Table 3 gives an overview on relevant substrate parameters.

Table 3: Food waste from Kindergartens in Klaipeda, Lithuania, August 2013, DM, oDM and estimated biogas/methane yields

	Unit	Results
Dry matter content (DM)	%	23.48
Organic dry matter content (oDM)	%	22.71
Methane content	%	58
Estimated biogas production		
- **per Mg fresh matter**	Nm^3/Mg (FM)	147.06
- **per Mg organic dry matter**	Nm^3/Mg (oDM)	647.66
Estimated methane production		
- **per Mg fresh matter**	Nm^3/Mg (FM)	85.23
- **per Mg organic dry matter**	Nm^3/Mg (oDM)	375.33

Algae

Figure 15: Algae, collected near Klaipeda, Lithuania, August 2013

The algae as shown in Figure 15 have been collected at different locations near Klaipeda: fresh algae directly from the water surface of the Curonian Lagoon, dried algae from the Curonian Lagoon coastal zone (mostly near Juodkrante) and algae collected from the coastal zone together with sand and marine litter (sandy). All samples have been examined in batch tests. For continuous test dried algae have been used in the beginning. After all of the material was used fresh algae have been dried and used in the tests.

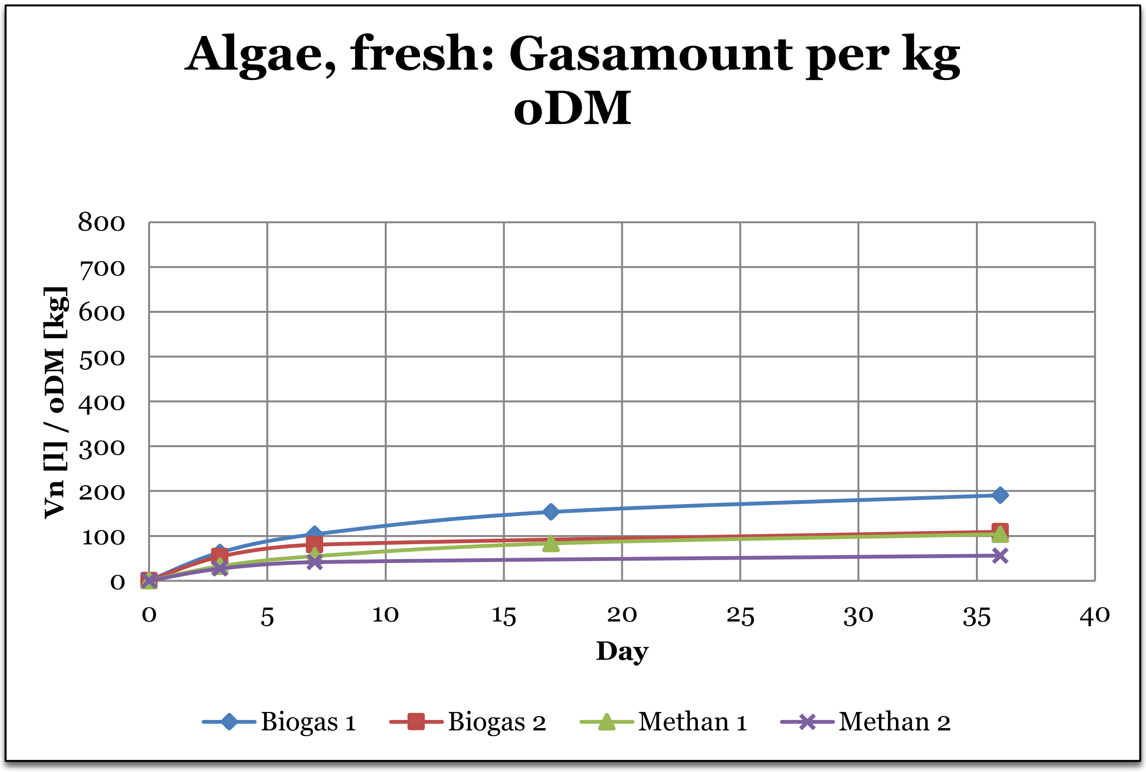


Figure 16: Fresh algae, Lithuania, August 2013, cumulative gas amounts; biogas/methane 1+2 derive from twofold test for each substrate, test duration was 35 days

As seen in Figure 16 the fresh algae produced only small amounts of biogas. Due to leakages the second test produced minor amounts than test 1.

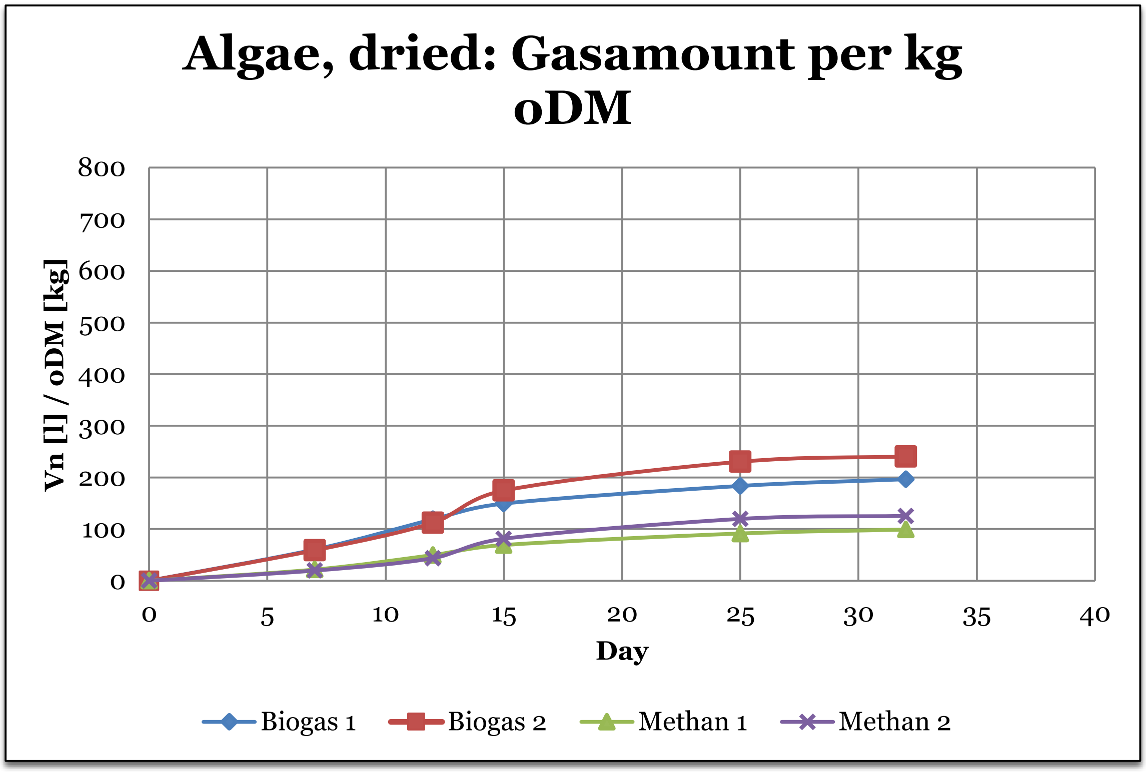


Figure 17: Dried algae, Lithuania, August 2013, cumulative gas amounts; biogas/methane 1+2 derive from twofold test for each substrate, test duration was 35 days

Compared to the fresh algae, the dried algae show a more constant gas production (see Figure 17).

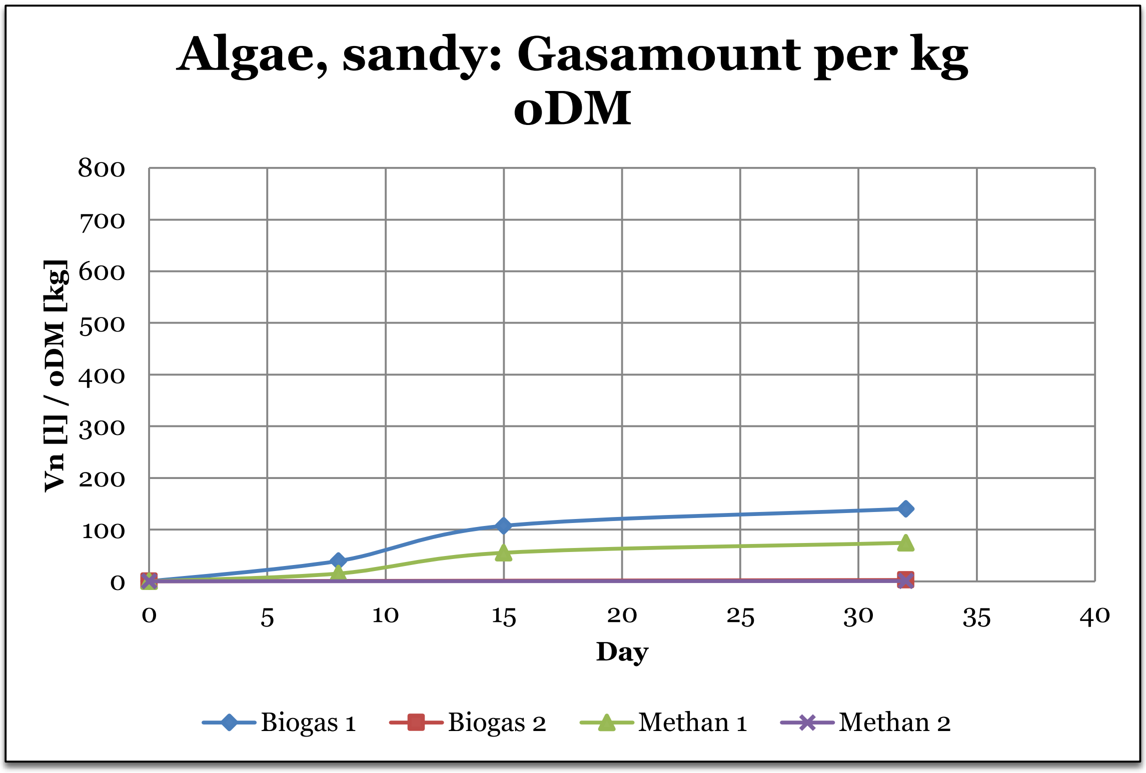


Figure 18: Sandy algae, Lithuania, August 2013, cumulative gas amounts; biogas/methane 1+2 derive from twofold test for each substrate, test duration was 35 days

The sandy algae show a comparable production as the fresh and the dried algae. Due to leakages only one of the test showed results at all.

Table 4, 5 and 6 give an overview on relevant substrate parameters.

Table 4: Algae, fresh, Lithuania, August 2013, DM, oDM and estimated biogas/methane yields

	Unit	Results
Dry matter content (DM)	%	22.86
Organic dry matter content (oDM)	%	14.12
Methane content	%	55
Estimated biogas production		
- **per Mg fresh matter**	Nm^3/Mg (FM)	26.20
- **per Mg organic dry matter**	Nm^3/Mg (oDM)	185.53
Estimated methane production		
- **per Mg fresh matter**	Nm^3/Mg (FM)	14.43
- **per Mg organic dry matter**	Nm^3/Mg (oDM)	102.23

Table 5: Algae, dried, Lithuania, August 2013, DM, oDM and estimated biogas/methane yields

	Unit	Results
Dry matter content (DM)	%	39.49
Organic dry matter content (oDM)	%	27.53
Methane content	%	51
Estimated biogas production		
- **per Mg fresh matter**	Nm^3/Mg (FM)	60.18
- **per Mg organic dry matter**	Nm^3/Mg (oDM)	218.60
Estimated methane production		
- **per Mg fresh matter**	Nm^3/Mg (FM)	30.90
- **per Mg organic dry matter**	Nm^3/Mg (oDM)	112.24

Table 6: Algae, sandy, Lithuania, August 2013, DM, oDM and estimated biogas/methane yields

	Unit	Results
Dry matter content (DM)	%	18.45
Organic dry matter content (oDM)	%	8.42
Methane content	%	53
Estimated biogas production		
- **per Mg fresh matter**	Nm^3/Mg (FM)	11.81
- **per Mg organic dry matter**	Nm^3/Mg (oDM)	140.22
Estimated methane production		
- **per Mg fresh matter**	Nm^3/Mg (FM)	6.27
- **per Mg organic dry matter**	Nm^3/Mg (oDM)	74.45

Table 7 shows an overview of characteristics of the different substrates. The food waste as well as the distillery waste show a high biogas potential regarding their fresh matter. The biogas potential of the algae is pretty low regarding their oDM. The values displayed in red cannot be evaluated due to leakages which appeared during the batch tests.

Table 7: Overview on biogas potentials of the substrates used in Lithuanian operating period

Substrate	Biogas (m3/Mg FM)	Methane m³/Mg FM	Biogas [l/kg oDM]	Methane Vn[l]/oDM[kg]	Methane content
Manure 1	37,45	21,70	397,52	230,41	57,96%
Manure 2	29,69	16,97	315,22	180,19	57,16%
Distillery waste 1	3,20	1,78	27,80	15,49	55,74%
Distillery waste 2	71,06	40,54	616,86	351,95	57,05%
Food waste 1	161,84	85,85	712,77	378,07	53,04%
Food waste 2	132,27	84,60	582,55	372,58	63,96%
Algae fresh 1	26,20	14,43	185,53	102,23	55,10%
Algae fresh 2	14,68	7,70	103,96	54,52	52,45%
Algae dried 1	54,10	27,25	196,51	99,00	50,38%
Algae dried 2	66,26	34,55	240,68	125,48	52,14%
Algae sandy 1	11,81	6,27	140,22	74,45	53,10%
Algae sandy 2 [1]	0,21	0,04	2,44	0,47	19,44%

[1] This test did not have a significant gas production, due to a leakage of the gas bag

Table 8 gives an overview on dry matter (DM) and organic dry matter (oDM) content of the different substrates.

Table 8: Overview on dry matter (DM) and organic dry matter (oDM) contents of the substrates used during Lithuanian operating period

Substrate	Date	DM [%]	oDM [%]
Manure Germany	11.06.2013	11,85	8,93
Manure Lithuania 1	24.06.2013	11,66	9,42
Manure Lithuania 2	16.08.2013	24,05	10,66
Distillery waste	27.06.2013	12,28	11,52
Food waste	02.08.2013	23,48	22,71
Algae dried	13.08.2013	39,49	27,53
Algae sandy	13.08.2013	18,45	8,42
Algae fresh	02.08.2013	22,86	14,12
Algae semi-dry	11.09.2013	37,97	23,36

1.4 Regional feedback regarding pilot plant operation

As mentioned in 1.1.2 the pilot plant was set up on a farm belonging to the family of a project colleague. Because he is working in Klaipeda, it was partially up to the rest of his family to operate the plant. The experience gained during the training in the Ostfalia in Wolfenbüttel made it possible to impart that knowledge to the family members. This shows the acceptability and the management suitability of biogas technology by local farmers.
Even events which seemed to be problematic in the first place turned out to be of great value to understand the technical difficulties that can appear when using an unknown technology. As alarms of the H_2S-sensor of the plants gas warning system appeared for no obvious reason, this lead to big concerns in the first place. When the reason for these alarms, a closed circuit in the sensor, had been identified the concerns could be resolved. For detailed information regarding Pilot B operation, operation period history see 1.5 . The troubleshooting on Pilot B for Lithuanian operating period is part of output report O4.2.
As time passed, the family acted as an intermediary for biogas technology. Neighbours and stakeholders visiting the plant side could be informed about the ongoing events and the technology directly by the family.

1.5 Timeline of the Lithuanian operating period

Table 9 gives an overview over mentionable events during the Lithuanian operating period. Major events will be described below.

Table 9: Timetable of mentionable events during the Lithuanian operating period.

Date	Event
30.04.2013	Initial filling of the fermenter with approx. 500 liters of cow manure
06.05.2013	Feeding stopped due to overfeeding
13.05.2013	System shutdown caused by lightning strike
15.05.2013	Feeding to rise manure level in the fermenter
20.05.2013	Oxygen level rising in the fermenter
21.05.2013	Changed fermenters substrate with new manure
31.05.2013 – 17.06.2013	Operation of fermenter in batch mode. Several H_2S-Alarms triggered (caused by closed circuit in the H_2S-Sensor)
17.06.2013	Start feeding manure and distillery waste
18.06.2013	First project partner and stakeholder visit to Pilot B (total 22 participants)
18.06.2013	Changing gas measurement outlets on the fermenter
18.06.2013	Installing gas bags
19.06.2013	Installing gas pump
19.06.2013	Building outdoor kitchen
20.06.2013	Installing gas utilization system with gas cooker
	Received CAT phone and some plastic valves
	Received gas leakage detector
23.06.2013	Oxygen in the system due too mistakenly opened valve from gas measurement system
24.06.2013	Changing rubber house of the diaphragm pump
02.07.2013	Installed gas bypass and one direction safety valve
23.07.2013	Start feeding manure and food waste
24.07.2013	Lithuanian stakeholder event including on-site visit of Pilot B and a questionnaire of the participants (total 38 participants)
25.06.2013	Video meeting between Lithuanian and German workgroup for on the draft results of the stakeholder meeting
22.07.2013	Collecting of food waste from kindergartens in Klaipeda
26.07.2013	Installing active coal gas filters
27.07.2013	Changing H_2S alarm sensor
04.08.2013	Start feeding manure, food waste and algae
02.09.2013	Start feeding manure only
08.10.2013	Shutdown due to electrical problems (grid)
09.10.2013	Shutdown of the heaters.
10.10.2013	Removing of fermenter content. Cleaning of fermenter and filling with water. Heating up fermenter with water to 60°C for at least 24h.
14.10.2013	Complete shutdown of fermenter. End of Lithuanian operating period.
15.10.2013	Transport to Estonia

In the following a more detailed description of some of the major events (see Table 9) will be given.

- <u>30.04.2013: Initial filling of the fermenter with approx. 500 litres of cow manure</u>

Figure 19: Initial filling of the fermenter with the help of a manure pump.

After setting up all of the equipment, the initial filling of the fermenter has been done with the help of a manure pump (Figure 19). The fermenter has been filled with approx. 500 litres of cow manure. Afterwards the fermenter was closed and heated up to a temperature of 42°C (mesophilic conditions).

- <u>31.05.2013 – 17.06.2013: Operation of fermenter in batch mode.</u>

Due to the early start of feeding the digester was overfed, resulting in bad biogas production rates. Additional problems like shutdowns caused by lighting strikes and rising oxygen concentrations in the fermenter exacerbated the plant performance.
To eliminate these problems, the fermenter was refilled with new cow manure. To make sure that the methanogenic biocenosis can adapt best, the fermenter was operated in batch mode (no feeding) for a bit more than two weeks.
Afterwards feeding with manure and distillery waste started.

- <u>18.06.2013 – 20.06.2013: A couple of new installations in the container</u>

Because the in- and outlets for the gas measuring system got clogged some time, they have been exchanged by bigger ones (see Figure 20).

Figure 20: Exchanged gas in- and outlets to the gas measuring system.

In order to fulfill possible air pollution guidelines, a gas utilization has been installed. This consists of: three gas bags (250 litres each), a gas pump and an outdoor kitchen equipped with a 2-flame gas cooker (see Figure 21). The cooker was used to sanitize the food waste and also for regular cooking needs on the farm (pig food, marmalade, etc.) as well as coffee preparation for the stakeholder events.

