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Operation Process Evaluation & Consulting

Biogas Plant Laubegg/St. Georgen

(AK ÖKO Energie GmbH)

Final Report

The project was performed for LandesEnergieVereinSteiermark (LEV)
within the Bio-methane Regions Project (funded by IEE)



March 2014

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INTRODUCTION

This report presents information about knowledge transfer and consulting for the biogas plant in Laubegg/St. Georgen (AK ÖKO Energie GmbH) in terms of the Bio-methane Regions Project (funded by IEE). The biogas plant has chronic operation problems and is not able to exploit the permitted grid capacity. In the first phase, the outgoing situation and operation process at the biogas plant Laubegg was evaluated. Actions were then recommended to improve the biogas plant operation. In the second part of the project, the biogas plant operation was monitored for 2 years (1/2012-12/2013). The aim was to implement the actions leading to at least 10% higher methane production compared to the reference year 2011. In the practice, for the biogas plant operator, the most important parameter is the amount of electricity fed into the grid. Simply said, the more methane produced, the more electricity can be produced and fed into the grid. In the year 2011 the biogas plant fed 2,759,449 kWh_{el} into the grid and the project aim was to overcome this score, that means increase at least 10 %. The possibilities and proposals for the alternative process operation were presented to the biogas plant operator. The possible impacts of the changes have been taken into account and the Biogas Consulting and Research Group (IFA Tulln) supported the biogas plant operator during the project time and implementation. Even though it was not possible to reach all defined targets, the project outputs will serve to future stable, sustainable and more efficient biogas plant operation.

MATERIAL AND METHODS

The first step is to collect process data and stabilize the current biogas plant operation. The weaknesses and strengths of the used technology and its operation will be determined. The second step is to rearrange the operation process to be able to feed at least 10 % more electricity into the grid compared to year 2011. Main parts of the operation data used for this report were obtained from the biogas plant operator within interviews and visits of the biogas plant. The next part of the data comes from measurements, calculations and chemical analysis (digester samples, biochemical methane production etc.) carried out by IFA Tulln Biogas Consultation and Working Group. Data from both sources were a basis for process evaluation and designing of a new operation scenario.

RESULTS

Installed power capacity

The biogas plant Laubegg is an agricultural biogas plant operated by the company AK ÖKO Energie GmbH. The biogas plant was established in 2004 as a 500 kW_{el} biogas plant (2x 320 kW_{el} and 420 kW_{th} MDE CHP-units with MAN biogas engines, nominal el. efficiency 38%, see Picture 1). That means, even if the installed electric power is 640 kW_{el},

the biogas plant is not allowed to feed more than 500 kW_{el} into the grid. The biogas plant can practically feed into the grid maximal 4 380 MWh_{el}/a; that corresponds nearly to 7 360 MWh_{th}/a. The produced electricity is delivered into electricity grid by feed-in tariff 14,5 cent plus 3,0 cents (since 7/2012) respectively 4,0 cents (since 1/2013) for 1 kWh_{el} fed into the power supply grid. The produced thermic energy is partially utilized in the process (10%) and in the close Red Cross social facility (90 m pipeline) for heating and warm water supply (40% from in biogas plant in total produced heat). The communal heat supply grid operator pays 26 EUR / MWh_{th} to the biogas plant and sells the heat for 52 EUR / MWh_{th} to the Red Cross social facility.

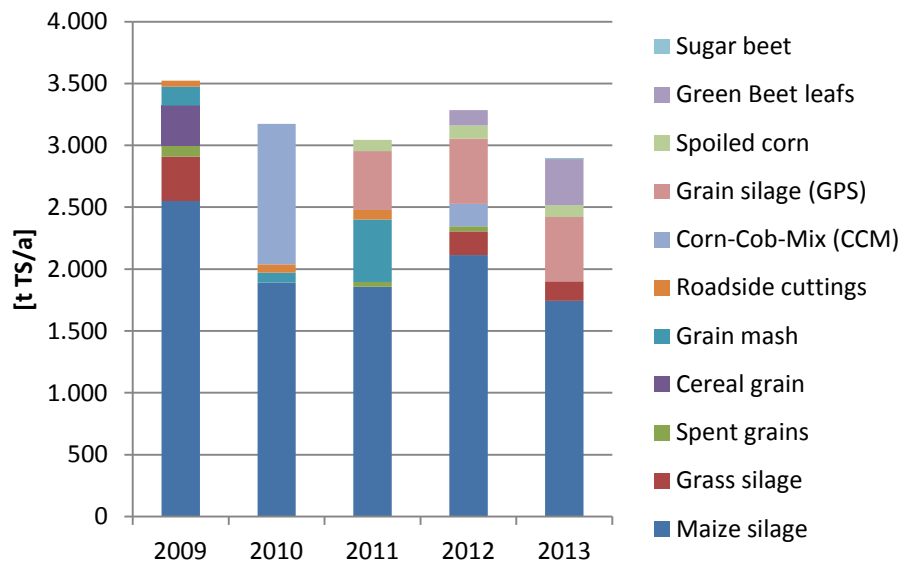
Usually a biogas plant needs to produce about 10 % el. energy more (parasitic energy demand) to deliver the permitted electricity amounts into the grid. That means a 500 kW_{el} biogas plant has to produce about 530-550 kWh_{el} to deliver 500 kWh_{el} into the grid. The parasitic energy demand of the biogas plant Laubegg was in range of 15 % which is relatively high value.