Figure 21: Pilot B gas utilization: (1) one of three 250 liter gas bags, (2) gas pump, (3) outdoor kitchen, (4) 2-flame gas cooker

- 23.07.2013: Start of feeding manure and food waste

The food waste used in the pilot plant has been collected in three different kindergartens in Klaipeda. It has been homogenized using a kitchen blender and afterwards being frozen in 2 kg portions. Before feeding the food waste it was sanitized using a pressure cooker. The food waste was boiled under saturated steam atmosphere for at least 15 minutes. Afterwards the manure and the food waste have been premixed and then fed (see Figure 22).

Figure 22: Sanitized food waste in pressure cooker (left) and premixed manure and food waste for fermenter feeding (right).

- 24.07.2013: Lithuanian stakeholder event including visit to Pilot B

On Wednesday the 24th of July 2013 the main stakeholder event took place. After meeting in Klaipeda the stakeholders travelled to the farm for a presentation of Pilot B. Roundabout 38 people participated in that event. Beside the presentation of Pilot B, posters explained the biogas process and the biogas utilization. Coffee was served, prepared with biogas produced by Pilot B (see Figure 23).

Figure 23: Lithuanian stakeholder event on 24.06.2013 including visit to Pilot B. Coffee preparation with biogas in the outdoor kitchen (left). Presentation of Pilot B to the stakeholders (right).

- <u>26.07.2013: Installing activated carbon filters</u>

In order to eliminate H_2S-traces in the biogas an activated carbon filter has been installed (see Figure 24). Measurement showed that no H_2S could be detected after the biogas passed the filter.

Figure 24: Activated carbon filter for H_2S-elimination from the biogas.

- <u>27.07.2013: H2S-alarm-sensor exchanged</u>

After several false alarms caused by a closed circuit in the H_2S-alarm-sensor (see Figure 25, the broken sensor has been exchanged by a new one. False alarms stopped.
These false alarms caused a feeling of insecurity in the family operating the plant. They emerged randomly and for no assignable cause, sometimes in the middle of the night. As the reason for these alarms was detected (closed circuit) the family could be assured that there was no real danger. (Dauksys, 2013)

Figure 25: Broken H_2S-alarm-sensor, caused by closed circuit in the sensor.

- 30.07.2013: Shutdown due to lightning strike to the electrical grid

In the morning of Tuesday 30th of June there was a blackout on the whole farm. The reason was found soon. A lightning strike destroyed the main fuse of the farms electrical connection (see Figure 26). After the exchange of the main fuse electricity was working again as expected.

Figure 26: Damage caused by lightning strike to the electrical grid. (1) farms` main electric cabinet, (2) electric meter with only phase L1 showing light, (3) + (4) broken main fuse, (5) electric meter showing light on all phases after repair.

- 04.08.2013: Start of feeding manure, food waste and algae

In addition to the manure and the food waste, algae were added to the substrate mixture (see Figure 27). At least three different kinds of algae have been used in the plant (see chapter 1.3.2). In order to avoid problems in the pilot plant, the algae have been chopped a little bit. By doing this no long fibres could wrap around the stirrers.


Figure 27: Premixed manure, food waste and algae for fermenter feeding.

- <u>10.10.2013 – 14.10.2013: Removing of the fermenter content, sanitation and complete shutdown of the pilot plant</u>

After switching of the heaters, the measuring of a cooling curve has been done. Afterwards the removing of the fermenter content began, using a manure pump (see Figure 28). Rough cleaning was done with a pressure cleaner.
Accompanied by an inventory control the sanitation of the fermenter was performed. For this the fermenter was filled with water and closed. The water was then heated up to 60°C and kept on this temperature level for at least 24 h. The water was drained finally.

Figure 28: Removing of the fermenter content using a manure pump (left). Inventory control and sanitation of the pilot plant (right).

During the cleaning of the fermenter, a protective tube for a pH- / temperature sensor was found on the bottom of the fermenter (see Figure 29). It had fallen off the spare mounting on the end of the fermenter. Luckily it did not cause any damage. This could have happened if it had fallen between two operating stirrers. Major motor and/or gearbox damage could have been the consequence.
After cleaning the fermenter with a pressure cleaner, a lot of sand came to light (see Figure 29). Beside making the cleaning a little more time-consuming, the sand did not cause any problems for the plant performance.

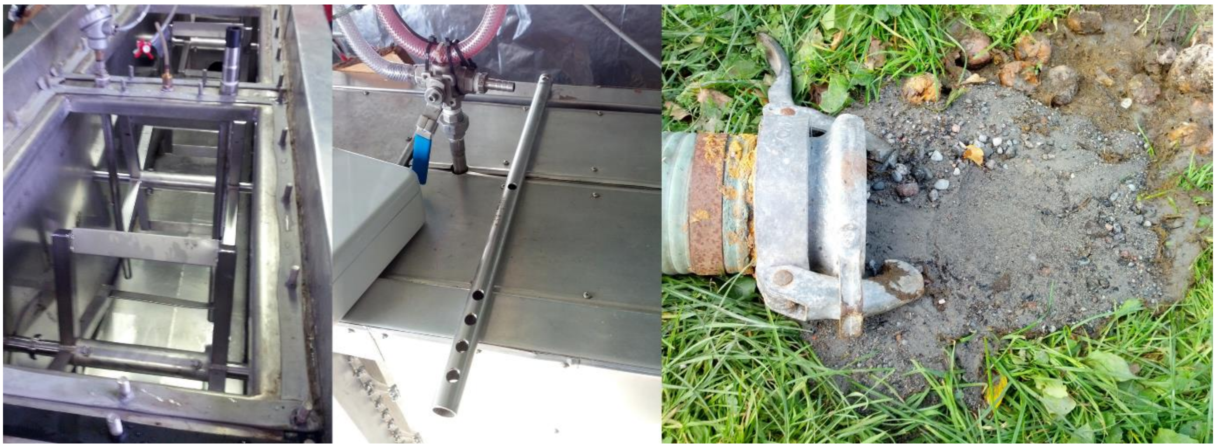


Figure 29: Cleaned and sanitized fermenter (left). Protective tube for pH- / temperature sensor found on the bottom of the fermenter (center). A lot of sand from the bottom of the fermenter (right).

- <u>15.10.2013: Transport to Estonia</u>

Finally on Tuesday 15th of October 2013 the container was loaded and transported to Estonia. Due to the lesson learned from the difficult loading procedure in Germany, this time a truck without superstructure had been ordered (see Figure 30). This made to loading procedure much easier (see also chapter 1.1.3).

Figure 30: Loading of the container (left). Transport leaving the farm, heading to Estonia (right).

1.6 Comparative reporting of on-site operational data with parallel laboratory gained data from Ostfalia lab

In this chapter the gathered information from plant operation will be compared to the results of parallel laboratory analysis of the substrates used during the testing period. For materials and methods see 1.6 .

1.6.1 Evaluation of the continuous fermentation test

Parallel to the operation of the pilot plant in Lithuania continuous fermentation tests have been performed in Ostfalia laboratory. The aim was to show correlation between lab scale and pilot scale reactors. To achieve the best comparability the feeding amounts as well as the substrate composition should have been equal. To evaluate the long term behaviour of all substrates the composition of the continuous lab tests differs from the pilot plant composition.

Figure 31 shows an overview over the weekly feeding amounts and compositions of the continuous lab tests performed in the Ostfalia laboratory. Compared to the feeding amounts of the pilot plant (see Figure 33) the differences are clearly visible. In laboratory test the distillery waste have been used for almost the whole operating period while feeding of this substrate was stopped in the pilot plant. The main reason was a major change in the substrates water content in Lithuania. The water content rose to a very high amount, so that the decision was made to stop the feeding.

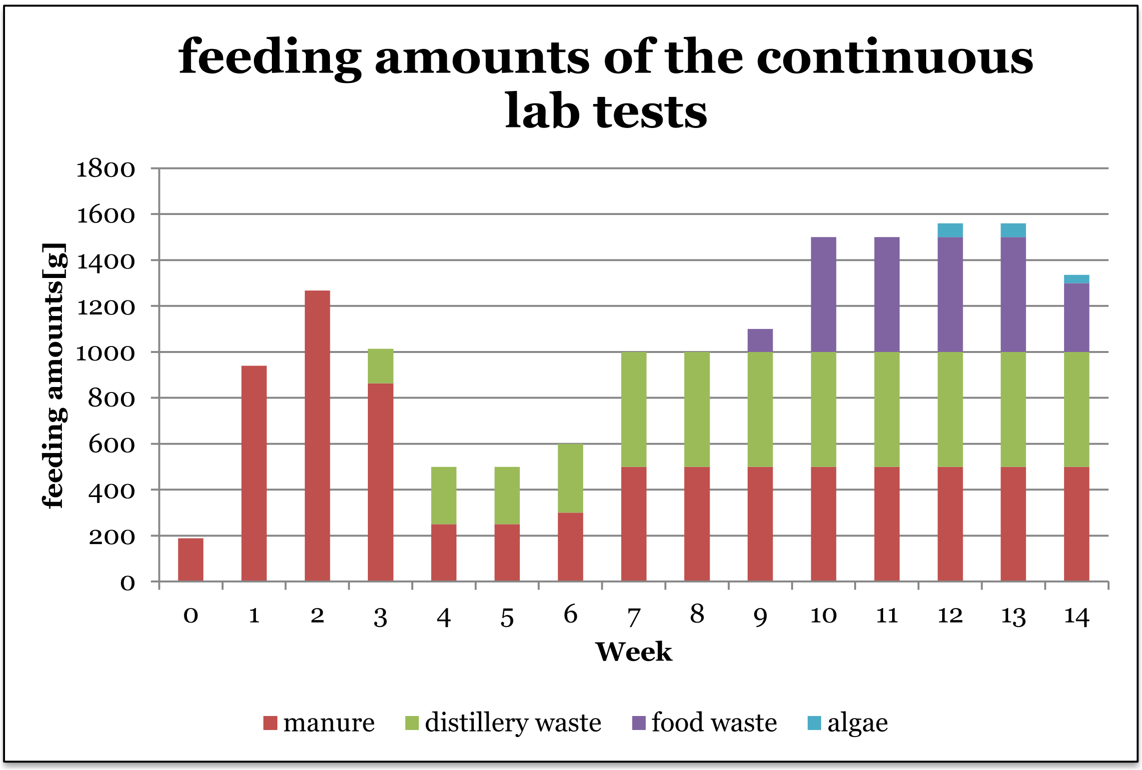


Figure 31: Feeding amounts of the continuous lab tests

As shown in Figure 32 the methane yield of the continuous tests shows good correlation to the expected yields calculated from the batch tests.
This proves the comparability of the continuous tests regarding benchmarking of fermentation performances with the estimated results from previous batch tests.

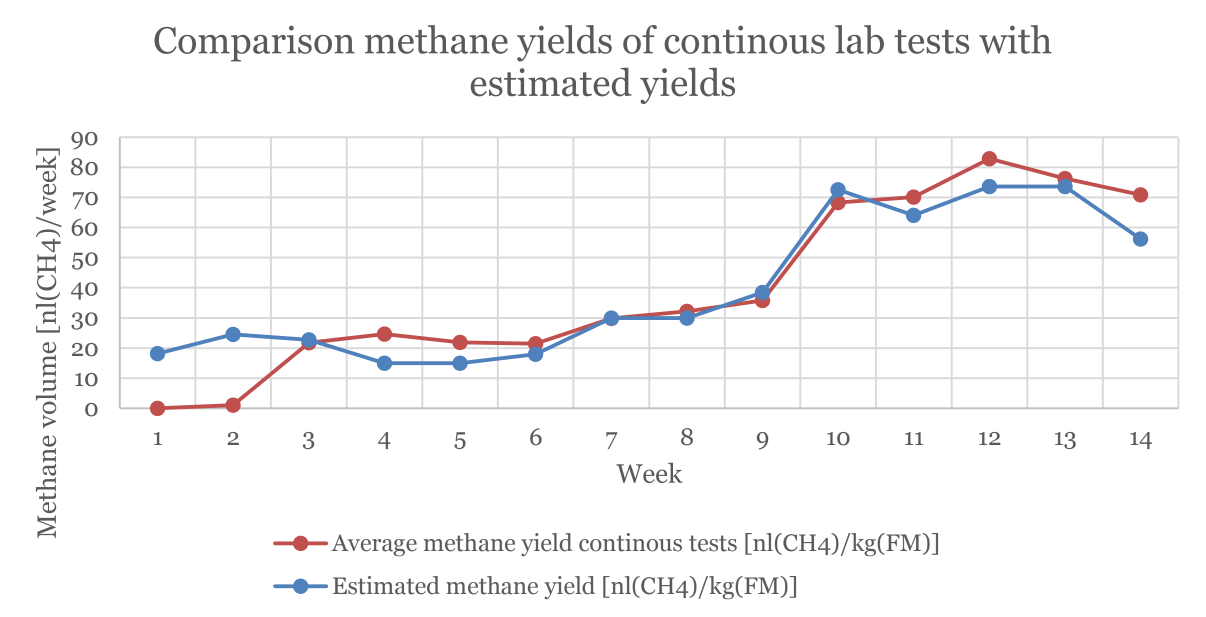


Figure 32: Comparison of methane yields of continuous lab tests with estimated yields calculated from batch tests

1.6.2 Evaluation of Pilot B performance data

Figure 33 gives an overview over the weekly feeding amounts and compositions of the pilot plant during Lithuanian operating period. Compared to the feeding amounts of the continuous test (see Figure 31) the feeding of the distillery waste was stopped after week 5. After week 11 (feeding amounts until this time comparable to continuous tests) the single use of manure has been examined in addition to the scenarios explained earlier in chapter 1.1.1 .

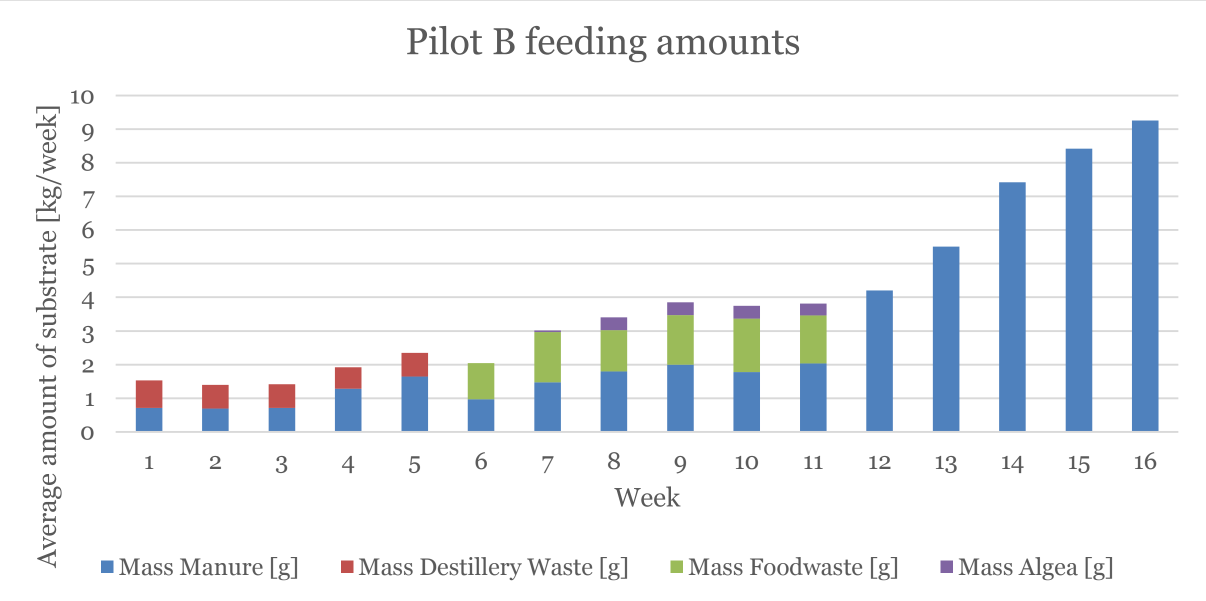


Figure 33: Overview on Pilot B feeding amounts during operating period in Lithuania

As well as the continuous lab tests, the pilot plant shows very good correlation between estimated and measured methane yields as seen in Figure 34. This proves the comparability of the pilot plant regarding benchmarking of fermentation performances with the estimated results from previous batch and continuous tests.

The high amount of methane produced in the first 4 weeks is a results of previous overfeeding and following batch operation. Good visible is the almost parallelism between the two curves. Only the results with the manure as single substrate show a weak performance of the pilot plant. The reason for this could be a variation in the organic matter content of the manure in comparison to the one used for the batch test.

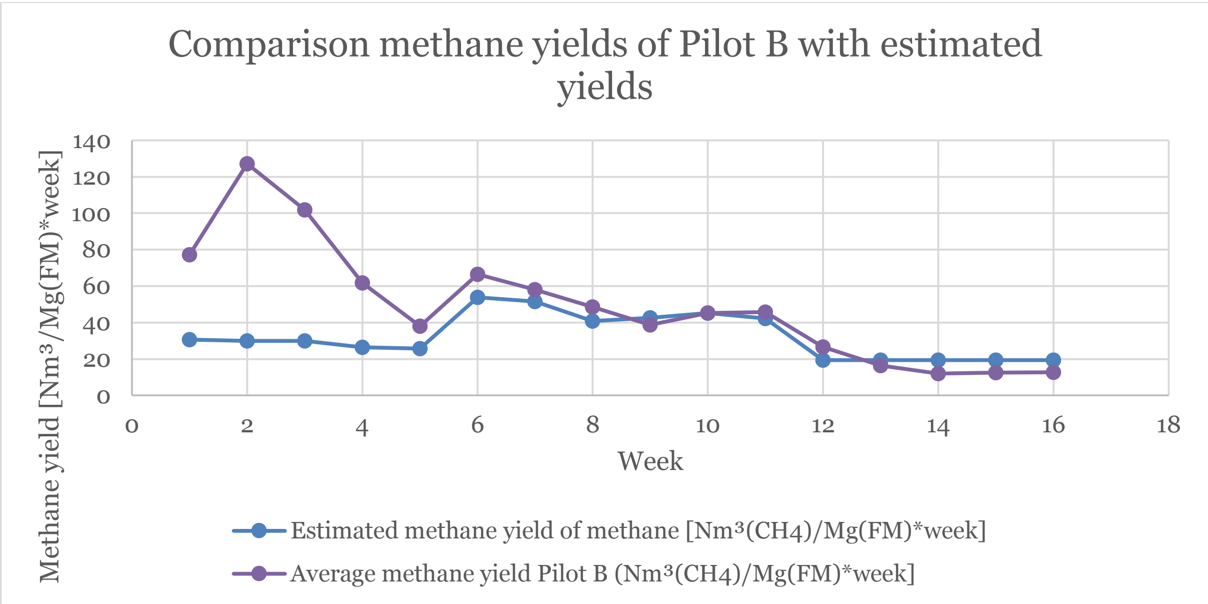


Figure 34: Comparison methane yields of Pilot B with estimated yields calculated from batch tests

Figure 35 shows the development of the volatile organic acid and total anorganic carbonate ratio (VOA/TAC) which is an indicator for the fermentation performance. After bad performance after start-up of the fermentation (due to overfeeding) the VOA/TAC decreased to a level that would have allowed a higher loading rate of the process. This shows that the pilot plant can deal with a higher loading than used in this operating period.