Picture 1: MDE biogas engine with control panel

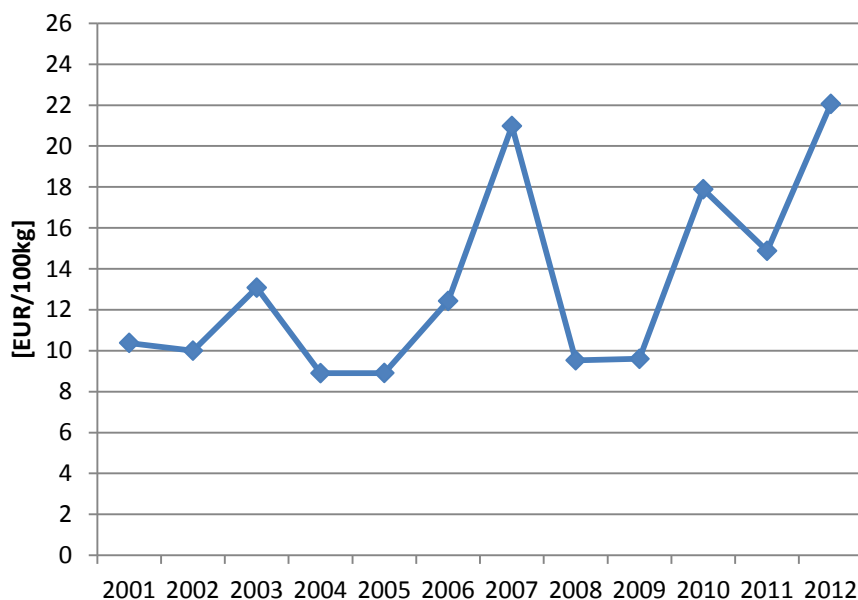
Substrates

The biogas plant (BP) uses several solid substrates for the bio-energy production. The liquid substrates are used just very rare. The amount of each substrate type varies and depends on the year season and substrate availability (see Picture 2). The frequently used substrates were maize silage, whole plant silage (GPS) or CCM (in the year 2011). The solid substrates are stored in a bunker silo with capacity of 6.000 t. The liquid substrates can be stored and mixed in former manure storage tank (220 m³).



Picture 2: Overview of used solid substrates (annual total solids intake) since year 2009

Unfortunately just a very small part of the needed substrates (maize) can be produced on own farmland (34 ha). The substrates have to be nearly in 100% bought from external suppliers, mostly from abroad (e.g. Hungary or Slovenia). Then the substrates are stored in bunker silo with a capacity of 6 000 tonnes. The dependency on suppliers makes the plant operation very vulnerable and sensitive to the developments on the feedstock market (see price development on the Picture 3). It has to be noticed, that such a situation is very typical for the big majority of Austrian agricultural biogas plants. E.g. the maize price in year 2012 doubled compared to year 2004 (planning and putting plant into service) .



Picture 3: Maize price in Austria since 2001 (Source: EUROSTAT)

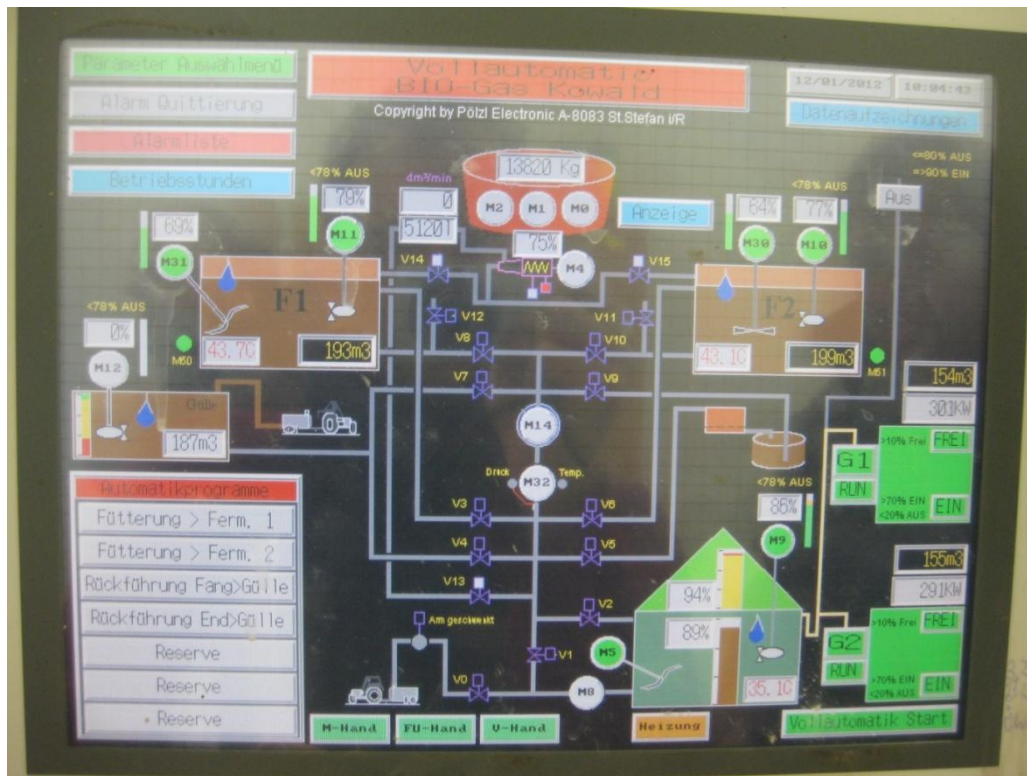
The substrate costs influence on the biogas plant operation can be always fully observed in the next season. The biogas plant operator buys for the same money less substrate that means, less feedstock (see bunker silos on Picture 4) for the biogas plant and less produced energy.



Picture 4: The bunker silo at the BP Laubegg in January 2012 (left) and in February 2013 (right)

Technology

The biogas plant was built und equipped by company AAT Abwasser- und Abfalltechnik GmbH (www.aat-biogas.at) as a two stage anaerobic digestion plant with two in parallel fed digestors (each volume of 1 000 m³) and one covered and heated storage tank (2.400 m³). Each digester has a feeding screw system for solid substrates (maize silage, GPS and sugar beet slices). But these feeding screws are since 2011 out of order and the fermenters are fed by a pump now. The today's feeding mechanism consists from one reservoir for substrates (capacity of 50 m³ solid substrates) and Vogelsang lobe pump (10 kW). The reservoir is filled two times per day. The operation temperature in both digesters (F1 and F2) is 40-43°C. The digestate from digesters F1 and F2 is pumped into heated post-digester F3 (T = 35°C) which represents herewith a covered storage tank as well. The digestate production is nearly 8.000 m³ / a. The digestate is used as a fertilizer and in the spring and autumn spread on the cultivated farmland.



Picture 5: Operation scheme (BP Laubegg)

Feeding and pumping

Digester feeding with liquid substrates and pumping of digested material to the storage tank is executed by a lobe pump 1 (Vogelsang, 10 kW, $Q = 20\text{--}30 \text{ m}^3/\text{h}$). The pump station enables independent pumping of the material into each digester and digestate storage tank and additional cutting of substrate particles (Vogelsang RotaCut, 5,5-6,3 kW). The pump 2 (12 kW) is a centrifugal pump. The main task of the pump 2 is the support of the mixing in the F3. Each digester (F1 and F2) is daily fed approximately by 13 t of solid substrates (25 – 30 t FM / day in total). The reservoir for the substrate (capacity ca. 20 t) has to be filled twice a day. Then the solid substrates are transported from the reservoir (2x30 kW motors), mixed with digestate from the storage tank F3 (in ratio 1:3) and pumped into digesters (F1 and F2). The digesters are fed every 2 hours (switching between F1 and F2). One feeding interval takes nearly 20 minutes (see Picture 6). The theoretical hydraulic retention time of solid substrates in the digesters F1 and F2 makes just about 20 days (high recirculation rates). Because of using covered digestate storage (F3) achieves the average retention time of substrates in the gas tight system at least 90 days. The average organic load (ORL) in the digesters F1 and F2 in 2011 was $3,75 \text{ kg VS}/\text{m}^3_{\text{F}} \cdot \text{d}^{-1}$. The residual methane potential in the digestate of $56 \text{ Nm}^3/\text{t VS}$ is compared to other biogas plants in normal range.



Picture 6: Solid substrate feeding (left) and mixing unit (liquid + solid)

The originally for each installed feeding screws are since 2011 out of order. After 7 years of operation the needed reconstruction costs were estimated on 40 000 EUR and that was for the biogas plant operator not reasonable. Because of this the plant was rebuilt into to current design.

Biogas quality, production and storage

The produced biogas is stored in biogas holder located above the F3 and combusted in previously mentioned biogas engines. To the desulphurization of biogas serves an aeration unit so the digester free space is aerated by regulated air addition. There were not observed any significant problems with high H_2S concentrations in the past. The biogas has for the CHP unit relatively constant composition (51 – 54 % CH_4 , 48 – 49 CO_2 , < 200 ppm H_2S and < 0,5 % O_2). The H_2S content is an important parameter as well. High H_2S (e.g. > 500 ppm) concentrations could be dangerous for biogas motors. In case of increasing of H_2S concentration shorter service periods are needed to prevent engine damage. The biogas engine producers give generally strict limits for maximal H_2S concentration in combusted biogas.

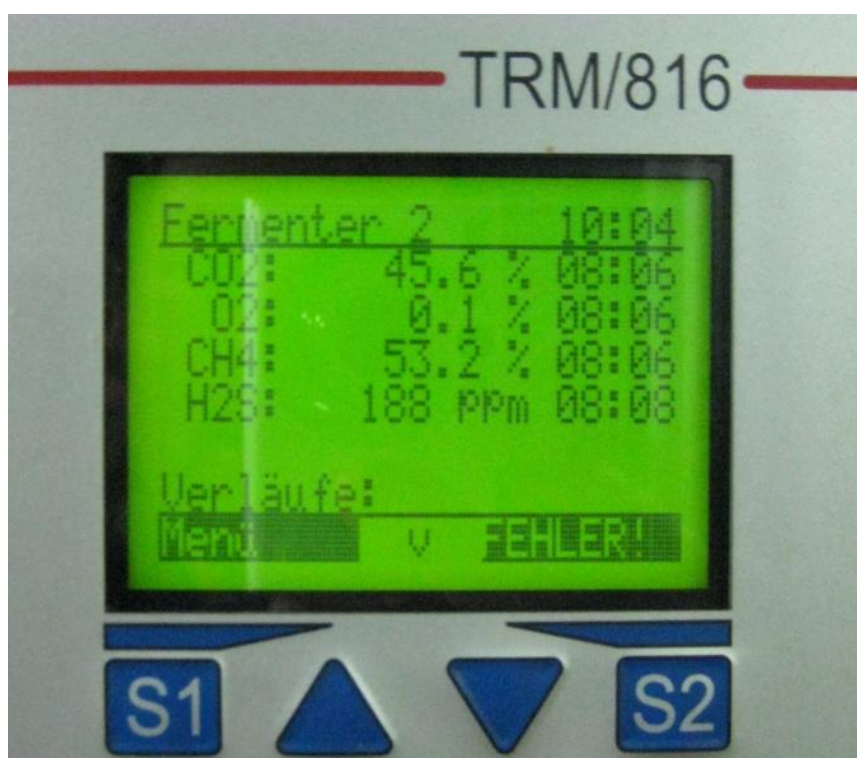


Picture 7: Biogas releasing from the biogas slurry (left) and swimming layer with desulphurization bacteria in post digester F3 (right)

Tab. 1: Average CH₄ content in Biogas in the biogas plant Laubegg

Average CH ₄ content in biogas [%]			
Year	F1	F2	F3
2011	n.a.	n.a.	n.a.
2012	52,1	52,8	52,5
2013	52,0	54,6	53,9

The volume of produced biogas can be measured by installed biogas-meters for each CHP unit separately. The biogas production varies in range of 180 – 250 m³ / h. The biogas holder capacity is 1 800 m³.

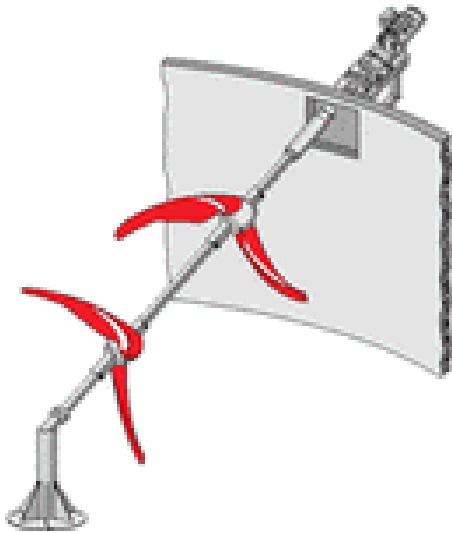


Picture 8: Gas composition at BP Laubegg (F2)

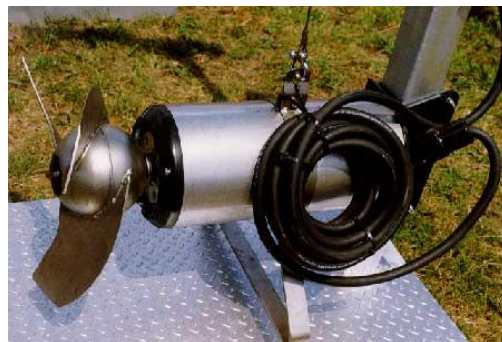
Agitators and mixing system

The mixing system in digester F1 consists of one skew placed long arm agitator (15 kW) and one submersible propeller agitator (10 kW). The 15 kW agitator is a slow going agitator (max. 40 rpm), the propeller is a fast going agitator (ca. 390 rpm). The mixing system in F2 consists from vertical decentralized placed slow going agitator (12 kW) and submersible propeller agitator (10 kW). The mixing intervals are as follows: 10 minutes for feeding, 20 minutes during feeding and 10 minutes after feeding. The mixing systems in F1 and F2 (see Picture 9 and Picture 10) deliver under given conditions a good mixing performance and no

considerable problems concerning mixing quality were observed in the past. On another hand there have to be mentioned problems like break off the agitator shaft by the slow going agitator or spent propeller blades (fast going stirrers). The estimated optimal total solids content in the suspension for mentioned mixing systems (F1 and F2) is in range between 7-10 %. The centrifugal pump 2 is used for supporting of mixing in F3 together with one mixer-agitator (15 kW) and submersible propeller agitator (15 kW). The mixing intervals in F3 are normally 35 minutes each 2 hours. In the F3 can be very often observed swimming layers on the suspension surface because of technical problems or insufficient mixing performance.