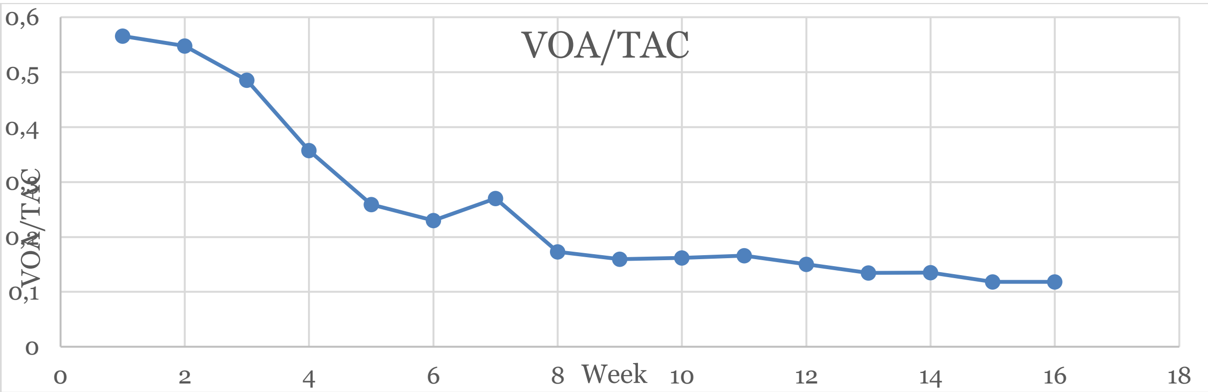


Figure 35: Development of the VOA/TAC ratio of the pilot plant during Lithuanian operating period

Figure 36 shows the development of NH4-N in the fermentation residues of Pilot B during the operating period in Lithuania. The values in the weeks 3, 6, 7 and 8 are not zero but no data has been acquired in these weeks. The high value in week 14 is too high and is not significant. There may have been a problem with the measurement. The Ammonia concentrations are on a regular level.

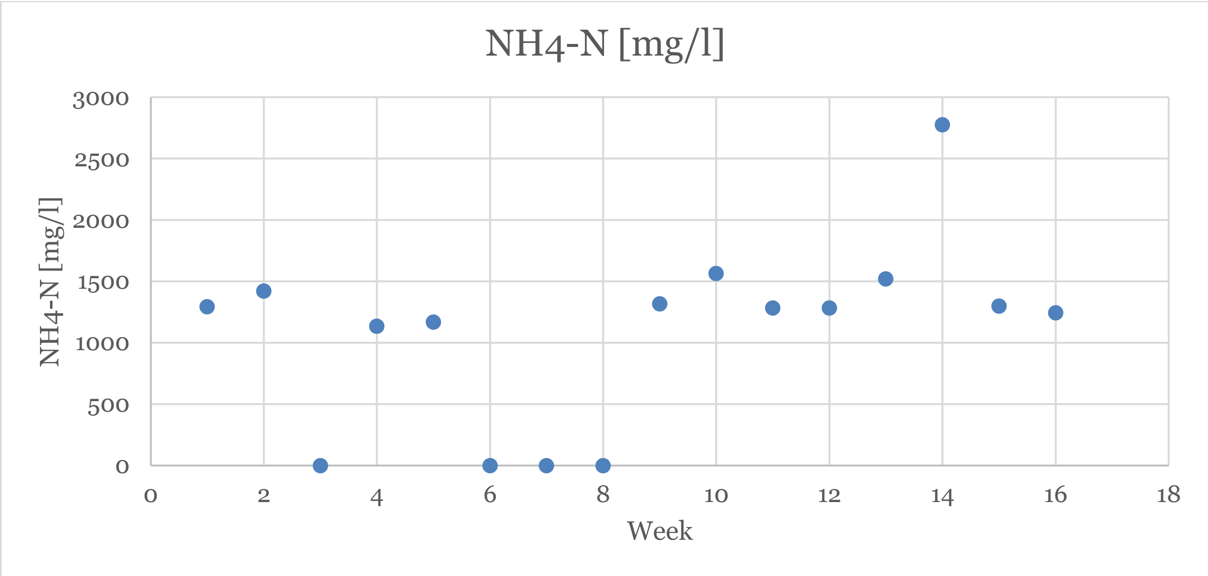


Figure 36: Results of NH4-N determination of fermentation residues during Lithuanian operating period

1.7 Technological up-scaling to implementation scenarios "farm scale" and "large scale"

The following calculations have been made with some assumptions which can be Figure **37**.

The data for estimated methane productions come from the batch test made in Ostfalia laboratory with the original substrates used during Lithuanian operating period.

The calculations are made for the scenarios described earlier (see 1.1.1) and shown again in Figure 37.

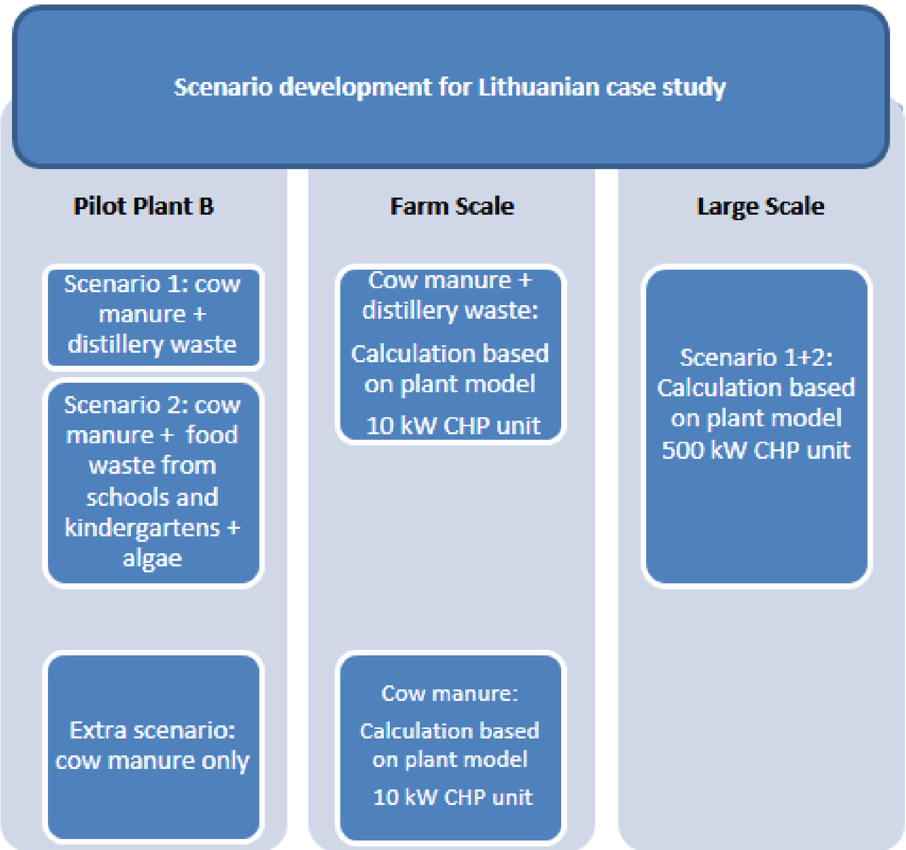


Figure 37: Overview on Lithuanian case study scenarios.

Table 10: Assumptions for up scaling calculations

Full load operating time CHP unit	8,760 h/a (7,900 – 8,200 h/a realistic)
Electric efficiency CHP unit	34 % (10 kW), 41% (500 kW)
Energy content methane	9.97 kWh/m³
Organic loading rate fermenter	3 kg(oDM)/m³*d

The following calculation gives an example for plant design calculations fora farm size plant (10 kW CHP unit) operated with manure as the only substrate.

From the assumed operating time of the CHP unit and its power, the overall power can be calculated:

$$W_{overall} = P_{CHP} * t_{runtime,CHP} = 10\ kW * 8{,}760 \frac{h}{a} = 87{,}600 \frac{kWh}{a}$$

With the efficiency of the CHP unit, the true energy demand (from the biogas) can be calculated:

$$W_{biogas,demanded} = \frac{W_{overall}}{\eta_{CHP}} = \frac{87{,}600\ kWh}{0.34a} = 257{,}647 \frac{kWh}{a}$$

With the energy content of the methane the corresponding methane volume can now be calculated:

$$V_{methane} = \frac{W_{biogas,demanded}}{W_{CH4}} = \frac{257{,}647\ kWh\ m^3}{9.97\ kWh\ a} = 25{,}842 \frac{m^3}{a}$$

The estimated methane productivity of manure makes it possible to calculate the necessary manure amount:

$$m_{manure} = \frac{V_{CH4}}{Productivity_{CH4,per\ substrate}} = \frac{25{,}842\ m^3 Mg(FM)}{19.34\ m^3 a} = 1{,}336\ \frac{Mg}{a}$$

The assumed organic loading rate of 3 kg (oDM)/m³*d for the fermenter, as well as the organic dry matter content of the substrate allows to calculate the necessary fermenter volume:

$$V_{fermenter} = \frac{m_{manure} * w_{oDM}}{oLR * 365\ d} = \frac{1{,}336\ Mg * 0.1066\ m^3 * d * 1{,}000\ kg\ a}{3\ kg(oDM) * 365\ d\ a\ Mg} = 130\ m^3$$

Calculation of the remaining residues after fermentation can be done with the density of CO_2 and CH_4. This will give the mass of the produced biogas. The amount of water leaving the process is calculated via the partial pressure of water steam (157,37 mbar at 55°C) in the gaseous phase (55°C, 1013.25 mbar)and the density of dry steam (0.768 g/l at 1013.25 mbar and 0°C).

$$m_{residues} = m_{substrate,input} - \left(V_{CH4} * \rho_{CH4} + V_{CO2} * \rho_{CO2} + \frac{p_{H2O}}{p_{amb}} * \frac{V_{CH4}}{\varphi_{CH4}} * \rho_{steam}\right)$$

$$m_{residues} = 1{,}304\ Mg - \frac{\left(25{,}842\ m^3 * 0{,}7168 \frac{kg}{m^3} + \left[\frac{25{,}842}{57\%} - 25{,}842\ m^3 * 1{,}9769 \frac{kg}{m^3}\right] + \frac{157{,}37\ mbar}{1013{,}25 mbar} * \frac{25{,}842 m^3}{57\%} * 0.768 \frac{kg}{m^3}\right) Mg}{1000\ kg} = 1285\ Mg$$

Table 11 summarizes the calculations given above. This would be the necessary plant size for a farm based, manure operated biogas plat with a 10 kW CHP unit (electric power).

Table 11: Manure only; 10kW CHP unit

Estimated methane production manure	19.34Nm³/Mg(FM)
Average methane content	57 %
Organic dry matter content manure	10.66 %
Resulting energy demand	257,647 kWh
Resulting methane volume	25,842 m³/a
Resulting annual feeding amount	1,336 Mg/a
Remaining residues after fermentation	1,285 Mg
Resulting fermenter volume	130 m³

The following calculations correlate with the feeding composition of the pilot plant during the Lithuanian operating period. Calculations are made for a small scale scenario (farm based, 10 kW CHP-unit) as well as for a large scale plant (500 kW CHP-unit), see also Figure 37.
To calculate the maximum design data an unrealistic runtime of the CHP-unit is chosen (8,760 h/a).

Table 12 shows the calculated design data for a farm scale plant operated with manure and distillery waste in addition. Due to the higher energy content of the distillery waste this reactor can be about 1/3 smaller than the reactor operated with manure only. By raising the amount of high energy substrates, the reactor volume could be lowered even more.

Table 12: Scenario 1 (1/2 manure + 1/2 distillery waste; 10 kW CHP unit)

Estimated methane production manure	19.34 $Nm^3/Mg(FM)$
Estimated methane production distillery waste	40.54 $Nm^3/Mg(FM)$
Average methane content	57 %
Organic dry matter content manure	10.66 %
Organic dry matter content distillery waste	11.52 %
Resulting energy demand	257,647 kWh
Resulting methane volume	25,842 m^3/a
Annual feeding amounts	432 Mg manure + 432 Mg distillery waste
Remaining residues after fermentation	812 Mg
Resulting fermenter volume	87 m^3

Table 13 gives the plant dimension of a full scale plant (500 kW CHP unit) with the same substrate mixture as the farm scale plant mentioned in
Table **12**. While the up scaling factor for the CHP unit is 50, the factor for the reactor is only ~28. This derives from the efficiency factor of the CHP unit, which gets better with rising power of the CHP unit. In this case assumed 34% for the 10 kW CHP and 41% for the 500 kW CHP.

Table 13: Scenario 1 (1/2 manure + 1/2 distillery waste; 500 kW CHP unit)

Estimated methane production manure	19.34 $Nm^3/Mg(FM)$
Estimated methane production distillery waste	40.54 $Nm^3/Mg(FM)$
Average methane content	57 %
Organic dry matter content manure	10.66 %
Organic dry matter content distillery waste	11.52 %
Resulting energy demand	10,683 MWh
Resulting methane volume	1,071,507 m^3/a
Annual feeding amounts	17,894 Mg manure + 17,894 Mg distillery waste
Remaining residues after fermentation	33,647 Mg
Resulting fermenter volume	3,625 m^3

Table 14 gives the design results for a full scale plant (500 kW CHP unit) and a mixture of manure, food waste and algae. The chosen mixture has been used in the same composition during the Lithuanian operating period in the pilot plant.

Table 14: Scenario 2 (52% manure + 38% food waste + 10% algae; 500 kW CHP unit)

Estimated methane production manure	19.34 $Nm^3/Mg(FM)$
Estimated methane production food waste	85.23 $Nm^3/Mg(FM)$
Estimated methane production algae	30.90 $Nm^3/Mg(FM)$
Average methane content	57 %
Organic dry matter content manure	10.66 %
Organic dry matter content distillery waste	11.52 %
Organic dry matter content algae (dried)	27.53 %
Resulting energy demand	10,683 MWh
Resulting methane volume	1,071,507 m^3/a
Annual feeding amounts	12,237 Mg manure + 8,942 Mg food waste + 2,353 Mg algae
Remaining residues after fermentation	21,390 Mg
Resulting fermenter volume	3637 m^3

The resulting fermenter sizes can be seen as regular plant sizes by German standards. The biogas plant in Figure 38, built by a German biogas company in Estonia in 2013, has two fermenters with a used volume of approximately 2,600 m^3 each.

Figure 38: Estonian biogas plant, Vinni, Estonia, October 2013

1.8 Conclusion of testing period regarding envisaged roadmap

In Table 15 you can see an overview of the main performance data of Pilot B during the Lithuanian operating period.

Table 15: Overall data for Pilot B operating period in Lithuania

Overall mass manure	519.09 kg
Overall mass distillery waste	35.62 kg
Overall mass food waste	82.68 kg
Overall mass algae	15.39 kg
Overall mass	652.78 kg
Overall volume of produced biogas	38.62 Nm^3
Overall volume of methane	21.85 Nm^3
Resulting average methane concentration	56.6 %
Fermenter temperature	42°C (mesophilic)
Overall electricity consumption	2,183.8 kWh

Although the practical on-site work is completed, working on biogas development in Lithuania has not ended yet.

Before the last stakeholder meeting in Klaipeda on October 4th 2013, the idea came up to develop a feasibility study for the village of Švėkšna. This village is the next bigger settlement situated near the farm where Pilot B has been operated. Officials from Švėkšna used their chance to visit the pilot plant, before it was transported to Estonia.

The plan for the future is to seek specific information on substrate availability in and around Švėkšna as well as energy demands and potential stakeholders. When these substrates are identified, practical process simulation, as done for Lithuania in general, will be performed in the Ostfalia laboratory.

On the basis of this data, a possible biogas implementation for the village of Švėkšna will be developed.

1.9 Summary

This report describes the practical aspects of Pilot B (pilot scale dry digestion biogas reactor) testing period in Lithuania from May 2013 till October 2013. It deals with the development of suitable scenarios for full scale biogas implementation in Lithuania. On the basis of these examined scenarios now concrete implementation scenarios can be developed.

In order to gather the necessary information on substrate usability and their long term process behaviour a parallel approach has been realised. Laboratory work on the one hand as well as pilot scale examinations of chosen substrate mixtures on the other hand led to usable conclusions for further implementation planning.

On the basis of the results from the practical testing period calculations could be made regarding the necessary full scale fermenter sizes and the required substrate amounts as well as the disposable (reusable) fermentation residues. The basis of these calculations were a farm scale plant size CHP unit with 10 kW of electric power and a full scale plant size with 500 kW CHP unit of electric power.

This report shall show how a concrete implementation approach will look like, consisting of:

- Identification of available usable substrates (in the best case consisting of waste)
- Laboratory substrate analysis regarding specific methane yields
- Parallel examination of fermentation behaviour in lab- and pilot size
- Calculation of plant design on the basis of the previously gained information

The Lithuanian case shows that this approach is right step in this direction. As Pilot B already moved to its next place of action, the work in Lithuania continues. For the village of Švėkšna the first steps for full scale implementation just start from data compilation…

2. Financial implementation report

Implementing of biogas technology requires assessment of many aspects concerning the economy efficiency. In this financial implementation report these aspects are considered and therefore relevant information is compiled.

2.1 Introduction

The financial implementation report aims for answering the questions, if regional implementation of biogas technology is attractive concerning the financial and economic aspects.

The main financial and economic aspects are:

- Investment costs
- Operating costs
- Proceeds respectively savings achieved by the production and use of biogas, utilization of wastes and use of digestate as fertilizer

With reference to the different scenarios (see chapter 1.1.1 and the results which arose from the operation of Pilot B this report will among others be basis for the consideration of farm scale biogas plants and large scale biogas plants.
The main target of the financial report (with respect to the investment memo) is to constitute which way is attractive for investors to build biogas plants in the partner regions (here: Lithuania). Therefore the detailed investigation of the data which have an influence on the cash flow is an important requirement for the decision making process. Based on the investigated data the cash flow of exemplary biogas plants will be determined in the following of this project.
Anyhow it is important to notice, that biogas plant Pilot B is an experimental plant supporting the dry digestion technology idea and not for commercial production of biogas.

2.1.1 General overview of the national political and legislative framework in Western Lithuania regarding waste and energy

Concerning renewable energies and waste disposal there are diverse Directives existing.

The Directive 2009/28/EC decrees a RES (Renewable Energy Sources) target by 2020 of 23%for the final energy consumption with at least 10% renewable energy in the transport sector. Moreover the National Energy Strategy of 2007 contains national commitments. According to that the RES-share on the primary energy balance had to be increased by 1.5% per year until 2012 and has to be 20% until 2025. [20]

In 2007 the share of renewable energy was 8.7% of the total primary energy consumption.[21]The share of the total electricity consumption was 5% in 2008. The electricity generation by biogas reached 5GWh of the whole RES-electricity generation of 579 GWh in 2007.

The NAT (National target fulfilment) scenarios provide an important role for biogas till 2020. According to that the contribution of biogas to the electricity consumption is estimated to increase up to 17% in 2020.[20]

The main treatment of waste in Lithuania is based on landfilling. By 2010 several hundred dumps had been closed and replaced by 11 modern landfills. Several green waste composting facilities, bulk waste acceptance facilities and container sites for secondary raw materials were built. [29]

Municipal solid waste (MSW)

By 2010 the amount of biodegradable municipal waste which was landfilled was estimated to be 81 % of the amount generated in 2000. That means that the target of 75% of the Landfill Directive was not achieved and a large effort has to be undertaken to reach the 35% requirement by 2020. [30] Initially the Directive provided this goal for 2016, but the countries which struggled to reach these targets got an extension of four years. [36]
According to the state commitments in the field of waste management, the waste management infrastructure and system will have been optimized by 2015 in order to treat no more than 50% of biodegradable waste in the landfills of the target region.
Actually gas of closed landfills is captured and used for heating systems for living districts (for instance Vilnius-Kazokiskiai landfill gas heats houses and flats in the small town Vievis). [37]
Biogas is for example being generated by using the sludge of a waste water treatment plant in Western Lithuania (Klaipeda). The generated biogas is utilized in a combined heat and power plant. Presently 15 biogas plants are working in Lithuania. [37]

Approach of Abowe

Against this background the approach of ABOWE is to implement the biogas technology to use waste for the production of energy in relation to the actual legal situation. Here the European Union targets specific goals till 2020 and beyond.
One of the major difficulties regarding implementation of biogas technology against all obvious advantages is the high investment costs for the installation of biogas plants. Therefore possible investors have to be informed in detail about this technology and scruples have to be silenced.