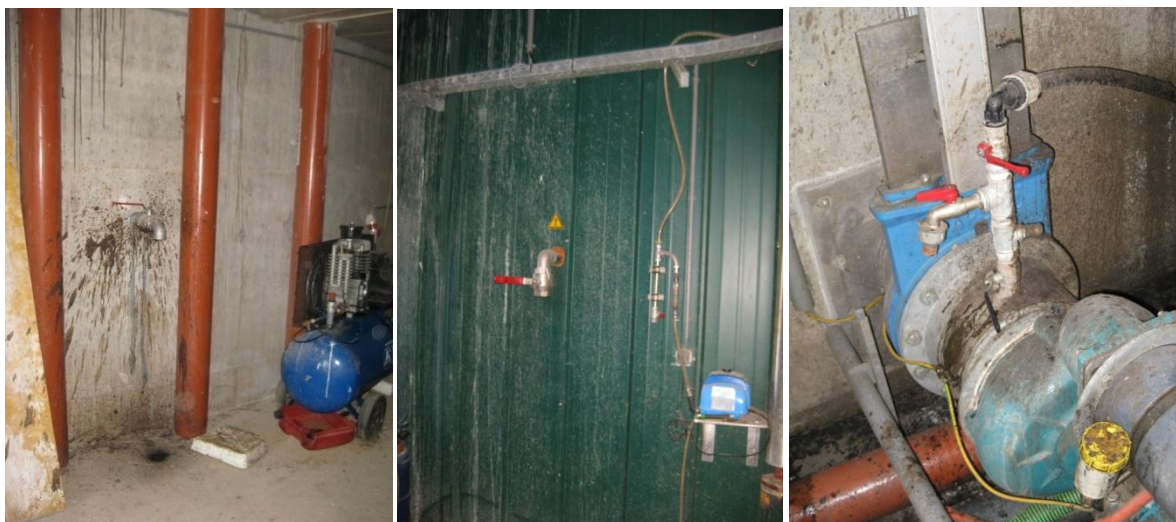
Picture 9: Slow going agitator in F1 (left) and vertical decentralized placed slow going agitator (F2)



Picture 10: Mixer installed in F3 (15 kW, 80 - 200 rpm, www.suma.de) and submersible propeller agitator installed in F1, F2 and F3 (right)

Biological process stability

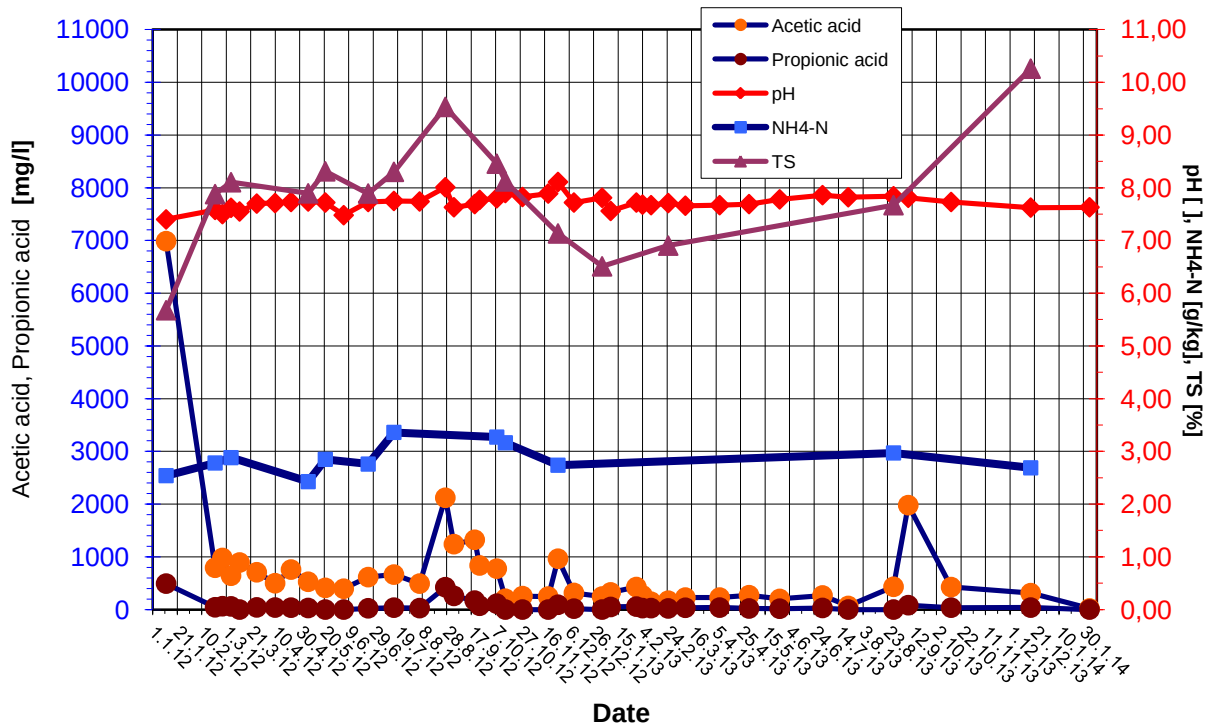
For a well-balanced biogas production is a stabile biological process necessary. It should not be made any non well-considered changes in the feeding and substrate quality. The Picture 12, Picture 13 and Picture 14 show the development of the main chemical parameters in each digester during the last more than 2 years. In January 2012 (project start) was observed a high VFA concentration in all tree digesters. This could be caused by higher organic load and changing in the substrate mixture. Afterwards, in the next months the VFA concentrations were, except of short peaks (short-time overloading), in a safe or very low range. The pH and $\text{NH}_4\text{-N}$ were without outstanding variations. That means, the biological conversion process stayed during the project time sufficient stable. On another hand the most significant changes were observed in the TS values (range 5,5 - 10%). During the project, the lowest values were achieved in January 2012 and in August 2013, when, because of technical problems, the feeding was nearly stopped. The highest TS values were measured in December 2013, when sugar beet pulps were fed. The reason was inorganic soil residues (e.g. sand, clay) on the pulps. In the year 2012 was made out higher organic load in F1 and F2 than in year 2011 (from approximately 3,75 to 4,05 $\text{kg VS/ m}^3_{\text{F}} \cdot \text{d}^{-1}$). The lowest average organic load was observed in the year 2013 (just 3,57 $\text{kg VS/ m}^3_{\text{F}} \cdot \text{d}^{-1}$). The situation in 2013 had a negative influence on the produced power (see picture Picture 16).