2.1.2 Description of pilot B site surroundings; the Šilutė region (see also chapter 1.1.2)

The region of Šilutė is located in Western part of Lithuania at the Curonian Lagoon (see Figure 1). The region of Šilutė constitutes of the city of Šilutė, seven small towns and more than 300 villages. It is the second biggest city of the coastal area with more than 52,000 inhabitants. [3]

Figure 39Region of Šilutė [19]

54.7 % of the region of Šilutė is agriculture area, 18.84% are forests and 16.4% waters. The rest of the region is town area, industries, ways and others. The industrial sectors are: food/beverages, bioethanol, wood processing, furniture and textile.
Though there is a high share of agriculture and the productivity index is low. Because of yearly floods caused by the river Nemunas pastures and water grassland are dominating.
The Šilutė Municipality energy system consists of a district heating supply and decentralized heating. There is a regional electricity supply system via national grid and distributed electricity generation by RES producers. Natural gas networks do not exist in the near regions.
Šilutė is involved in a project named ENNEREG which is a European Project supported by the Intelligent Energy - Europe programme. 12 Pioneer regions in the EU are involved in this project which shall be the “driving forces” in fulfilling the aims of the EU 20-20-20 goals. [4]

Project ENNEREG

Šilutė Municipality is as Twin region of Kaunas Region as ENNEREG Pioneer Region, which is the part of the project ENNEREG(Regions paving the way for a Sustainable Energy Europe), a European project aimed to establish and inspire a network of regions to produce regional Sustainable Energy Action Plans (SEAPs) and implement Sustainable Energy Projects (SEPs). The project started in May 2010 and ended in April 2013. [4]
The aim of this project is it to take up the challenges of fulfilling the EU 20-20-20 climate and energy targets. These are to reduce the greenhouse gas emissions (at least 20%), increase the energy efficiency (20%) and to produce 20% of energy from renewables by 2020.[5].

The activities in the regions who are involved in the project ENNEREG focus on eight key Sustainable Energy themes:

- Energy efficient buildings
- Energy efficiency in industry
- Energy efficient products
- Sustainable transport
- Renewable energy
- Energy services
- Intelligent energy education
- Energy monitoring [4]

The Pioneer regions guide their respective Twin regions.

The main objective in the mentioned project which the region of Šilutė wants to achieve is the reduction of CO_2- emissions by 20% by 2020 under obligations to the Covenant of Mayors. More activities are planned as follows (in excerpts):

- Establishment of favourable legislation for enabling implementation of obligations
- Wide use of RES (Renewable Energy Sources)
- Modernization of district heating sector
- Improvement of energy efficiency in buildings via renovation of block residential houses
- Improvement of public transport sector and use of biofuel
- Participation in international programs and sharing of experience
- Implementation of "clean technologies"
- Public information and awareness raising
- Implementation of environment management systems [4]

SEAP (Sustainable Energy Action Plan) was developed by municipal Environment officer. Because of lack of experience and missing of data on municipal energy sector SEAP has to be revised considerably. [4]

2.1.3 Description and evaluation of implementation Scenario 1: Treatment of cattle manure and waste from distillery (see also chapter 1.1.1)

Scopes of the scenarios are to determine the capability of existing waste streams and the amount of biogas which could be produced by using them for anaerobic digestion. Thereby the determination of the possible covering of the energy demand (electricity and heat) is a basic aim of this project.

The scenarios which were developed within the project are simulation scenarios. That means they describe possible scopes. The scenarios were and will not be implemented in this form. As one outcome of the project a feasibility analyses for the small village Švėkšna will be conducted and therefore the possible implementation of a biogas plant considered.

As a first result of the project work two scenarios for the operation of the pilot biogas plant and consequential considerations (economic, financial, socio-economic, political and legal implementation) were developed for the region of Šilutė in Lithuania. In the first scenario the digestion of cattle manure and waste from bioethanol distillery was been considered. Therefore cattle manure of the farm on which Pilot B was located and residues of the bioethanol distillery which is located in Šilutė where used for operation of Pilot B. Detailed results of the biogas production can be seen in chapter 1.6 .

Bioethanol distillery in Šilutė

The bioethanol distillery is located in the city of Šilutė and owned by “MG Baltic”. Since 2004 bioethanol (dehydrated ethyl alcohol) has been manufactured. Currently the factory produces 40,000 tons per year. Ethanol which is used for fuel or for chemical industry is sold in Lithuania and also to Western Europe.[6]The residues of the process are sold to farmers as animal feed for about 30 Lt/ton (8,66 €/ton). [15]

Distillery waste provides a high potential for the use as input material in biogas plants. It yields a well utilizable amount of biogas and is a waste product which is available in a sufficient quantity. The use of distillery waste may constitute a possible solution for factories to utilize it in a profitable way. The produced energy contributes to the covering of their energy demand.

Analytics at Ostfalia labs

Ostfalia University analysed the biogas potential of the distillery waste and cow manure in lab (see also REMOWE).

Biogas yields:

- distillery waste: about 40 Nm^3/t fresh mass.
- cow manure: about 20 Nm^3/t fresh mass.

Based on the results of these laboratory batch tests it can be expected that mixtures of these substrates yield corresponding partial results (e.g. 50% distillery waste and 50% manure = app. 30 Nm^3/t)
The results of the laboratory tests are listed in chapter 1.6 .

Biogas plant at distillery "Sema" in north-eastern Lithuania

An example of a working biogas plant which is installed at a distillery already exists in Lithuania. The biogas plant is located at alcohol and yeast factory "Sema" in north-eastern Lithuania. The factory installed biogas technology because the aerobic treatment of waste water was inefficient. Therefore it was switched to anaerobic treatment. The installation of the biogas plant also had an important influence on the company's economics, because the natural gas was substituted by biogas. The biogas had a calorific value of 6.5 kWh/Nm³, which equals to app. 70% calorific value of Russian gas. The amount of biogas planned to be produced was 19,000 Nm³ per day. [31]

2.1.4 Description and evaluation of implementation Scenario 2: Treatment of cattle manure, food waste from schools and kindergartens and algae

In second scenario cattle manure with food wastes from different resources, here from schools and kindergartens were used for anaerobic digestions in Pilot B. Because there are no data concerning the solely amount of food waste from schools and kindergartens available the share of food and kitchen wastes in Lithuanian municipal waste are taken as basis.

Theoretical food waste potential

In general food and kitchen wastes have a large share of the waste in Lithuania, exemplarily in Kaunas region it is 39 %. [7]Therefore the use of food wastes as substrates for anaerobic digestion constitutes a high quantity potential. Based on the amount of 357,873 ton/a of municipal waste which is been generated in Western Lithuania in 2008 [8] there would be a share of food and kitchen waste of about 140,000 ton/a (1,030,000 inhabitants) usable for anaerobic digestion. Therefore the region of Šilutė with about 52,000 inhabitants has a theoretical bio waste potential of about 7,000 ton/a. Laboratory tests at Ostfalia University showed a theoretical biogas yield of about 85 Nm³/ton of the used food wastes. Therefore the theoretical amount of 7,000 ton/a provides a methane potential of approx.600,000 m³/a (separate collection provided).

In reality the amount of available food waste is much less. Based on actual statements an amount of 27 kg/inhabitant is the most probable current yield. The reason is that many schools and restaurants as well as many cafés and restaurants explain, that they have only very small amounts of food waste usable for utilization and that it is utilized by one or two small farmers "free of charge". Also the missing waste sorting is one of the reasons for the small amount of available biodegradable waste. [37]

Algae

Tentatively algae were additionally fed into the Pilot B-fermenter. The algae were collected from Curonian Lagoon surface and shores.
The amounts of algae which were identified in summer and autumn season are shown in Table 16. Apparently algae constitute a great biomass potential.

Biogas yields:

- algae: about 30 Nm^3/t fresh mass.
- food waste: about 85 Nm^3/t fresh mass

Table 16: Macroalgae and reeds biomass indentified during Submarine Project [37] DW=dry weight; 200m: of water surface or coastal zone

Type	**Time**	**Place**	**Length of coastal zone / area**		**Biomass, t**	
					Min	Min
Macroalgae		Baltic sea coastal zone	~99 km	-		1 700 t (only *Furcellaria lumbricalis)*
Macroalgae	Summer	Curonian Lagoon coastal zone of Curonian Split	~60,35 km	1-185 kg DW/200 m	~0,3	~55,82
Macroalgae	Summer	Curonian Lagoon Coastal zone of Klaipeda region	~98,94 km	2-27 kg DW/200 m	~0,9	~13,35
Macroalgae	Autumn	Curonian Lagoon coastal zone of Curonian Split	~60,35 km	0,4-44 kg DW/200 m	~0,1	13,27
Macroalgae	Autumn	Curonian Lagoon Coastal zone of Klaipeda region	~98,94 km	1,2- 3123 kg DW/200 m	~0,59	1544,95

2.2 Reporting under consideration of on-site operational data

In strong correlation to socio-economic and legal aspects data were scanned concerning the actual energy situation in Lithuania. Therefore an intensive contact to the Lithuanian partners was necessary to match the needed information.

For the implementation of biogas technology in farm scale Lithuanian stakeholders were contacted within a project meeting in Klaipeda/Lithuania. In this first meeting the investors were informed about the main objects of the project Abowe. During an investor event the possible investors got to know Pilot B and were informed about the results of the operation of Pilot B.

Because Pilot Plant B was located in the region of Šilutė where a distillery is operated, the main focus was on the utilization of the waste of this distillery, which farmers of this region buy for feeding of their cattle. Therefore in the first period of operating Pilot B cow manure and waste from distillery was used for production of biogas (see also chapter 1.1.1).

In scenario 1 the possibility for the utilization of the distillery waste has been considered. Scenario 2 cared for food wastes from schools and kindergartens. As a result of the first meeting of stakeholders in Lithuania it became clear, that the deposition of this waste is an important problem at the moment. Therefore concerning to scenario 2 in the second period of operating Pilot B cow manure, waste of the distillery, food waste and also algae were been used for the production of biogas.

2.2.1 Investigated data concerning tariffs and prices

The economic consideration will be a general view on the use of waste of the distillery and also on the use of food waste from schools and restaurants. Therefore at first the available amounts of these substrates had to be determined. Unfortunately there were no data available concerning the amounts of distillery waste and also food wastes from kindergartens and restaurants. Therefore assumption had to been made for further calculations.

As table 1 shows it has to be considered that the price for electricity is one crucial factor for investors when deciding about the implementation of biogas technology.
Therefore first of all the actual energy prices were investigated. A first overview of the prices for energy and also the substrate “distillery waste”, as it is used for feeding is given in Table 1 and Table 17.

Table 17: Lithuanian tariffs

electricity	natural gas	mineral fertilizer	compost
0.1059-0.1561 €/kWh [16]	0.60 €/m³-0,78 €/m³[17]	294-297 €/ton[18]	18.75-63.48€/m³ [28]
fresh water	**feed-in tariff electricity biogas AD**	**residues/ distillery**	
0.56-0.65€/m³[14]	0.12-0.19 €/kWh [26] 0.14-0.17€/kWh [1]	8.66 €/ton [15]	

1 €=~3.4528 Lt

Referring to a report of the "Baltic Forum for Innovative Technologies for Sustainable Manure Management" the prices for electricity produced by biogas plants are 0.14-0.17 € per kWh in 2013. The prices decreased from 0.14-0.19 € in 2012.
For biogas plants with a capacity of 30 kW or lower, the prices of the produced electricity are fixed. The prices for electricity produced by biogas plants with a capacity of more than 30 kW are not fixed. The operators are allowed to participate in auctions, so the price will be set according to market values. [1]

2.3 General information to financial and economic implementation of biogas technology (partly as contribution to investment memo)

For planning the construction and implementation of a biogas plant many aspects have to be taken into account. Among technical aspects especially the economic aspects are significant for the implementation of biogas technology.

Especially those factors which affect an influence on the cash flow have to be taken into account. These factors are the sourcing and sales markets, operating costs, financing conditions and also influence quantities of the public sector.[24]

In the following the possible cost factors of biogas plants of different sizes and noticeable biogas plant characteristics concerning the size of the plant and the substrates which will be used as input materials are specified.

It is also of importance to consider the risks which occur at these factors. In any case the most important factor when implementing biogas technology is to assure safe substrate availability. The biogas plant has to be supplied with material during the whole year. Also the use of the produced energy either the conditioned biogas itself, resulting heat or the electric energy generated by CHP unit has to be assured.

2.3.1 Cost factors

Besides investment costs for the building of the biogas plant there are operational costs (both in extracts):

Investment costs:

- Engineering, permission of the authority, connection to the public grid
- Functional units (substrate delivery and pre-treatment, digester, gas storage, biogas treatment, CHP unit, pumps, piping, offices, land costs, digestate storing, vehicles and others)

Operational expenses:

- Variable costs: substrate costs, analysing costs, process energy, consumables, maintenance and repair
- Fixed costs: capital-expenditure-dependent costs (depreciation, interest, insurance), labour costs, land costs [9]

Moreover it has to be kept in mind that a biogas plant does not work economically in the start-up phase because the biogas production starts gradually (start-up phase dependent on substrate up to 6 month).

2.3.2 Specific investment costs

Dependent on the size of the biogas plant especially the specific investment costs are varying. Below (Table 2) specific investment costs are listed:

Table 18: specific investment cost related to biogas plant size [11](German literature source)

Size of biogas plant	**Specific investment costs**
75 kWel	ca. 9,000 €/kWel
150 kWel	ca. 6,500€/kWel
250 kWel	ca. 6,000€/kWel
500 kWel	ca. 4,500 €/kWel
1 MWel	ca. 3,500 €/kWel

Comparing the specific investment costs it is remarkable that the bigger the size of the plant the lower the specific costs for the investments (see also Figure 40). Therefore the possible investor has to consider very carefully which size of the biogas plant would be profitable.

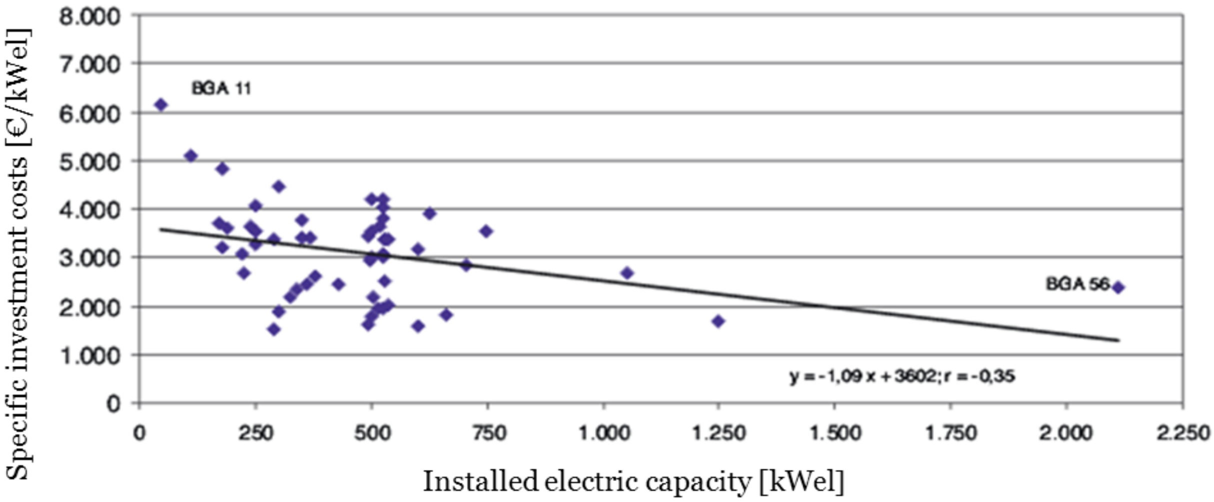


Figure 40: Relation between installed electric capacity and investment costs per kWel (2009) [27]

The costs in Figure 2are of data collections before 2009 and therefore less than the specific costs in Table 18. Nevertheless this figure illustrates the spreading and correlation of the investment costs to the installed electric capacity.

Considering theses prices it has to be taken into account that they represent full equipped biogas plants. For any costs which may arise e.g. concerning the biogas conditioning or the pre-treatment of the substrate there are some savings (or additional costs) possible (depending on the substrate and the use of the produced biogas there are possibly some plant components unnecessary or additionally necessary).

Definition of farm/small scale and large scale

First of all the different sizes of biogas plants which will be considered in this paper have to be settled. When we think about farm scale biogas plants a size of < 25 kW is being considered, large scale biogas plants have a size of about 500 kW and full scale plants more than 500 kW.

As a rule of thumb it can be considered that for 12 to 15 m³ biogas production per day 1 k W CHP-power has to be assessed. The investment costs for a CHP-unit (power range 15-250 kW) are between 500 and 750 € per kW (German data base) installed electrical capacity. [25]

Considering large scale or full scale biogas plants and especially regarding the handling of household bio waste it has to be taken into account that bio waste demands a special treatment. Especially the hygienisation of the material is a necessary demand. The hygienisation of biowaste which is used for anaerobic treatment is regulated by EU-hygiene regulation (VO 1774/2002/EG) [43] or German Biowaste Ordinance (BioAbfV) [43]. Thus bio waste has to be hygienised for example by heating it up to 70 °C for one hour.

Thus it has to be taken into account that the investment costs for biogas plants using biowaste as substrate are about one third higher than for biogas plants using for example renewables (see Figure 41).

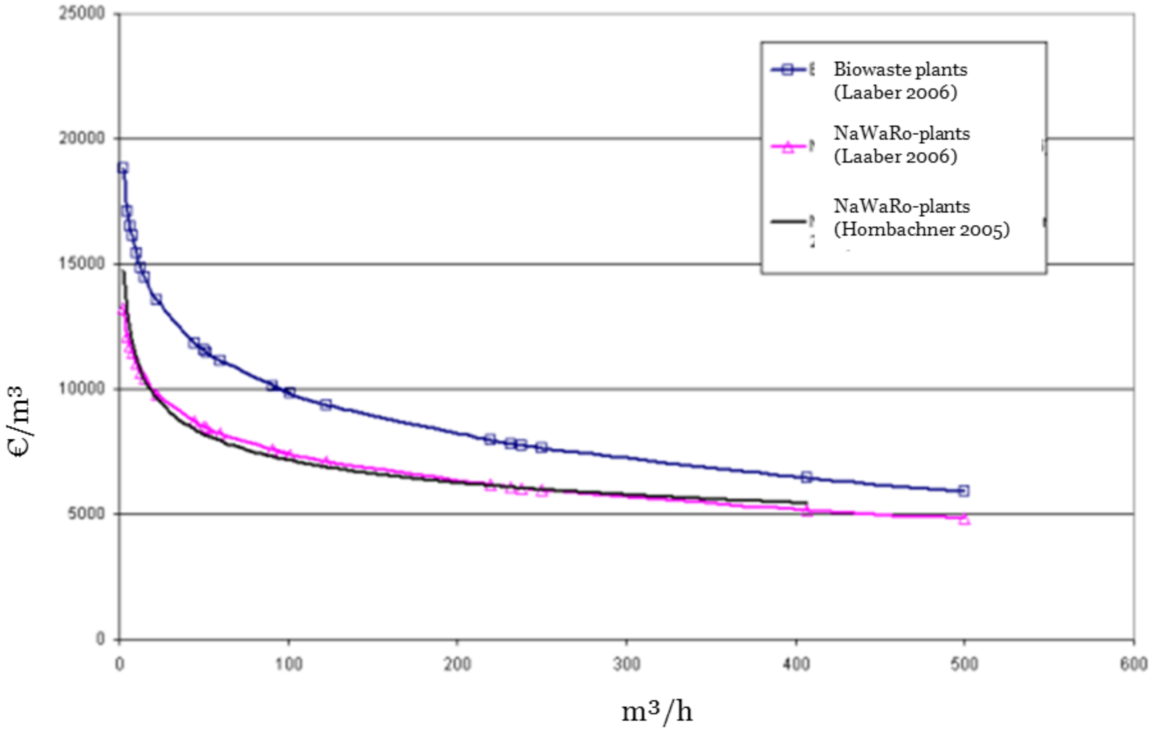


Figure 41: specific investment costs (without CHP and biogas processing in €/m³ related to size of biogas plant (m³/h) [10]

Nevertheless the specific investment costs tend to decrease with the larger sized the plant capacity is. Identifying the different groups of the investment expenses it makes obvious that part of the costs for planning and construction are personnel expenses. They should be considered separately, because there are considerable variations in the different countries. Regarding the investment costs the biogas technology can be divided into several functional units (see also Table 8).

The major investments here are the digester, gas storage and CHP unit whereas components such as office buildings, substrate storage, pump and piping technology have a smaller share. Basically the components which include high technology have higher influence on the overall costs.

Nevertheless it has to be taken into account that some parts of the biogas plant have to be reinvested regularly because of a short operational life span such as pumps, stirrers and also the CHP unit. Therefore the lifetime of pumps is considered to be 4 years, of CHP units about 6 years. [33]

2.3.3 Operating costs

In general the specific operating costs of a biogas plant are higher the smaller the biogas plant is. There is a decrease of the specific costs with the increase of the size of the plant (see Figure 4).Especially the operating costs for a biogas plant using biowaste are higher than the costs when using renewable raw materials. The lowest operating costs occur when using manure (without consideration of the substrate costs). [10]The figure shows the correlation of operating costs to the plant size (regardless that the prices date back to an older literature source). Nevertheless it has to be considered, especially for full scale biogas plants, that substrates with a high energy potential should be used, so that costs and effort for transport are minimised.

Considering the economy of a biogas plant it has also to be regarded that between 5 to 20% of the electrical energy produced by CHP technology (this amount has to be drawn from the public network) are used for own requirements of the biogas plant (pumps, stirrer and others) The heat of the CHP unit can be used for the heating of the fermenter (heat demand biogas plant: 5-25%). [10] So, if the feed-in tariffs of the produced electricity are higher than the prices for the electricity it might be economical to sell all of the produced energy and buy the needed energy from the national energy supplier.[34]

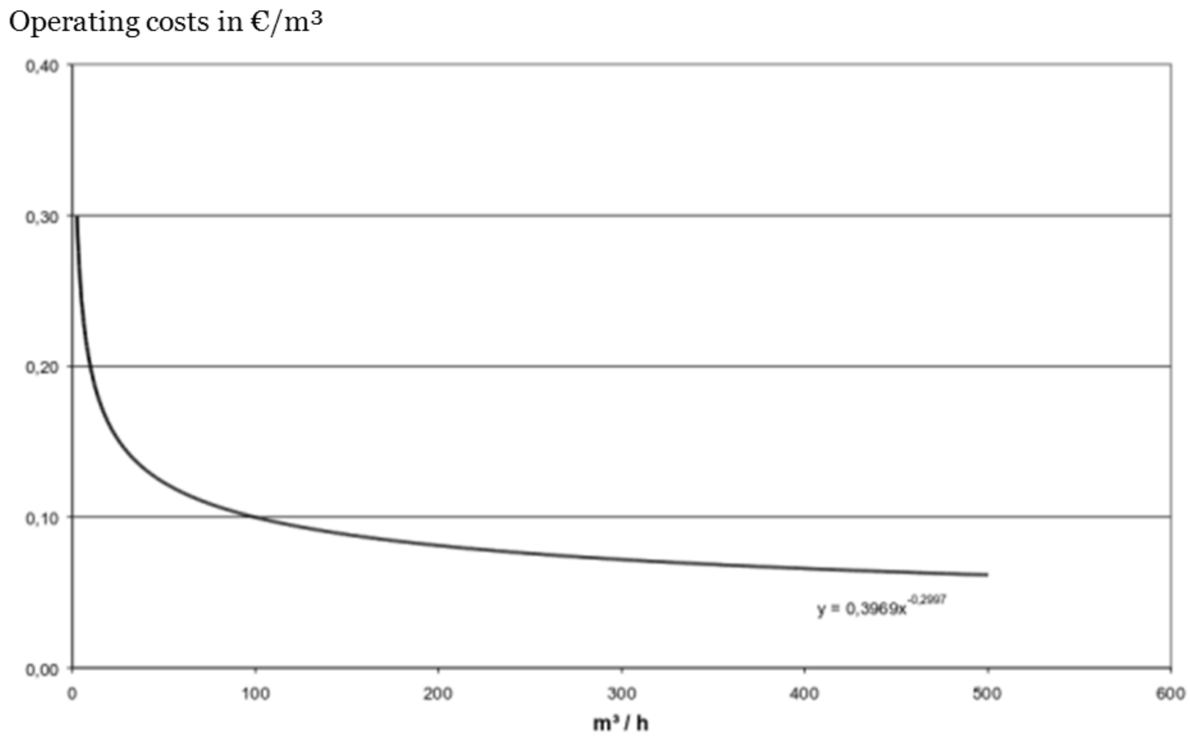


Figure 42: specific operating costs for biogas in €/m³ related to the plant size in m³/h [10]

Fixed and variable operating costs

Referring to Table 23 the operational expenses can be divided into variable and fixed expenses. Here the substrate costs may be up to 50 % of the total variable expenses depending on the kind of the used substrate and required transport . [9]

Considering the operating costs of biogas plants, costs for maintenance and repair have to be charged for the whole amount. The expenses are depending essentially on the components. In Table 8 the estimated shares on the expenses in percentages as share of the purchase price are listed. According to this list the highest expenses (proportionally) for maintenance and repair are caused by pumps and stirres. Here the expenses for the CHP unit are estimated to be 1.30 €ct/kW$_{el}$. [33]

If biogas is conditioned to biomethane a CO_2-elimination is necessary. Therefor costs of about 1.35 €ct/kWh arise. [44]

For maintenance a yearly amount of about 6% of the one-time investment costs can be assessed. [2]

For biogas plants operated in Germany costs for maintenance can be estimated to be at 2.5 €cent/kWh (including a reserve for replacement investment, e.g. CHP general overhaul after 6 years). [35] Lab analyses are necessary for supervision of the biogas process. Therefore six analyses per digester and year are proposed as a guideline. [9] In Germany the expenses for one analyse are approximately 150 €.

2.3.4 Personal costs

One significant cost item of the operating costs is the personal costs. Especially the treatment of biowaste requires more working time and has to be taken into account.
Figure 43 shows the dependency of the required working time on the power of the installed CHP unit. Here also the required time for troubleshooting is considered. The higher the nominal capacity the higher the total required working time for supervision of a biogas plant, but the more automated the biogas plant is, the less personal is needed. However the specific required working time decreases the higher the installed power of the CHP unit.

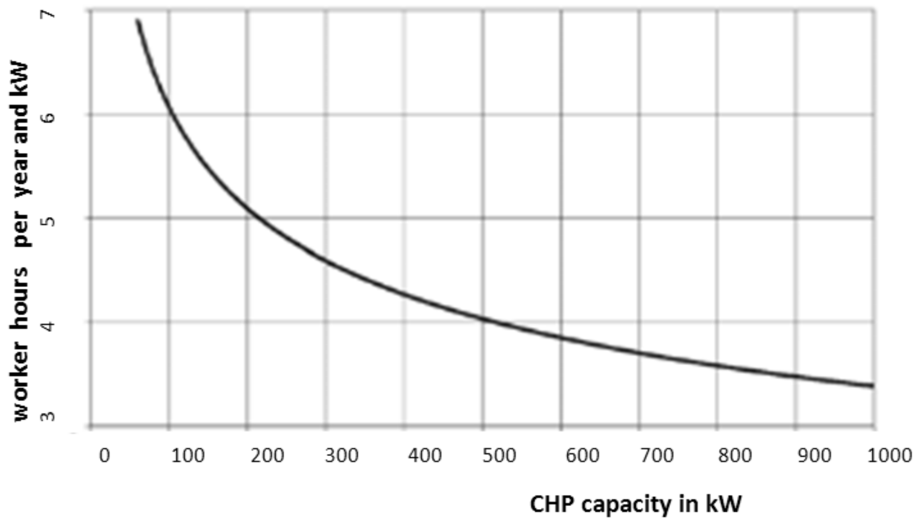


Figure 43: specific required working time for plant supervision and maintenance [13]

Considering the required working time it is obviously that it is very important to notice that for a small scale/farm scale plant there is already one person required (though it is just few hours per day) caring for the biogas plant. In case of a biogas plant with 500 kW CHP unit a worker needs about 2000 hours per year for maintenance.
Also here it has to be taken into account that the use of biowaste causes a higher amount of working hours for maintenance.

2.3.5 Revenues

Generated revenues of a biogas plant can be:

- Sale of electricity
- Sale of heat
- Sale of gas
- Sale of digestate

Usually there is no risk for the sale of electricity. The payment of the electricity depends on different factors especially the regulations of the government concerning the feed-in tariffs. The sale of heat constitutes among others the problem that the heat consumers have different seasonal demands.
Therefore the sale of the produced gas by upgrading and feeding it into the grid presents a suitable possibility. However the upgrading of the biogas is only suitable for bigger sized biogas plants, because of the high investment costs. Moreover a suitable gas grid has to exist.

2.4 Economic and Financial Analysis in reference to existing German biogas plants

With examples of some German biogas plants (data from operators or internet data sources) the data which are of great importance shall be illustrated in the following chapter.
A collocation of the considered plant sizes and examples of applications are illustrated in Figure 44. Pilot B is represented by the performed scenarios, whereas farm scale and large scale plants are represented by means of internet sources as well as personal information of plant operators.

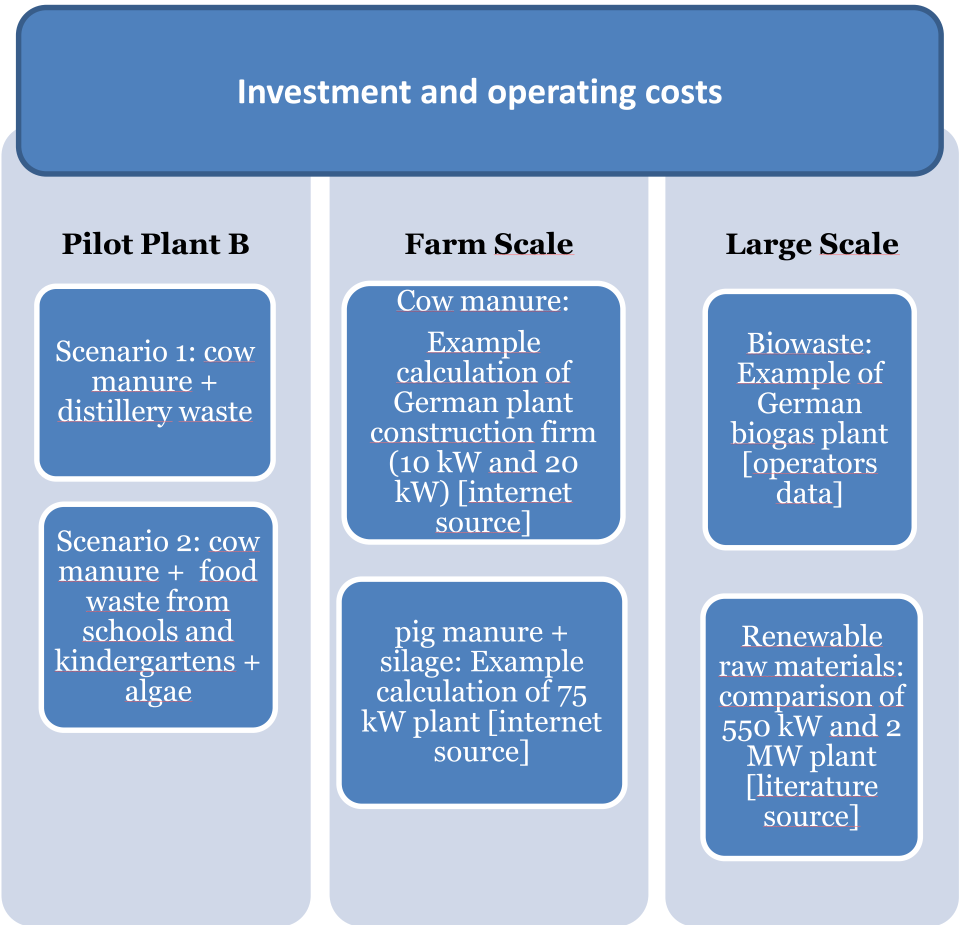


Figure 44: Illustration of considered biogas plants

2.4.1 Investment costs and operating costs in reference to existing German biogas plants

Pilot B

Target goal is to perform full practical process simulation from advanced laboratory scale to pilot scale under consideration of regional implementation and knowledge generation.

Table 19: Investment costs of Pilot B

	description	costs
Dry digestion pilot plant	Dry digestion pilot plant including loading and transportation costs	183,855.00 €
Extra Equipment	Tools	1,515.15 €
Laboratory Equipment	Measurement devices, safety clothings, chemicals, etc.	2,760.49 €
Gas utilization	Storage devices, pumps, pipes, etc.	1,500.00 €

Anyhow it is important to notice, that pilot B biogas plant is designed to be an experimental training plant and not considered for commercial production of biogas in small scale. The outcomes of the operation of the pilot plant B in each partner region shall become the basis for a manual for regional decision taking of implementation of full scale dry digestion applications.

At first location the pilot plant had been installed in Lithuania in the region of Šilutė and was been in operation there till beginning of October 2013 with waste streams from local suppliers. Because Pilot B is a biogas plant for training people in biogas technology it is not constructed for profitable biogas production. Therefore it is not possible to calculate an economic analysis.

The operating costs for Pilot B are listed in Table 20. Here the required working hours, the energy consumption (electricity) and the consumption for laboratory work were gathered. The produced amount of biogas and the theoretical by the use of biogas replaceable energy demand was not determined because of above mentioned reasons.

Table 20: operating costs Pilot Plant B

	amount	**expenses in €/month**
Electricity consumption	400 KWh/month	58
Water consumption	75 l/month	0.05
Consumable lab materials		20.96
Required working time	1 h/day	ca. 80.00
Substrates: **Cow manure** **distillery waste** **algae**	 7.1kg/week	 - 0.25 -
Total produced biogas amount	38 Nm^3	
total		ca. 160

As mentioned before the operation of Pilot B in Lithuania is non-profitable but for testing and representing the biogas technology with different substrates which are available in the region of Šilutė. Because it was a very short period of operation (including the start-up phase) and different substrates were tested during the period it is not possible to calculate any productivity rates of Pilot B. Therefore batch fermentation tests were run at the same time at Ostfalia University of Applied Sciences in Wolfenbüttel. The results of these batch tests, the theoretical gas yields, are used for the calculations concerning the substrates.
The produced gas amounts can be found in chapter 1.3.2 .

Farm Scale

Talking about farm scale biogas plants a size of up to 25 kW is being considered. Especially for single farms and also communal biogas plants of some farmers this size would be appropriate.

In Germany there are some manufacturers of small farm scale biogas plants. As an example there is a producer of biogas plants which are installed in container and predominantly operated with manure. Two possible plant systems are presented in Table 21 [22].

In any case it has to be kept in mind that these cost factors concerning the investment and also the operating of biogas plants can differ considerably between the relevant countries (here: German and Lithuania).

Table 21: system data, small scale biogas plant for manure (German plant construction firm)[22]

Plant system	**10 kW with 1 fermenter**	**20 kW with 2 fermenter**
Fermenter volume	50 m^3	100 m^3
Gas storage	ca. 70 m^3	ca. 70 m^3
CHP-unit power	10kWel, 25 kWth	20kWel, 50kWth
Substrate	2-5 m^3 per day	4-10 m^3 per day
Retention time	10-20 days	10-20 days
Investment costs	ca. 150,000 €	ca. 200,000 €
Required working time	Maintenance CHP, ca. 2 hours for process monitoring	
Usable heat	250 kWh_{th}/day	500 kWh_{th}/day

The plant system presented in Table 21 is a container- based small biogas plant for liquid and thus pumpable agricultural substrates with up to 10 % dry substance (e.g. cattle and pig manure). Based on a daily amount of about 0.05m^3 manure produced by one cow, between 40 and 100 cows would be a necessary and sufficient feeding amount for a small 10kW-biogas plant.
Assuming that cow manure is costless available, there are transport costs and also working hours responsible for the accruing costs (regarding substrates, same for other costless available substrates).

For operators of small/farm biogas plants it is probably most economical to use the produced biogas as well as the heat for own requirements. The conditioning of the biogas is to expensive and mostly there is no gas grid for feeding in available. Also the prices for electricity in Lithuania are relatively advantageously priced whereas the prices for natural gas are relatively pricy. Therefore the electricity generation by a small CHP unit and own use as well as the use of the produced heat provides the best solution for use of the biogas.

The residues of the biogas process are suitable as fertilizer use for soil enrichment. The possible savings by using digestate as alternative to mineral fertilizer depend on the composition of the digestate (and kind of used substrate). In this respect more analytics will be done later. A detailed consideration concerning the use of digestate will be done as part of the scenario regarding the possible implementation of a biogas plant in Švėkšna (see chapter 3.3.3).

A twinning between several farmers with only few cows would be an asset. A joint use of the digestate storage and use of the digestate and also use and sale of the heat would be practicable and an advantage. Gas conditioning is really expensive and therefore probably not adapted for small/farm scale plants. An owner-occupation of the biogas would be ruled out.

For both kinds of biogas plants less working time is required. About two hours per day/one person is sufficient for operating a small scale biogas plant.

75 kW- biogas plants

According to the actual legal situation in Germany the building and operating of biogas plants with a capacity of 75kW is of importance. The German Renewable Energy Law (EEG) decrees that these plants get fixed rates for their produced electricity, which is really attractive on the electricity market. Therefore a sample calculation for a 75kW biogas plant in Germany is been shown in Table 22. [23] Here the different cost items of an exemplary 75 kW-biogas plants are listed.

So called mini-biogas plants are sponsored by the EEG §27 b in a special and a comparatively easy way. Operators of biogas plants of this size receive a feed-in tariff of 0.25 €/kWh charged as a lump sum. [2] Therefore it is really attractive to build and operate biogas plants of this size in Germany at the moment.