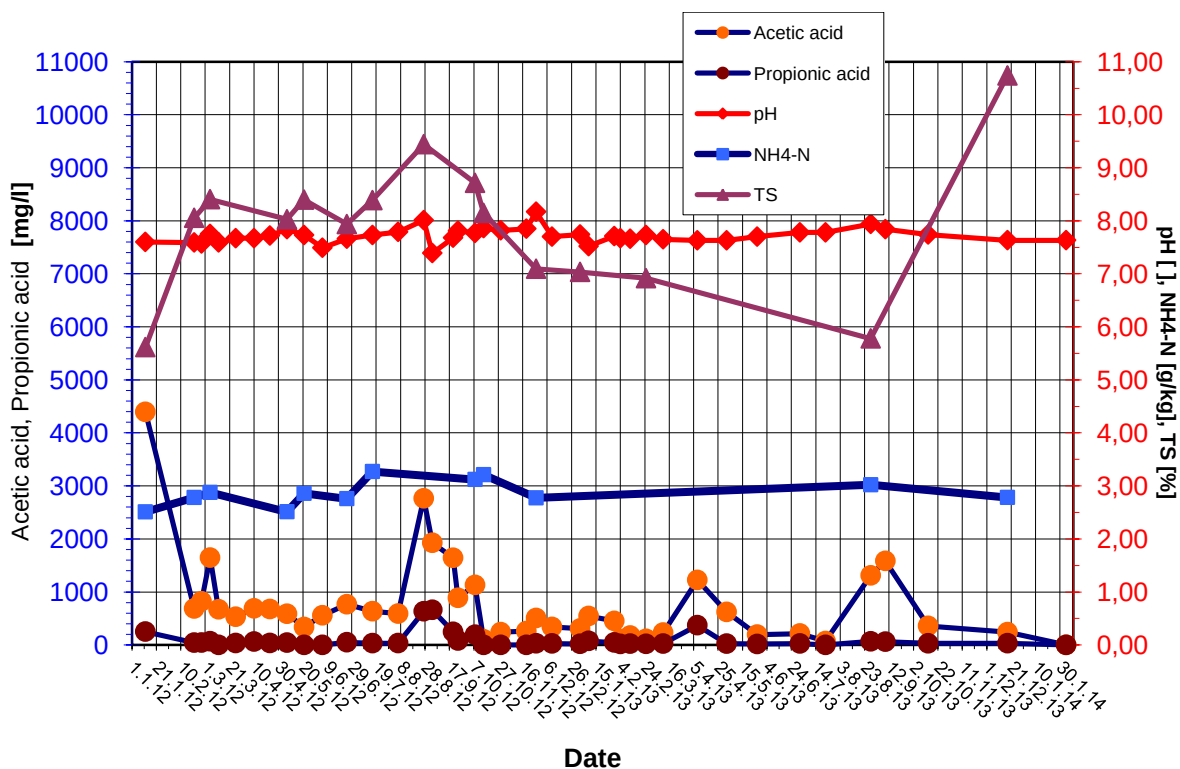
Picture 11: Sampling valves F1, F2 and F3 (from left to the right)

Into the biogas digesters have been added since year 2009 trace elements (costs nearly 600 EUR / month). During the project carried out analysis did not show any significant lack of micronutrients. The only one significantly missing micronutrient was selenium. Nevertheless the lack of selenium the biological process in digester seems to be sufficient stable now, so an urgent lack of micronutrients can be excluded. Because of this the micronutrients addition

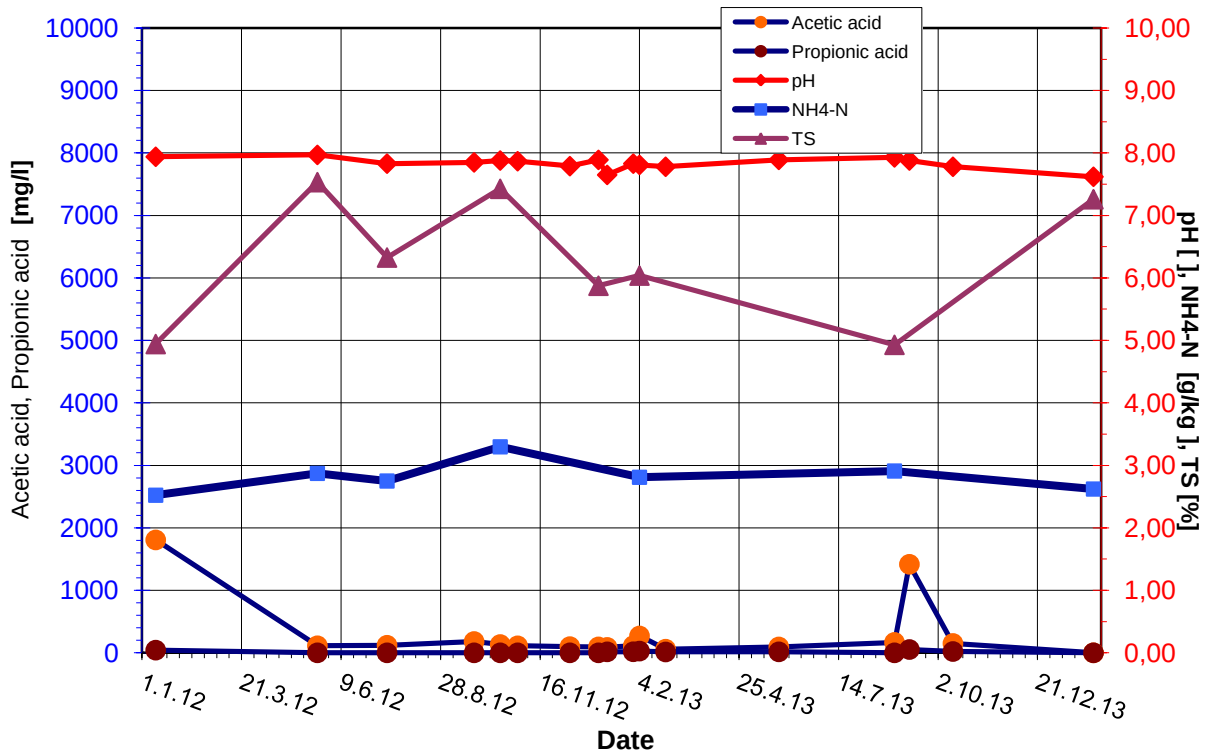
was stopped in October 2013. If needed, the micronutrients can be added additionally when a lack micronutrients or biological process instability will be detected.