Table 22: Example biogas plant: 75 kW manure (85%) and renewable raw materials (German literature source) [23]

Investment costs	5,000 €/kW plus 63,000 € digestate store, 114,000 € silo	552,001€
Substrate demand	Pigs: 350 Heavy livestock units, 394 t gras-silage, 750 t corn silage	7,532 t/a
Operating costs	Maintenance, incl. labour costs	22,463 €/a
Costs for substrate and electricity demand	1€/t pig manure, 35 €/t silage, 8% electricity	66,291€/a
Other costs	laboratory, management	8,760 €/a
Profit on a sale of electricity	0.25 €/kWh_{el}	10,000€/a
Profit on a sale of heat	200,000 kWh_{th} (0.05€/kWh)	10,000 €/a

Yearly utilization ratio of CHP: 34.5%
Assuming that cow manure is costless available, there are transport costs and also working hours responsible for the accruing costs(regarding substrates, same for other costless available substrates).The transport costs for cow manure cause with over 80 mass percent an important effect on the economy. [23]

Large Scale

As mentioned in chapter 0 biogas plants with capacity of about 500 kW are considered as large scale biogas plants. Comparable German specific costs for the investmentof biogas plants of this size are available but they are besides others depending on the kind of substrates which is used for the running of the plant and therefore the configuration and plant system.

Especially when using biowaste as input material a sophisticated pre-treatment is necessary which causes higher costs for the investment as well as for operating (see Figure 41). Table 23 includes the different cost items concerning the implementation of a biogas plant. A detailed costing is only possible with concrete demands for the planning of a biogas plant and therefore a specific plant design (technical and financial).

Table 23: Cost items of a biogas plant

Investment costs		
Phases of the planning and construction of a biogas plant		Engineering
		Administrative permission
Construction phase	Construction work, personnel costs	
	Functional units	Substrate storing and pre-treatment
		Substrate delivery
		Main digester
		Secondary digester
		Gas storage
		Biogas treatment
		Flare
		CHP unit
		Pumps and stirring technology
		Piping
		Office building
		Control unit
		Grid connection
		Land costs (road, fence and other
		Digestate storage and conditioning
Start-up phase		External expertize
		Machines and vehicles

Operational expenses		
Variable		
Maintenance and repair		Share of acquisition value in % (per year)
	Substrate storing and pre-treatment	2
	Substrate delivery	5
	Main digester	1
	Secondary digester	1
	Gas storage	1
	Biogas treatment	1
	CHP unit	0,013€/kWel
	Pumps and stirring technology	5
	Piping	1
	Office building	1
	Control unit	1
	Grid connection	1
	Land costs (road, fence and other	1
	Digestate storage and conditioning	1
	Substrate costs	
	Analyzing costs	
	Process energy	
	Consumable supply (including ignition oil)	
	Output costs	
	Variable costs of vehicles	
	Variable costs of machinery	
	Fuel for machinery	
Fixed	Staff (wages and travel)	
	Insurance	
	Others (rent, current assets, fees, miscellaneous)	

For an economic assessment expenses for the investment in a biogas plant and the operation of a biogas plant have to be outlined as precisely as possible. Therefore the operative cash flow and the discounted cash flow are important methods of calculation in financial accounting for estimation of profitability.

To perform economic assessments for the investments in biogas plants several data are necessary. Therefore a portfolio was developed which contains all possible cost items (investment, operation and others) related to the investment and the running of biogas plants. Considering different plant sizes and different operating modes these cost items are varying. Aim of this consideration is it to give an impression onthe economics of a biogas plant and the different factors which play a role when deciding about implementing in biogas technology.

Based on data of German biogas plants the matrix with the possible existing cost items was drafted and will be continued. In Table 23 the basic model of the form of the needed data is shown (it has to be further developed till end of the project). Possible stakeholders can find information about data they have to consider when thinking about the implementation of a biogas plant and possible investors can take this information for an assessment of the investment costs.

The table serves as guide to orientation for the implementation of the biogas technology. The cost items are depending not only on the construction type of the biogas plant but also on the size of the plant (especially of the fermenter) and the used input materials. Especially when using biowastes/food wastes for the anaerobic fermentation a hygienisation of the material is necessary. Like the use of biowaste the use of residual waste of households requires a very elaborately and costly pre-treatment. (see also chapter 2.3).

German biowaste biogas plant

An exemplary German large scale biogas plant using biowaste as input material represents the biogas plant in Braunschweig. Braunschweig is a city in Lower Saxony with about 250,000 inhabitants. The biogas plant handles about 20,000 tons of separate collected biowaste per year in two horizontal 800 m^3-fermenters by dry-fermentation. The plant produces 1,500,000 m^3 of biogas with an own energy demand of 1.7 GWh heat and 600 MWh electricity. For the operation of this kind and size of a plant about 1,300 person days are necessary per year (2 engineers, 3 craftsmen, 1 businessman). [32] Economic data were, as it is mostly the case and understandably, not named by the operator of the plant.

Comparison: investment costs of 550 kW and 2 MW-plant

A comparison of the investment costs (divided into functional units) of two German agricultural biogas plants of different sizes are shown in Figure 45. Though the data are of the year 2004 they serve as comparative values for the investment costs of different plant sizes.

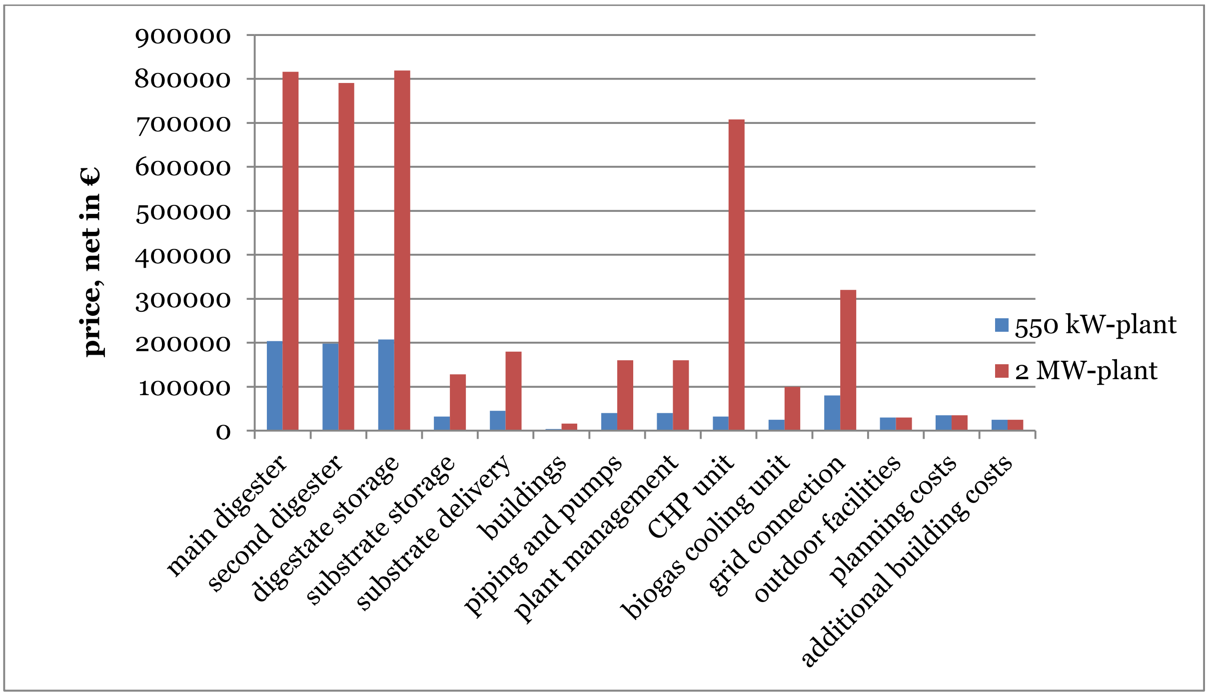


Figure 45: investment expenses of two German agricultural biogas plants (2004) [38]

A comparison of operating expenses of the two mentioned biogas plants are shown in Figure 46.

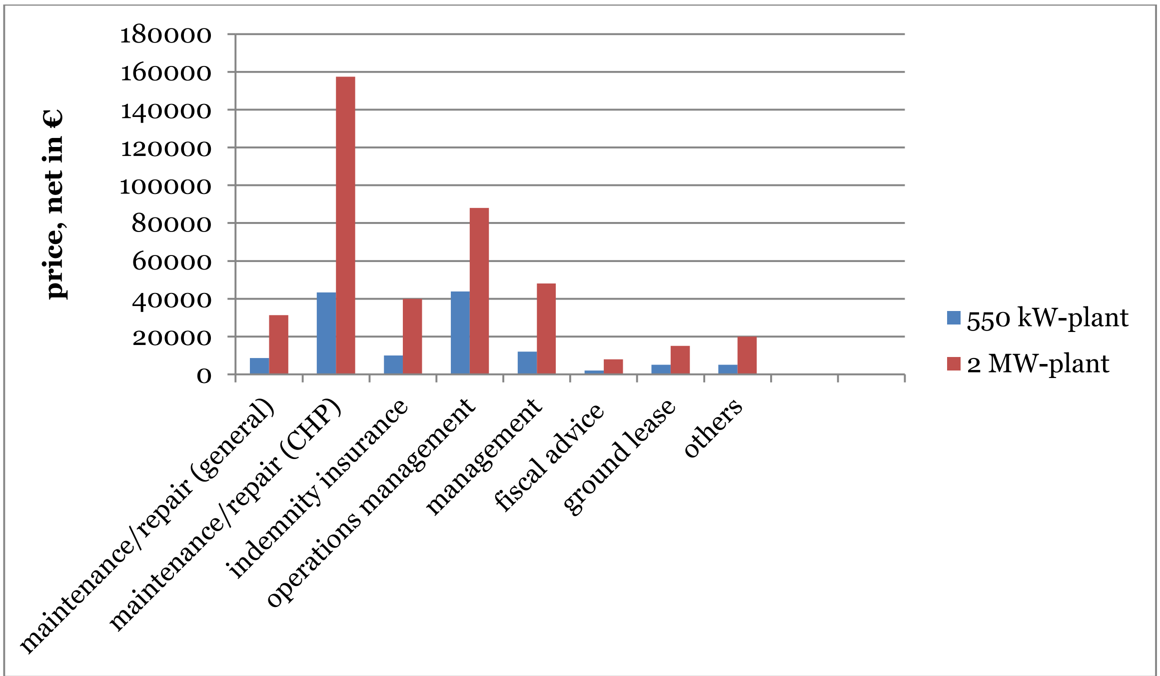


Figure 46: operating expenses of two German agricultural biogas plants (2004) [38]

2.4.2 Proceeds and subsidies

Electricity

Dependent on the substrate used for anaerobic digestion the biogas yields are varying. Some of the methane yields of different substrates are listed in table 3. According to these results table 9 shows some exemplary theoretical calculations concerning revenues out of the sale of electricity produced of biogas (based on Lithuanian feed-in tariffs).

Table 24: theoretical revenue calculations (sale of electricity)

Substrate	methane yield [Nm^3/ton]	Energy production [kWh_{el}/ton]	Revenue (theor. max.) (kWh_{el}) [€/ton]	Heat production [kWh_{th}/ton]
cow manure (Lithuanian)	19	74	11	87
distillery waste (Lithuanian)	41	159	24	188
biowaste	74	288	43	339
food waste (Lithuanian)	85	330	49	390
algae	31	120	18	142

(based on: feed-in tariff 0.148€/kWh for 10-500 kW plants; el. efficiency 39%, th. efficiency 46%, 9.97 kWh/m^3 methane)

Besides sale of electricity and digestate there are also revenues out of the sale of heat possible.

Heat

One of the main products of the biogas process is heat. Because direct heating grid would be necessary in most cases the own use of the produced heat will be economically reasonable (in farm scale as well as large scale, e.g. in industry-operated biogas plants as energy replacement).

Digestate

Residues of the biogas process are principally suitable for use as fertilizer and soil conditioner. Disposal of digestate as fertilizer is conceivable. The composition depends among others essentially on the used substrates. Further proceeds are possible by using biowaste or organic parts of municipal household waste, because the gate fees for waste disposal are available for the operating of the biogas plant.

Funding

Thinking about funding possibilities there are some institutions which could be addressed. Mentioned are e.g. the Energy Saving Fund (under control of Lithuanian Energy Agency), the Agriculture Support Fund, the Environmental Funds and municipalities. [31]
A detailed financing of biogas plants is very individual and there are several possibilities for the way of funding. A detailed assembling of plant-specific data and requirements therefore is a basis for the decision-making process.

2.5 Economic and financial implementation in reference to Lithuanian models and conditions

In chapter 2.3 general data were collected concerning the investment and operational costs of biogas plants. Chapter 0was especially related to German biogas plants and contains data of plant operators as well as plant construction firms (internet information sources or personal information of firms).

Based on the results of the Pilot B operation and lab test at Ostfalia University model biogas plants were calculated in chapter 2.5 . Basing on these results a rough economic estimation is been made in the following (see Table 25).

For the economic and financial implementation the different cost items are varying according to the country in which the biogas plant shall be build

The calculation is based on some specific data which vary according to the relevant countries. Therefore some general consideration before:

- Investment costs: it has to be considered which parts of the plant are most cost-effective manufacturable in Lithuania
- Operational costs: these are the most specific costs depending on the relevant countries and percentile on the investment costs; especially the personal costs are varying strongly
- Revenues: the prices for the sale of electricity and heat are country-specific, also the sale of digestate

Wage level in Lithuania

- Minimum monthly salary: 1000 Lt (290.92 €)
- Minimum hourly wage: 6.06 Lt (1.76 €)
- Average monthly salary: 2232 Lt (646.43 €) [39]

For the investment costs an estimation of the economy concerning the point of acquisition and construction was been made in Table 25. Anyhow the building of these plant components which have to be built on site (e.g. these which consist of concrete) will probably be more economic in the regarding country (here Lithuania).

Table 25: Estimation of the economy for building of plant components

plant component	Acquisition and construction in Lithuania estimated economically	
	Probably yes	Depending on quality/availability
Substrate storing and pre-treatment	x	
Substrate delivery	x	
Main digester	x	
Secondary digester	x	
Gas storage	x	
Biogas treatment		x
Flare		x
CHP unit		x
Pumps and stirring technology		x
Office building	x	
Control unit		x
Digestate storage and conditioning		x

Figure 47 illustrates which calculations (concerning financial aspects) were done in relation to the different scenarios and plant sizes in comparison to an existing Lithuanian biogas plant.

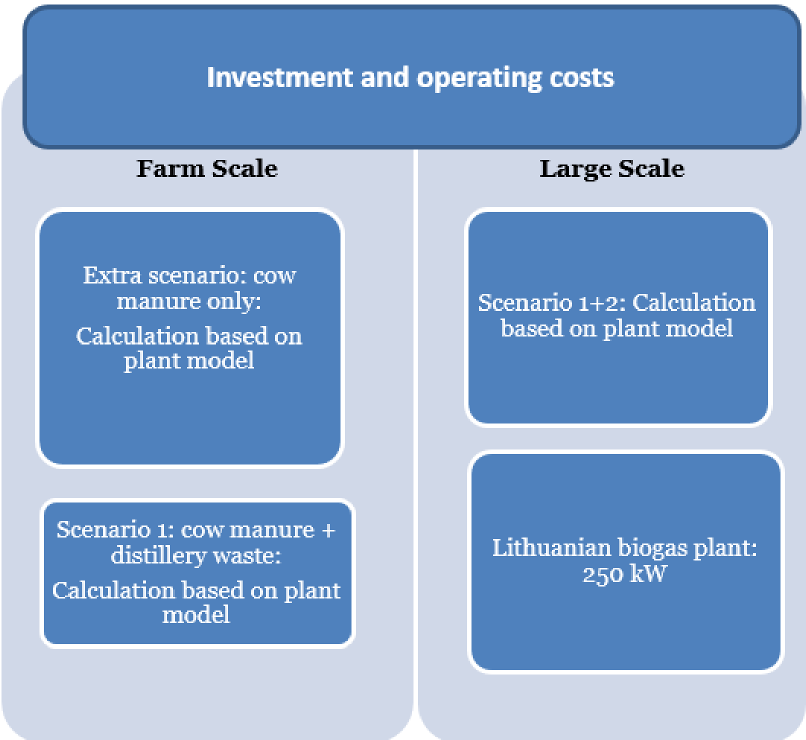


Figure 47: illustration of calculated scenarios calculations based on results in chapter 1.1.1

Table 26 shows a comparison of theoretical calculated biogas plants with the different scenarios to a 250 kW-biogas plant which was built on the UAB Dotnuva Experimental Farm in Lithuania (Biogas Feasibility Study/EU Baltic Sea Region Programme). Cattle manure and maize silage of the farm are used as input material for the biogas plant. The listed prices are based on Lithuanian and EU market prices. [40]

Table 26: Estimation of investment and operating costs

	10 kW: Scenario 1: (cow manure + distillery waste)	**10 kW: manure only**
Investment costs (total)[1]	ca. 150,000 €	ca. 150,000 €
Required working time	2-3 hours/day	2-3 hours/day
Personnel costs[2]	~250 €/month	~250 €/month
theor. revenues (electricity; without deduction of own requirements)[2]	12,964 €/year (0.148€/kWh)	12,964 €/year (0.148€/kWh)
Substrate costs[2]	Manure: - Distillery waste: 8.66 €/ton: 3,334 €/year	Manure: -
Maintainenance and repair (CHP) [1]	1,139 €/year	1,139 €/year
Maintenance (total, up to 6%)	9,000 €/year	9,000 €/year

	500 kW: Scenario 1: (cow manure + distillery waste)	500 kW: Scenario 2: (cow manure + food waste + algae)	250 kW (Experimental Farm) [40]
Investment costs (total)[1]	2,250,000 €	2,700,000 €[3]	1,724,637 € (6,900 €/kW_{el})
Required working time	2000 hours/year	2000 hours/year	2 employees
Personnel costs[2]	~1,000 €/month[4]	~1,000 €/month[4]	11,594 €/year[5]
theor. revenues (electricity; without deduction of own requirements)[2]	648,240 €/year (0.148€/kWh)	648,240 €/year (0.148€/kWh)	156,521 €/year (0.2/0.3LT/kWh) Heat: 86,956 €/year)
Operating costs (total)	150,672 €/year[6]	150,672 €/year[6]	159,420 €/year
Substrate costs[2]	Manure: - Distillery waste: 138,560 €/year	Manure: - Food waste: not specified Algae: -	Silage production: 86,956 €/year
Maintainenance and repair (CHP) [1]	56,940 €/year	56,940 €/year	
Maintenance (total, up to 6%)	135,000 €/year (6%)	135,000 €/year (6%)	2.5%; 43,478 €/year

[1] based on German data base
[2]Lit.: Lithuanian specific data
[3]Assumption: 20% higher investment costs because of necessary pre-treatment
[4]based on assumption: average monthly salary 646.43 € + social security contributions
[5]based on SODRA, but no more indications concerning working hours and hourly rate
[6]based on figure 4

Table 10 is partly based on the following specific data:

- Investment costs for 500 kW-biogas plants: 4,500 €/kWel
- 1 €=~3.4528 Lt
- 6% of investments – for maintenance

Cumulative discounted cash flow

The discounted cash flow constitutes a calculation method to estimate the attractiveness of an investment opportunity. The discounted cash flow method is often used in investment finance calculating the future cash flows present values. The purpose of a DCF analysis is to estimate the benefit which will arise from an investment and to adjust for the time value of money. [41]

Figure 48 shows exemplary two possible resulting discounted cash flows of different financing models for biogas plants. Financing model 1 shall constitute a scenario with sale of electricity on a free market whereas financing model 2 a scenario with funding of electricity prices describes.