Picture 12: Main monitored process parameters during the project (digester F1)



Picture 13: Main monitored process parameters during the project (digester F2)

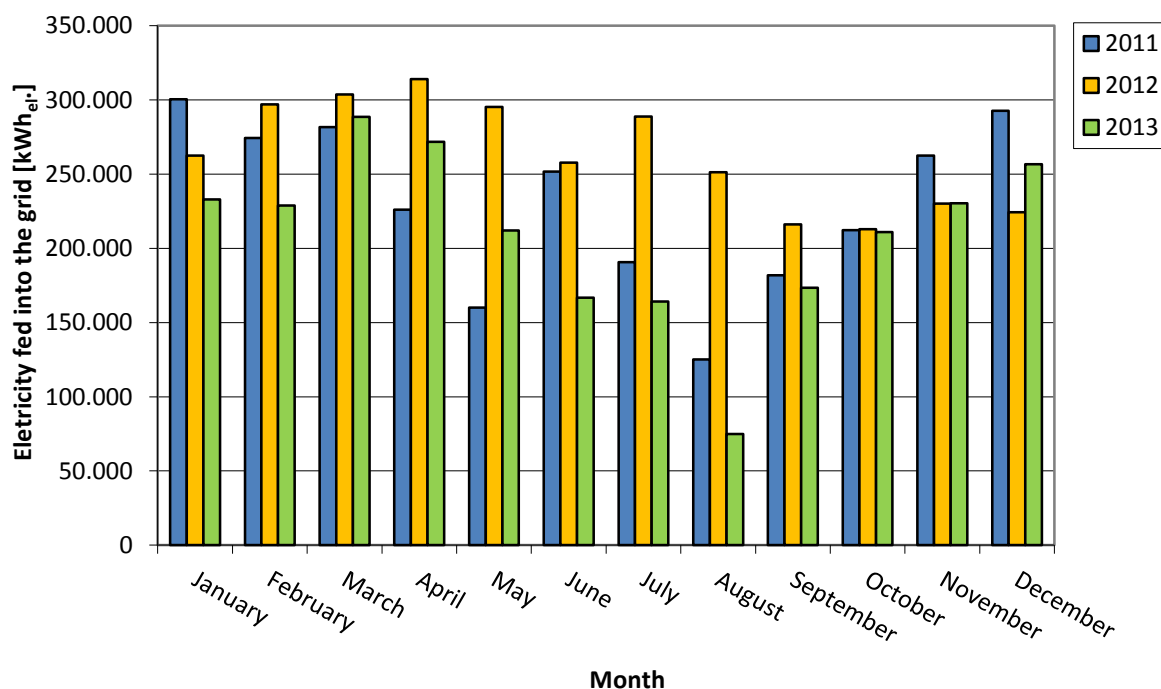


Picture 14: Main monitored process parameters during the project (digester F3)

During the project it was necessary to search for alternative substrates to overcome feedstock market fluctuations. It was possible to find and analyse several alternative substrates (see Picture 15). The results of biochemical methane potential analysis (BMP) are presented in the annex (batch tests).



Picture 15: Analysis of biochemical methane potential or residual methane production (batch test)



Picture 16: Electricity fed into the grid in the reference year 2011 and project years 2012 and 2013 (related to each month)

Communication, monitoring and operation diary

The biogas plant operator has unfortunately relatively poor computer skills (older man). To be able communicate more efficient, in the first project weeks an IFA co-worker established an email account for him. Other communication possibilities are telephone and fax. The process data like electricity production, amounts of fed substrates, gas production etc. could not be downloaded from process computer because of missing software tool. Because of this IFA co-worker installed a suitable software tool for downloading data and instructed the biogas plant operator how to download and send the data per email.

	A	B	C	D	E	F	G	H
1		Fermentor F1 Aktivvolumen [m3] =				1000		
2		BGA Öko Energie GmbH						
3	TS [%*0,01]	0,07	0,07	0,28	0	0	0	0
4	oTS [%*0,01]	0,8	0,8	0,9	0	0	0	0
5		Substrat [t/d]						
	Datum	Substart 1	Substart 2	Substart 3	Substart 4	Substart 5	Substart 6	Substart 7
6								
7	01.01.2012	0,0	0,0	26,0	0,0	0,0	0,0	0,0
8	02.01.2012	0,0	0,0	27,0	0,0	0,0	0,0	0,0
9	03.01.2012							
10	04.01.2012							
11	05.01.2012							
12	06.01.2012							
13	07.01.2012							
14	08.01.2012							

Picture 17: Proposal of operation diary for the biogas plant Laubegg

At the biogas plant is not available a daily updated operation diary. The operator has his own system of evidence. The operator's system is not very accurate and not very transparent for an extern person. The substrate quantity is measured but the substrate quality (each fraction) is just estimated. The total solids was measured just very rare. Annual balance sheets (fed substrate and produced power) are available.

Without above mentioned basic information it is very difficult to follow the material flows and it can lead to rough errors in during the daily balancing. To overcome this problem during the project was designed an electronic operation diary (excel sheet). Because of a very difficult implementation (limited computer skills), just a by hand written substrate data compilation sheet could be established (see Picture 18).

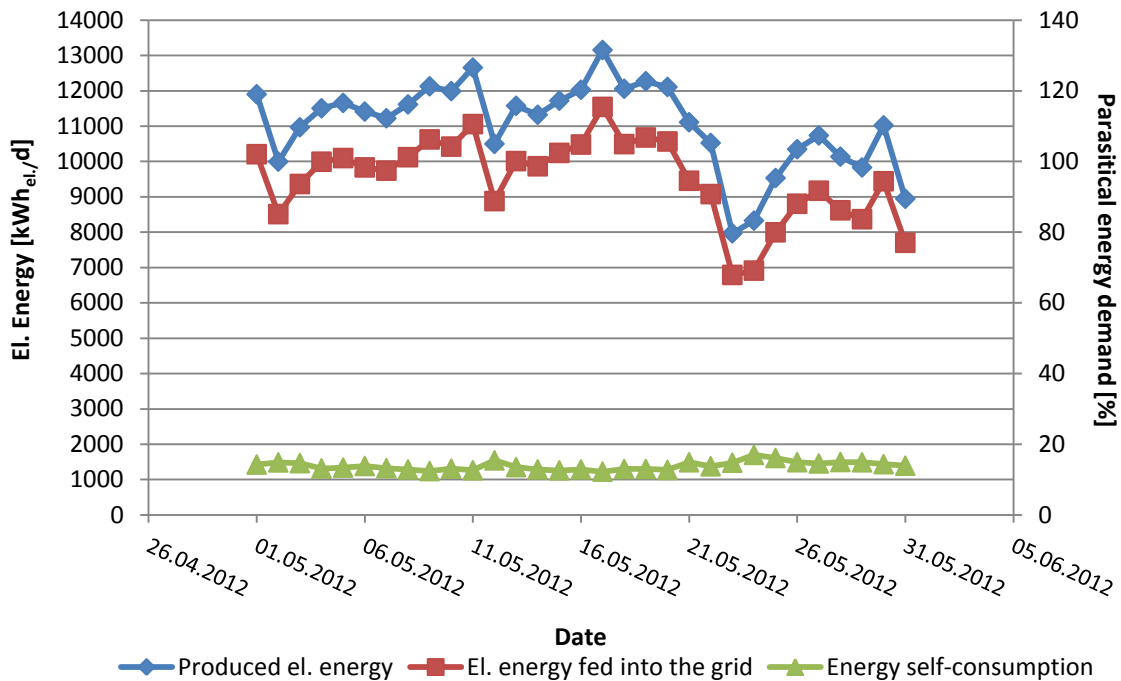
6.3.	Menge Frac.	TS %	TS kg	OTS/TSP	
7.	29.600 kg	25,21	7.366	6.630	+430 kg Füllstoff
8.	29.220 kg	24,96	7.293	6.564	- " -
9.	28.780 kg	22,97	6.610	5.949	- " -
10.	25.940 kg	23,04	5.973	5.376	kleiner Reparatur
11.	36.780 kg	24	8.827	7.945	- " -

Picture 18: Simplified operation diary (fed substrate amounts related to volatile solids in (2013)

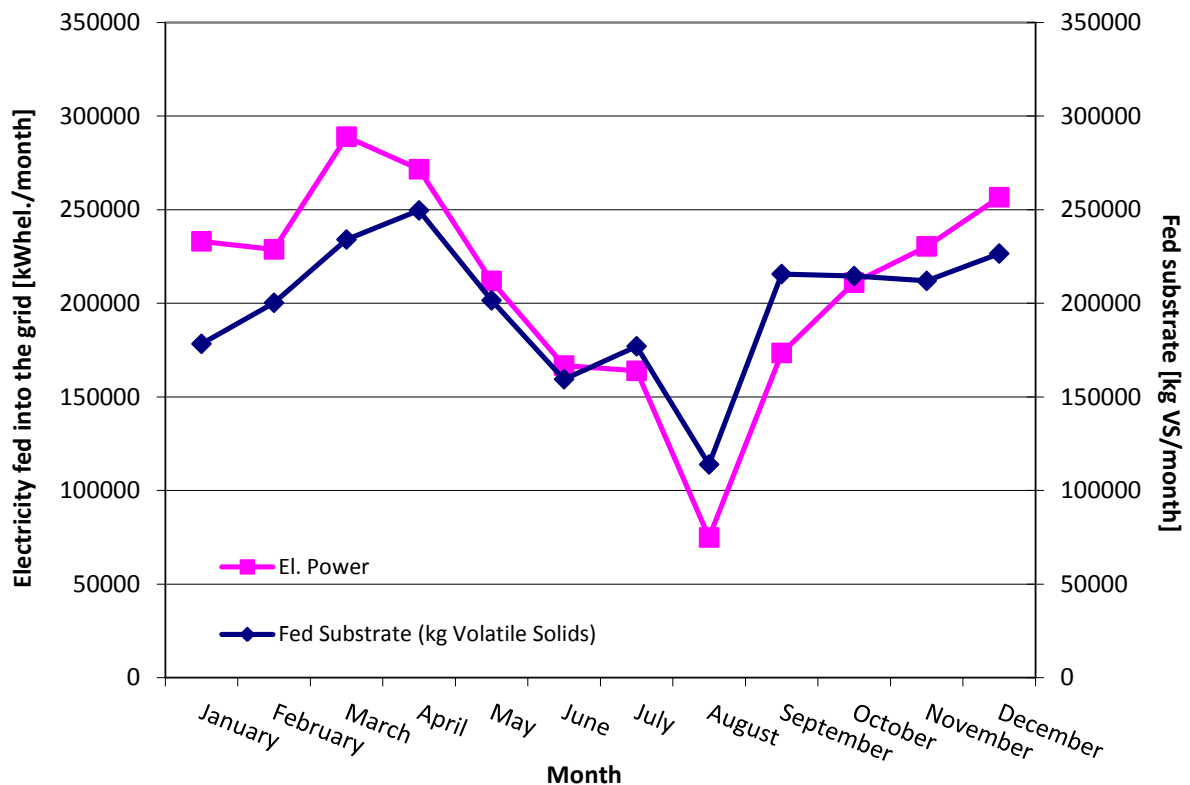
Produced electricity and parasitic energy demand

The biogas plant operation and bio-energy production at each biogas plant is connected to certain parasitic energy demand. The self-consumed energy is needed for transformer, biogas engines and other processes at the plant like feeding, mixing, pumping etc. The difference between produced and consumed energy can be fed into the grid. Excluded transformer, which is a mandatory consumer, the common biogas plants consume 7,0 – 10,0 % of the produced electric energy for its operation. In case of biogas plant Laubegg the observed parasitic energy demand was in range of 11-18 % with average value about 14,5 %. This is compared to other well-running biogas plants a higher value and a very wide range. The reasons are the technical problems during the plant operation. Generally, in case the plant runs, the parasitical energy demand stays more less the same (operation processes), independent how much of produced el. energy the plant delivers into the grid. That means, if the parasitical energy demand makes e.g. 900 kWh_{el.}/ day and the produced el. energy is e.g. 9 000 kWh_{el.}/ day, the relative parasitical energy demand will make 10 %. In case the biogas plant produces just e.g. 7 000 kWh_{el.}/ day, the relative parasitical energy demand will rise to 12,8%. Such a high variations like in case of biogas plant Laubegg is a

clear indicator of frequent technical problems and low exploitation of installed biogas motors. In the year 2011 was the annual permitted grid capacity utilisation only 63,0%, in 2012 was managed to reach 72,3% and in 2013 could be, because of lack of substrates, achieved just 57,3%.