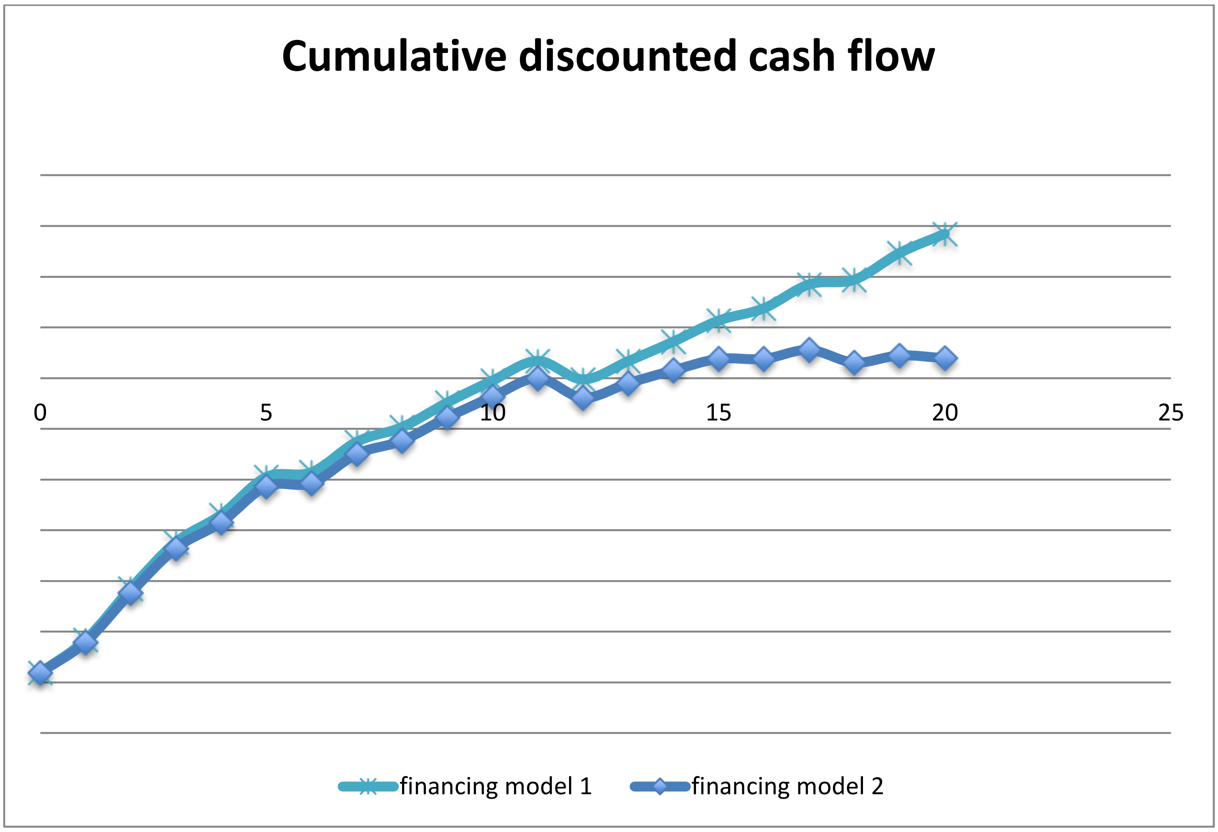


Figure 48: cumulative discounted cash flow of two financing models

2.5.1 Summary and outlook

The chapter: ”Financial implementation report” gives an impression on the various aspects thinking about implementation of biogas technology.

Therefore extensive enquiries were made about cost factors in a general way as well as in reference to existing biogas plants (especially using the examples of German biogas plants). Because it is really difficult to get economic data from biogas plant operators these cost factors are mostly described in terms of specific costs or exemplary calculations on the basis of plant construction firms.

Basically prices for investment and operating are varying between the regarding countries. Concerning investment it has to be proved which plant components are economically reasonable to be manufactured in the country where the biogas plant will be built and which plant component is better to import.

Concerning operating costs there are many variations possible. Especially the personnel costs are one of the most differing cost factors.

Substrates which can be an important cost factor are of important interest. Because wastes are considered to be used as input materials, the costs which arise are absolutely different to the costs which arise using renewable raw materials (possibly there is even an income).

A detailed calculation and estimation of cash flows is only possible by defining concrete system models. On the basis of these data (based on commercial offers) a detailed calculation of cash flows and with that the investigation of the economy of a planned biogas plant is possible. With data which will be collected in the following of the project and in the partner regions a general outlook and estimation for the financial implementation on a common basis shall be developed furthermore.

A concrete case arose from the first milestone of the project ABOWE which is the Scenario for the village Švėkšna which will possibly substantiated in the following of the project.

3. Strategy of communication

The pilot B plant was first situated in Lithuania and there the national and regional stakeholders successfully participated in the discussion process. To ensure their engagement a strategy of communication had been implemented, that includes elements of

- Marketing strategies
- Change processes
- Education strategies

This part of the output report considers these elements more deeply and gives guidelines for a successful communication in the field of technology transfer.

3.1 Stakeholders

Marketing defines, that the media and the ways, which are used to inform and persuade possible buyers has to be chosen under consideration of the target group, which is in this case the group of stakeholders.
Responsible for the selection and naming of the stakeholders is the regional partner, which has the best insight into which person, which organisation and which association has absolutely to be involved. In the Lithuanian case this was the duty of Olga Anne who defined following organisations and invited the people personally.
Identified stakeholders for Western Lithuania:

- Ministry of Environment
- Ministry of Energy
- Regional EPA
- Klaipeda Municipality
- Ministry of Economy
- City Environment department
- Environmental protection Agency
- strategic development committee
- Institute of Agrarian Economics
- District Heating Association
- Regional Waste management centres
- Farmers
- Banks
- Companies
- Researchers in from three scientific institutions
- Designer and Engineers
- Operator and staff from Wastewater treatment plant
- Klaipeda Public Health Centre
- Klaipeda Health Care Laboratory

3.1.1 Stakeholder Identification

The Identification of the stakeholders in Lithuania was mainly done by communication between the project partners in Lithuania and Germany. Leading questions have been:

- Who is affected by the results of the project?
- The area of responsibility of which institution is affected?
- Which people with influence are interested in the technology?
- Which inspection authorities have to be involved in the decision process?
- Which institutions are able and willing to invest money into new technologies?
- Which people of the personal network of the local project partner could be involved?
- Who could be an obstacle?
- Who has a problem that could be solved by the technology of anaerobic digestion?

The better the identified stakeholders are affected by the topic, the better the personal relationship to the inviting local partner the more likely is, that the invited people will attend and actively participate.

3.2 Local partners

The local partner in Lithuania have been the Klaipėda University, represented by the lead partner Olga Anne and the engineer Vygintas Daukšys.
From the communicative point of view the local partner are designing the way of communication in the country, they bring their personal and professional network as the source of all activities regarding presenting and representing the project. In Lithuania the differentiation between the both main actors was, that Olga Anne was more responsible on the institutional strategically level whereas Vygintas Daukšys was active on a local and operative level.

3.2.1 Olga Anne

The WP4 leaders have acknowledged, that Prof. Dr. Olga Anne has built a strong social network, since long time before the project started. As a respected personality she was capable to open doors and to inspire stakeholders. Convinced, that the project is a huge chance for Western Lithuania to come forward in the field of waste treatment she used the weight of her reputation for discussion and for convincing others.

3.2.2 Vygintas Daukšys

As an engineer Vygintas Daukšys was as the responsible operator of the biogas plant. He gave detailed feedback and reports regarding the operation of the plant (see chapter 1.4). Within the period of the project in Lithuania he acquired knowledge that qualified him to act as a trainer. He organized the site, where the plant stayed, brought his personal network for the support of operation and used his social network on the local level, to discuss with farmers and with responsible persons at Švėkšna.

3.3 Media

In case of Lithuania following media has been used:

3.3.1 Internet

The newsletter and all reports are published on the ABOWE web site.

3.3.2 Newsletter

Using the template of the ABOWE project a national newsletter edition has been established. The newsletter´s impact on the external stakeholder has not been measured but it can be considered as one successful part of the stakeholder management in Lithuania. The strong impact for the internal stakeholder can be shown, due to the direct experience of the reporting team.
The used newsletter is a mixture of old style and new media. It is available as hardcopy and can be sent by mail. It is published on the project´s web site, it is being sent via email and it could be posted on social media.
Three newsletter were published during the period the pilot B have been in Lithuania, at least one more is going to be published afterwards. All newsletter are available in English and in Lithuanian. The content of the newsletters is focused on the results of the WP 4 activities.

Impact

The internal impact of the newsletter was perceivable especially in the days before the final editing. To fix the content and to write short articles it is obligatory that the agreements between the partners are clear and that everybody knows what to do. Intensive discussions accompanied the editing process of each newsletter that created security and clarity for the partners.

First Newsletter

Immediately (within 10 days) after stakeholder meeting the first Newsletter was sent to the participants and all the other stakeholders who got an invitation for that event.

Content of the first Newsletter was:
ABOWE in Lithuania
A short introduction into the ABOWE project and the aims of the stay of pilot B in Lithuania.
Portrait of the operator
Introduction of Vygintas Daukšys as the responsible operator of the pilot B in Lithuania.
Start-up stakeholder meeting
Summary of the first stakeholder meeting, regarding programme, participants, discussions and results.
Next steps
First ideas regarding the planned scenarios with regard to the results of the stakeholder meeting.

Second Newsletter

The second Newsletter was published shortly (within ten days) after the stakeholder visit.
Content of the second newsletter were:
Second period of operation
Presentation of first operation experiences and results of methane yield and feeding amounts.
Dry digestion
Short description of the dry digestion technology.
Considered scenarios
First results regarding the considered and calculated scenarios for Šilutė.
Purpose of pilot B
Introduction of pilot B as a place of learning.

Third Newsletter

Two weeks before the stakeholder event the third newsletter was sent.

Content of the second newsletter were:
Trip to pilot B
Summary of the second stakeholder event which was a visit of the pilot B.
Stakeholder´s feedback
Evaluation of a questionnaire that was given to the participants of the visit.
Scenarios in progress
Description of the first results and adaptations of the scenarios.
Stakeholder event
Announcement of the stakeholder event.

3.3.3 Events

Three events were organized during the stay of pilot B in Lithuania with the aims:

- To inform
- To activate
- To come into contact
- To learn

Stakeholder meeting

In the start phase of pilot B the stakeholders were invited to a first meeting in 19th of June. Focus of that meeting was to activate the stakeholders and to initiate networking among them and with the project partners. Results of that meeting were documented and used for the further investigations in Lithuania.
All possible stakeholders were invited by Olga Anne to a representative venue at the University. The meeting languages were Lithuanian and English, whereas all was translated into Lithuanian and the Lithuanian contribution partly were translated for the foreign guests. Especially the phase of discussion was done in Lithuanian, to minimize the obstacle of a foreign language.
About 15 Lithuanian stakeholders and 15 international guests participated at the meeting.

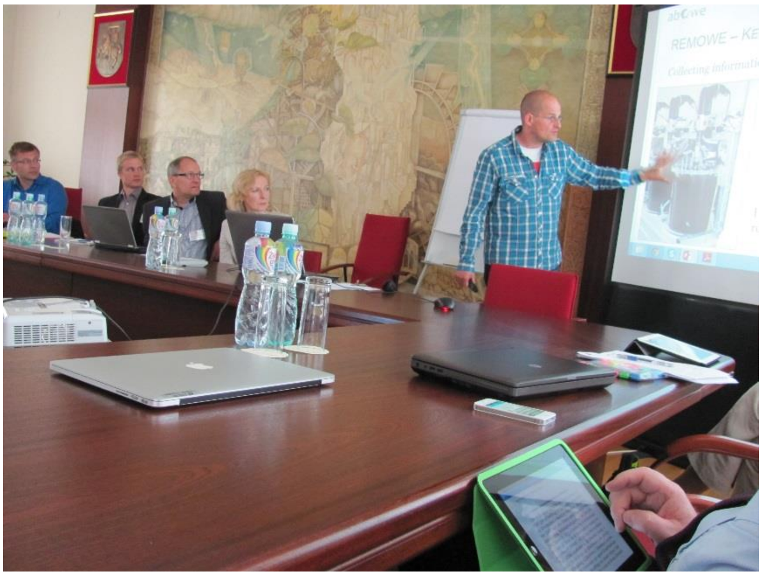


Figure 49: Impression from the first stakeholder meeting

Figure 50: Impression from the first stakeholder meeting

Programme

Date: 19th of June 2013
Time: 13.30 h – 17:00 h
Presentations

- Welcome
- ABOWE in General
- Pilot B
- Calculation of scenarios

World Café

- Discussion of the Lithuanian experts and stakeholders at four circles, at each circle one host, for facilitation and for conclusion of the thread and common themes at the circle. The discussion was in Lithuanian, conclusion was done in Lithuanian and in English.

Comments from experts
The conclusions were appreciatively commented by the experts, to give a feedback and to initiate a discussion.
Discussion

- Discussion, questions and contributions from the Lithuanian stakeholders to the international guests and project partners. Interchange of ideas.

Methodology

To create a common stage of information an informative part was before the world café. It also should show the competencies of the project team, the purpose of the project and the time frame.

Figure 51: A table at the world café

The world café is a method that creates a communicative atmosphere where the dialogue between the participants is in focus. In best case the attendees become owners of their ideas and are highly motivated to accompany the implementation in the further process. The participants discuss in small groups specific questions. For the stakeholder meeting the way was chosen, that the groups are stable and at each table there stays the host with the question and the group travels to another circle with another host and another question.

The questions were:

1. Current situation at waste and energy area, what are the needs and challenges, what pilot technology could change?
2. Who are the potential implementers / investors? What kind of different scales and business models could be feasible?
3. What are the strategies for full scale investments and operation?

After the circle discussions the thread were concluded by the hosts and these conclusions were commented by the experts from the project team, leading into a discussion between stakeholders and the project team.

Results

Main aspects are, that the process of communication could be initiated, between the 15 participants and the project partners. Several lively discussions between the Lithuanian experts and with the international project partners showed a broad interest of the national experts in the technology. The international consortium could present their way how they have started the project and describe the forth going process.
One result was, to consider food waste from schools and kindergarten as an additional co-substrate. This idea came from the municipality and was directly defined as a part of one scenario (see chapter 1.1.1).
The results were communicated to all stakeholders within ten days after the meeting by sending a newsletter (see chapter 3.3.2).

Stakeholder visit

In the middle of the presence phase of pilot B in Lithuania (24th of July) the stakeholder were invited to visit it personally. For that a bus transfer was organised and short presentation on site with following discussions took place.

Presenters were: Olga Anne, Vygintas Daukšys (University Klaipeda) and Tim Freidank (Ostfalia University)

Two weeks before the meeting all possible stakeholders had been invited and about 35 visitors came to the plant. Among them about ten people who already participated at the stakeholder´s meeting. The participants mainly represented local authorities, research institutes and ministries.

Part of the meeting was a questionnaire (see appendix), the main results showed, that the visitors are curious to see whether the new technology will be established in Lithuania and that they see the main obstacles in the capability to find suitable finance sources. The results were summarized in the newsletter (see chapter 3.3.2)

The local partner highlighted, that one important and critical multiplier gave a positive feedback, which is one indicator for the successful event.

Stakeholder event

The stakeholder event had originally been planned as the main act of the presence phase of pilot B. Participants from ministry, local authorities and Universities showed their interest and confirmed their participation, as speaker as well as part of the auditorium.

The programme included:

- Relevant aspects regarding operation of a full scale plant
- Results from pilot B testing
- Presentation of WP2 results

Disappointingly only five stakeholders attended at the event at 4th of October, mainly representatives of the Švėkšna town in the Šilutė district. This small number enabled a lively and very concrete discussion. The results led to further plans in Lithuania and shaped the next steps regarding the implementation of an anaerobic digestion plant there. Nevertheless, reasons for that apparently dramatic decrease of interest have to be mentioned.

About ten days before the stakeholder event, the main regional multipliers had been invited by the WP2 leader to participate at a workshop to prepare the investor´s memo. This document was going to be the main instrument for fostering the technology and for to convince possible investors to have a deeper insight into that interesting investment (see WP2-Report).

About 15 participants came to the workshop, some of them also wanted to come to the stakeholder´s event, but they didn't.

Reasons could have been:

- Too much dates in a short time slot.
- The workshop didn´t meet the expectations of the multipliers.
- They had known the content of the investment memo before the event and had no interest in listening to it twice.

For following projects stakeholder event must be seen as a crucial point of the activities. A close consultation between WP2 and WP4 is absolutely necessary to avoid an overloading of meetings in the final phase of the project.

3.4 Curriculum

The curriculum in this report shall give an idea of what kind of content was trained in the different phases and what skills and competencies should be acquired as well as a short critical evaluation of these first trainings.

3.4.1 Training Phase in Germany

The first training was realized at the laboratories of the Ostfalia Universities
Duration: 11th of March until 15th of March 2013
Participants:

- Olga Anna (Lithuania), Vygintas Daukšys (Lithuania), these both participants spent about four weeks in Germany in a whole
- Eva Skytt (Sweden), Eva Nordlander (Sweden), Maarit Janhunen (Finland)

Content

Get to know the starting and operating of the batch of anaerobic digestion, including the different phases of the AD process and the parameters to be analysed.
To learn how to do continuous tests for evaluation of different substrates for biogas production, determination of different parameters for process and substrate evaluation (DM, oDM, NH_4-N, VOA/TOA, pH, CH_4-, CO_2-, H_2S-concentrations, concentrations of organic acids)

Excursions to a full-scale dry digestion plant in Peine and to Pilot B.

Objectives

The objectives of that training were, to acquire following skills and competencies:

- to take trials and to do the necessary test
- to interpret the analysed parameters in the way to recognize that the process is stable
- to run the pilot B and to react on troubles

Evaluation

Feedback from the participants showed, that the objectives regarding the doing of the continuous test was fulfilled.
The interpretation of the analysed data, could not be done by the trainees independently after the training phase.
The necessary skills for the operation of pilot B could not be trained on the basis of the theoretical approach in the laboratory this had to be trained on the job in Lithuania.

3.4.2 Operation as Training

The operation of the plant in Lithuania can be considered as a part of the education of the involved local players like the operator and the direct environment.

Operator

Vygintas Daukšys was responsible for the operation, supported and trained by Tim Freidank who visited him four times during operation phase in Lithuania.

Content

The idea of this part of the training was, that the operator acquires the skills:

- to start the process of anaerobic digestion
- to run pilot B and
- to get an idea of how to run a full scale plant.

Objectives

The skills that should be acquired during the period of operation for him was:

- trouble shooting at the plant
- analysis
- to get a deep knowledge regarding function of the plant

Evaluation

Main operator of pilot B in Western Lithuania was Vygintas Daukšys, who was confronted with diverse obstacles and developments which had not been foreseen (see chapter 1.3). These obstacles led to an intense communication with the German experts.

Vygintas presented the operation of the pilot B during the visit of the national stakeholders. After the six months of operation he was the expert for the plant who was the responsible trainer of the future Estonian operator (v. 0).

Direct environment

The direct environment in Lithuania was the family of the farm, where pilot B was installed. This "target group" was not foreseen in the original curriculum. The start phase and the problem in this phase showed that the people who lived on the farm were highly concerned regarding the danger that is represented by the plant. There was explosive biogas, there were alarms and a kind of helpless, how to handle this situation. The direct environment had to learn to trust in the technology and the skills of its operator, by the way of communication, discussion and trustworthy improvement at the plant.

3.4.3 Training at Pilot B in Lithuania

The training was realized at the pilot B in Lithuania
Duration: 23rd to 27th of September 2013
Participants: Priit Freienthal (Estonia).

Content

Get to know the starting and operating of the pilot B, including the different phases of the AD process and the parameters to be analysed.

To get to know continuous tests for evaluation of different substrates for biogas production, determination of different parameters for process and substrate evaluation (DM, oDM, NH4-N, VOA/TOA, pH, CH4-, CO2-, H2S-concentrations, concentrations of organic acids).

Objectives

The objectives of that training were, to acquire following skills and competencies:

- to take trials and to do the necessary test
- to interpret the analysed parameters in the way to recognize that the process is stable
- to run the pilot B and to react on troubles

After the training the trainee should know the experiences of the operation, how to do trouble shooting and how to interact with the direct environment.

Evaluation

First impressions were that the training on the plant is much more effective. Further considerations are possible after the operation phase in Estonia.

3.5 Evaluation

Lessons learnt in the Lithuanian case from different points of view.

3.5.1 Marketing strategy

The stay of pilot B was the first step of an introduction strategy. The known technology of anaerobic digestion shall be shown as a useful and economically interesting possibility to treat different kinds of bio waste. In this niche several experts in Western Lithuania may decide and they are capable to foster or to hinder the implementation of this technology. So the marketing strategy was, to reach these important stakeholders and to convince them, that the anaerobic digestion is a good answer to the question: How shall we treat the organic waste so that the EU Landfill directive can be fulfilled until 2016?

The communication strategy enabled the WP-Team and the project partners from WP2 to come into contact with the important stakeholders and deliver data and information to them that was noted. The discussions showed, that there is an opportunity for anaerobic digestion to be implemented in the region and local aspects could be included into the investment memo.

At the end a broad support from the stakeholder couldn´t be reached so that a strategy for whole Western Lithuania could not be introduced. But the Town of Sveksna showed interest so that on a next step the calculation of an anaerobic digestion plant for that municipality gives the opportunity to show that the technology is feasible, which could lead to the planning and construction of a plant and/or to a further process of discussion of that technology among the experts.

3.5.2 Change process

The anaerobic digestion technology in Lithuania is known as a technology which is used to treat sewage sludge, manure from big pig farms or for the treatment of digestate. The use of that technology for the treatment of manure from small farms and bio waste is new. Obstacles are reservations like “is it economically feasible?” or prejudices like “it stinks and it is dangerous”. These obstacles are in the direct environment as well as in the group of stakeholder.

The stay of pilot B sensitised the neighbours of the site where it stayed that the technology can be handled and that its perils are not uncommon high. They could see, that a trained operator can run the plant in a secure way and that the educts are in a good quality. The experts could see, that the anaerobic digester can treat different kinds of substrates and that the process is stable.

Missing is a “change leader”, that is an organisation, a person, an institution that fosters the technology independently from resistance from outside and within his peer group. There is a well-trained engineer and a research institute that are convinced that anaerobic digestion is a good and suitable technology. They have the possibility to support a coming change leader which could arise from the results of the approach to calculate a digestion plant for Švėkšna.

3.5.3 Education strategy

The results showed clearly, that for the operators the theoretical training in the laboratory has to be accompanied by practical units on the plant. The training of Vygintas Daukšys was so successful, that at the end he could work as a trainer for the future operator. Especially the aspects of trouble shooting and interventions in crisis are an essential part of the training. If the curriculum would include some didactical and methodical aspects the training of the operator could be designs as a ToT (Training of Trainer).

The training of the local environment is very useful in that way, to involve the neighbours actively into the communication process. So their concerns can be addressed to invent solutions. Originally this aspect wasn´t considered in the curriculum, so that the further project might show, if it should become a part of the education strategy.

3.6 Attitude

Additionally to the lessons learnt here a few words regarding the attitude of the WP4-Team in the frame of their actions.

Experiences of members of the WP4 team in international projects showed, that it is not possible to introduce a new technology by force in other organisations or countries or cultures. To avoid that the local partners may get the feeling to get something they don´t need some guidelines are named in this chapter to show the attitude of the team.

3.6.1 technology as an offer

The anaerobic digestion technology is proved in Germany and in several other countries and it is suitable to solve specific problems. It is an offer to the region to get to know it and to decide whether it is a chance that could be taken.

3.6.2 local stakeholders as the experts

The members WP4-Team are the experts for the laboratories in Germany and in the beginning of the operation phase they are the experts for pilot B. The last expertise changes during the operation period so that the local operator becomes the expert.
Regarding the local and national conditions and problems the local and national stakeholders are the experts from the very beginning. The members of the WP4-Team ask them and try to give answers on enquiries. They are not able to judge the decisions of the national experts but to give support in the decision making process.

3.6.3 Pilot B as a place of learning

The pilot B is to be considered as a place of learning, for the operator, the Universities, the neighbours and the stakeholders of the region, where it is placed. Its intention is, to give an onsite impression of the technology and its possibilities.

Its purpose is to produce biogas, not for sale but for training.

abowe
Implementing Advanced Concepts for Biological Utilization of Waste

4. References

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1 Appendix

Implementing Advanced Concepts for Biological Utilization of Waste

Lithuania

Newsletter 01/2013

Implementing Advanced Concepts for Biological Utilization of Waste

In General

The first dry digester has been installed in Lithuania and will be there until the end of September 2013. This time shall be used to convience the lithuanian responsibles and professionals who are capable to initiate change, that this technology is a feasible solution for specific challanges in Lithuania.

To discuss these aspects, 19th of June 2013 stakekholders of Western Lithuania had been invited to participate at a start up meeting , to get brand new information from the implementation team.

More than 15 experts from regional organisations and companies participated in a very active and engaged way.

One result of the discussions and the workshop was, to deliver a monthly newslettter in which the development of the pilot plant and the actual results of project activities are mentioned.

ABOWE in Lithuania

Pilot plant in Operation

Objective of ABOWE is the transfer of knowledge, focusing on specific challenges in terms of biogas utilization in the Baltic Sea Region (BSR). Therefore a pilot plant is operated in three BSR-countries - the first is Lithuania- , with the aims:

- to train potential future biogas plant operators
- to use dry digestion application for biowaste to-energy concepts
- to face the challenges of on-site regional conditions
- and to develop solutions to existing challenges in the addressed region.

The pilot plant is downscale of existing biogas technology, which is 100% correlated to the operation principles of a full scale plant. It is equipped with all required on-site measurement equipment for process assessment.

The pilot plant in Daukšys family farm

The pilot digester´s volume is 600 liter with a maximum daily gas production of 2m³ methane, whereas a full scale plant can produce a volume of 10.000 m³ methane.

The gas is utilized for a kitchen stove (v. next page) or heating system (option for wintertime). Note: Pilot B is a process simulation pilot plant, it has not been designed for autonomous energy production!

Prof. Ahrens (2nd from left) explaining the function of the fermenter

Portrait of the operator

Vygintas Daukšys is the responsible engineer for the operation

Vygintas Daukšys is Master of Maritime Transport Engineering. He works at the air pollution from ships research laboratory of Klaipeda University as a researcher. He has been trained in Germany by the experts from the German Ostfalia University of Applied Sciences.

He made it possible that the plant could be situated on his mother´s farm and he is responsible for the operation of the plant. This includes analysis, feeding and trouble shooting.
The ABOWE team thanks him and his family for their extraordinary engagement.

Baltic Sea Region

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Lithuania

Newsletter 01/2013

Events

24th of July official invitation for all experts to visit the pilot plant

17th of September Investor Event

Contact

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First public presentation

Start up stakeholders meeting in Klaipeda

On invitation of Prof. Olga Anne, the first stakeholder meeting took place. The objective was, to involve at a early stage the responsible experts who are capable to initiate changes in Western Lithuania. More than 15 people participated, they came from local and regional administration, from the regional environment protection agency, students and researcher from the university, farmer and operator of the wastewater treatment plant in Klaipeda.

Prof. Olga Anne (2nd from left) in discussion with stakeholders

After presentations from the international project partners the participants generated ideas and questions regarding the project. The results had been intensive discussed and several ideas for the next steps regarding the pilot plant had been formulated.

The atmosphere was open and the participants showed, that they as experts are seeing attractive possibilities as well as concerns and open questions in the technology of anaerobic digestions.

All people who are interested in getting more information about the pilot plant and the ABOWE project in Lithuania are kindly invited to visit the pilot plant, our web site and to contact Olga Anne or Vygintas Daukšys.

Next steps

Scenarios for the pilot site

As a result of the above described discussions following Scenarios will be examined. Anaerobic digestion of:

- cattle manure
- manure and waste from bioethanol distillery
- manure, waste from distillery and schools and children gardens food waste

To get an on-sight impression of the placed plant everybody is kindly invited to visit the pilot plant, either at 24th of July or at another date. For separate visiting date please contact the responsible operator Vygintas Daukšys.

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Newsletter 02/2013

In General

The first stakeholder meeting, held in June, was characterized by substantial interest in the technology which led to intensive discussions.

A visit of the pilot plant is possible whenever wished, but on 24th of July the Klaipeda University organized a trip to the plant, that included the bus transfer, welcoming and explanations. About 100 Invitations have been sent by Olga Anne to the participants of the first meeting, to the interested public, and responsible persons.

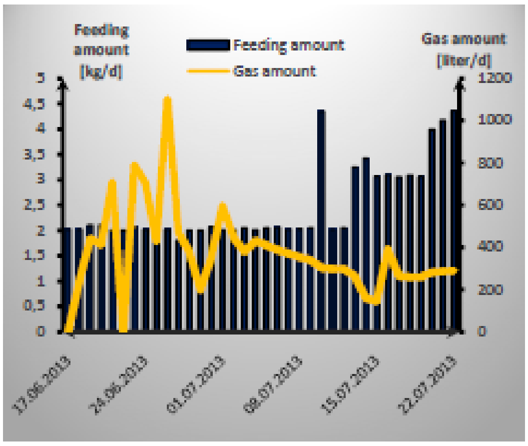
About 35 people participated, which shows the potential, that the experts are seeing in this technology.

Second period of operation

Experiences

Short comment on the status quo from Vygintas Daukšys (the local operator) and Tim Freidank (responsible Engineer from Germany, regularly on site), from the pilot plant:

"Plant is operating very well now, after some problems in the beginning. Technical problems with one of the gas-warning sensors caused emergency shutdowns of the plant and also led to a lightly uncertainty of the family operating the plant. After sensor has been replaced, the plant is working without any problems now. The fermenter is being fed with a mixture of cow manure and distillery leftovers, producing roundabout 400 litres of biogas per day, feeding 2.5 kg of the mixture on an average.



Feeding amounts and gas production

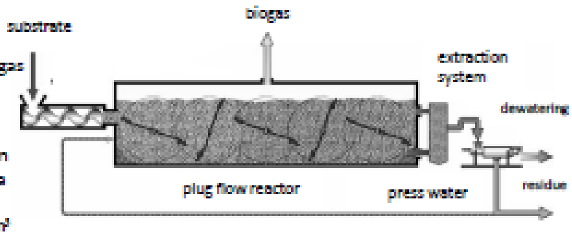
At the moment preparations are made to start feeding food waste from several kindergartens in Klaipeda. Furthermore activated carbon filters are being installed in order to get rid of H2S-traces in the produced biogas."

Both experts explained the function of the pilot plant, the challenges and their experiences during the visit of the interested public on 24th of July and will do so at the stakeholder event on 17th of September.

Dry digestion

A short description

Dry digestion allows biogas production from waste substrates at high efficiency rates. Just to give an example: German experiences show, that a dry digestion fermenter with a volume of 1.500 m³ can produce up to two million normal cubic meters of methane yearly. This equals a combined power-and-heat output of over 1.8 MW each year.



A dry digester produces only little amounts of digestion residues, this is important in case of waste utilization.

Residues can either be used directly as fertilizer or be further processed to compost.

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Lithuania

Newsletter 02/2013

Events

17th of September
Investor Event
- Investment memo
- Experiences
- Further steps

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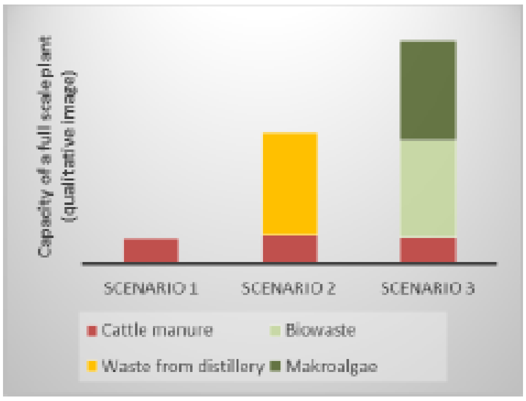
Considered scenarios

The Šilute region is in focus

According to the local conditions in the Šilute region three scenarios are being considered more detailed:

1. Cattle manure without any co-substrate; small full scale plants which could be situated close to the farms, fed by one farmer or a cooperation.
2. Cattle manure and waste from bioethanol distillery, whereas latter, with a share of 75% to 80%, is reference variable for the dimension of a full scale plant.
3. Cattle manure, and kindergarten food waste and makroalgae. The consideration of this scenario is one result of the discussions at the first stakeholder meeting.



The considered scenarios

A full scale plant in the third scenario will have the largest capacity. Theoretically the manure waste could be substituted by the biowaste amounts.

For the evaluation of the scenarios actually following data are in focus:

- Availability of the substrate
- Ways of financing the investment
- Possible revenue and income for a full scale plant
- Technical feasibility on basis of the results from pilot B
- Utilization possibilities for the residues.

Purpose of pilot B

Pilot plant as a place of learning

The pilot B is to be considered as a place of learning, for the operator, the Universities, the neighbours and the stakeholders of the region, where it is placed. Its intention is, to give an onsite impression of the technology and its possibilities.

Its purpose is to produce biogas; not for sale but for cooking 15 kg of wild berries, as the mother of our operator Vygintas Daukšys did in these days.

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Lithuania

Newsletter 03/2013

Events

New date!!

4th of October
Investor Event
- Investment memo
- Experiences
- Further steps

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Scenarios – in progress

The Šilute region is in focus

Based on the results of the pilot operation phase and on local framework conditions Silute scenarios are more specified as following:
1. Nearby two farms with about 200 cattle. It is estimated, that the manure is be fed into the biogas plant to operate a 25 kW CHP
2. Nearby a Distillery; estimation is, that the amount of 60 t/d of thin stillage are fed into the biogas process. The waste heat can be used as process heat in the distilling process.
3. Nearby a Wastewater treatment plant; estimation is, that the amount of 60 t/d of sewage sludge, biowaste and foodwaste is fed into the biogas plant. The generated waste heat can be used by a hospital which is nearby that site.

No.	Site	Substrates	Size
1	Nearby two farms	Cattle manure	25 kW
2	Nearby Distillery	Distillery residues (thin stillage)	60 t/d
3	Nearby WWT and Hospital	Bio- and Foodwaste + Sewage Sludge	60 t/d

WWT: Wastewater Treatement Plant

The considered scenarios

In all three scenarios the biogas is used in a combined heat and power device (CHP) and the electricity is sold.
The residues of the fermentation process is as fertilizer sold to farmers in the region.

Based on the mentioned estimations the scenarios will be included a calculation of the profitability of biogas plant of different sizes and with different substrates.

The economic calculation will include the investment costs, costs for maintenance and operation, revenue that can be generated from sales of electricity, heat and fertilizer. The results are going to presented at the stakeholder event

Stakeholder event

Ceremonial evaluation and presentation of investment opportunities

The most interesting presentation on full and pilot scale biogas plant efficiency as well as further Lithuanian scenario will be done by German and Finnish scientists and practitioners LisaTkocz, Thorsten Ahrens, Tuomo Eskelinen, Tuomas Huopana

Stakeholder Event
4th of October
at 12:45
KU Senate Hall

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Events

New date!!

4th of October
Investor Event
- Investment memo
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- Further steps

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Stakeholder event

Ceremonial evaluation and presentation of investment opportunities

When, Where, what, who (representative from government??)
short programme

Text Text

Stakeholder Event
4th of October
at 2 p.m.
Room .... at the

KLAIPĖDA UNIVERSITY

Baltic Sea Region Programme 2007-2013
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Agenda

9:30-11:30 WP2 Meeting, overview on WP activitiies, general discussion (Tuomo Eskelinen and 15 min each partner)

11:45-12:45 Lunch

INVESTMENT MEMO EVENT

12:45-13:00 Inauguration and welcome (KLU Prorector and Olga Anne)

13:00-13:25 Business environment in the region for biogas plant (speaker from Klaipeda municipality)

13:25-13:50 Relevant aspects regarding operation a full scale plant in comparison with the pilot B (Lisa Tkocz, INPUT, Ingenieure GmbH, Germany)

13:50- 14:15 Feasibility and technology selection - results from pilot testing (Thorsten Ahrens)
14:15- 14:35 Electricity production from biodegradable waste in Western Lithuania area (Tuomas Huopana)

14:35-15:00 Investment memo / Business model (Tuomo Eskelinen)

15:00-15:30 Coffee break**,** free networking

15:30-16:30 Interviews and discussions with potential investors: what, why, when, who, how?

16:30-17:15 Conclusions and next steps

***Place of event*:** H. Manto 84, LT-92294, Senate hall
***Language*:** english/lithuanian

Results of questionnaire

1. You are		Farmer	Waste manager	Decision maker	Representative of Environmental Quality Control	Researcher	Other	
		7	2	2	11	4	5	31
1. Do you support biogas development idea from biodegradable waste?	Yes	7	2	2	11	4	5	(31/31)
	No							
	Partly							
	No answer							
2. Do you enough confidence to install such technology in your farm/ in your waste management area (system)?	Yes	5	1					6/9
	No							
	Partly	2	1					3/9
	No answer							
3. Do you agree to invest to such technology if farmer's community organized it/ waste manager's community?	Yes	6	1					7/9
	No							
	Partly	1						1/9
	No answer		1					1/9
4. What are the reasons that limited yours intention to invest to this technology?	financial sources	3	1	1	8	2	3	18/31
	lack of knowledge	4	1	1	4	3	2	15/31
	Doubtable profit	4	1		4	2	4	15/31
	other				The cost effectiveness			
5. What are an advantages of this method	Using of raw material without any (special) preparation	3			2	2	2	9/31
	Technology doesn't require any water	2	1		2		1	6/31
	Possibility to use any biodegradable waste from the	3	2	2	10	4	2	23/31

	farm							
	other							
6. What do you think where should be applied this technology?	domestic animals farms			1	10	2	2	15/22
	landfills or dumps				6	1		7/22
	to organise/ establish food waste area			1	5	3	2	11/22
	other				Biofuel factory Food factory* 2		1	3/22
7. What way institution which you are represented could contribute to biogas from biodegradable waste development	To prepare documents (regional scale) promoted biogas development			1	3			4/22
	Financial support				4	1	1	6/22
	Researcher help to prepare general documents for Environmental Impact Assessment (EIA) of biogas economic activity. Creation of some general form of EIA helps a lot of actors to put biogas idea into practice.			1	5	1	2	9/22
	no answer				2	2		4/22

1. **What do you think who and what can mention (to be as an obstacle) biogas development from biodegradable waste in Lithuania?**

Lack of knowledge 5/31; financial sources 18/31; political aspects 2/31; consciousness 1/31; Imperfections of the legislation 2/31; Special programs have led to 1/31