Picture 19: Example of the power performance and parasitic energy demand of fluctuation



Picture 20: Correlation between fed substrate amount (kg VS / day) and electricity fed into the grid

PROCESS EVALUATION SUMMARY AND OPERATION SCENARIOS

The process evaluation indicates the evaluated biogas plant has significant operation problems. The frequented down times are caused by lack of substrates and forced operational imbalance. The most important project data summary shows the Tab. 2. As mentioned earlier mentioned, the degree of installed electric power utilization is very low. The carried out chemical analysis confirmed that a good biological stability was achieved in the investigated digesters.

The operator has had limited information about energy potential, chemical characteristics etc. of some substrates. A simplified operation diary was implemented to increase operator's awareness about quantity of the fed susbstrates.

Tab. 2: Electricity fed into power grid in reference year 2011 and during the project (2012 an 2013) compared to fed substrates amounts

	Electricity fed into the grid [kWh]		
	ref. year 2011	2012	2013
January	300.415	262.413	233.050
February	274.275	297.035	228.811
March	281.618	303.631	288.504
April	226.074	313.916	271.786
May	160.084	295.209	211.958
June	251.733	257.831	166.751
July	190.778	288.751	164.099
August	125.206	251.360	74.893
September	181.911	216.166	173.461
October	212.219	212.990	211.000
November	262.553	230.224	230.400
December	292.585	224.409	256.655
In Total fed into power grid	2.759.449	3.153.933	2.511.367
Fed substrates [t TS/a]	3.046	3.285	2.897

The strengths, weaknesses, opportunities and threats for the biogas plant Laubegg are concluded in Tab. 3.

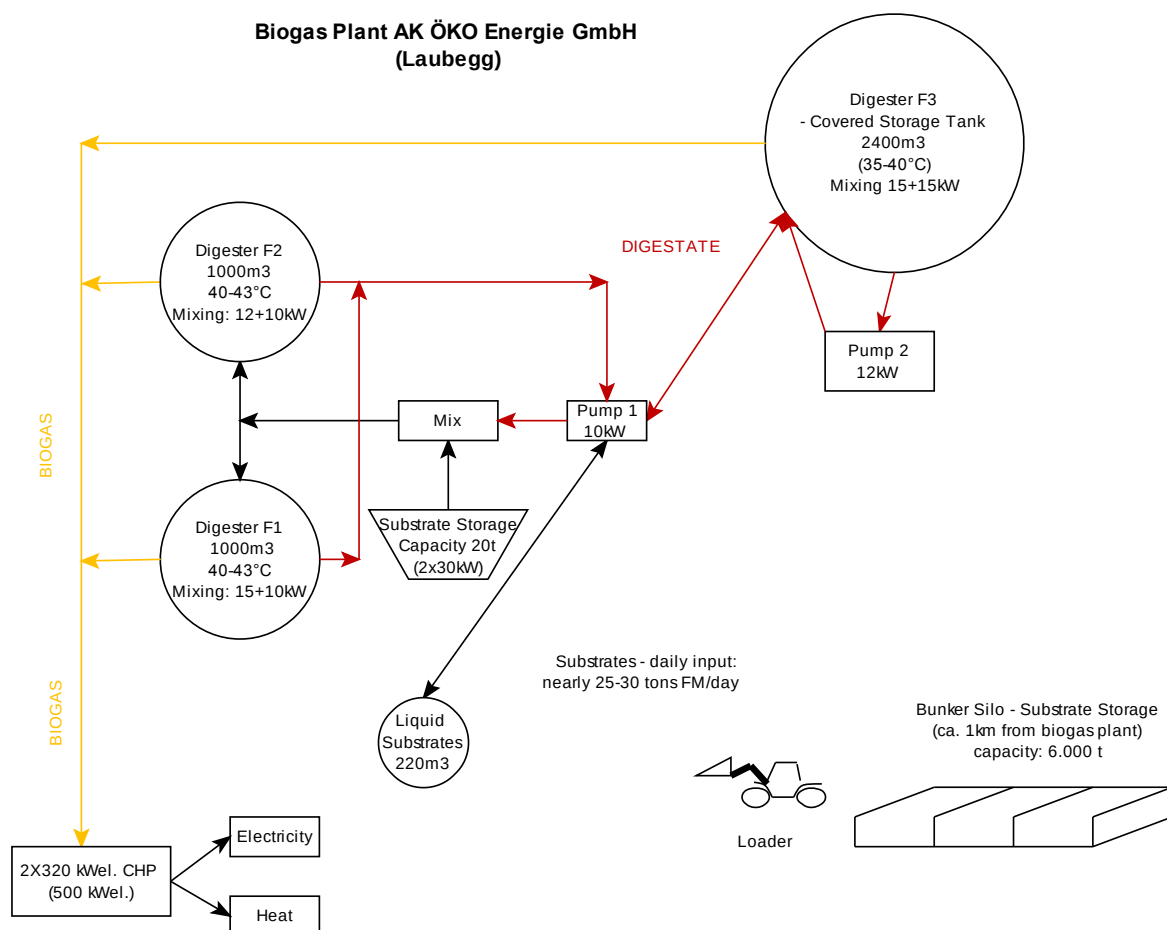
Tab. 3: SWOT analysis

Strengths	Weaknesses
- The company AK ÖKO Energy GmbH ist the only one owner and operator of the biogas plant Laubegg. - Good feed-in tariff (14,5 + 3,0 cents / kWh_{el.}). - Heat utilisation possible. - Big substrate storage capacity in the bunker silo.	- Chronic insufficient substrate amounts. - Very high dependency on extern suppliers and consumers (substrates, programming, digestate management e.g.). - The feed-in tariff runs out in the year 2017 and the will sink to common market price (e.g. 4-5 cents / kWh_{el.}). - Investment resources not available. - Feeding screws for solid substrates out of order. - The biogas plant operator does not have any substitute ("one man show"). - Problematical technology (e.g. feeding system, agitators). - Often down times. - Just short-term planning possible. - The bunker silo is not covered (energy losses in the leaching juice and oxidation). - Electronically treatable data and operation diary hardly available. - The biogas engines are not operated at full capacity (lower electrical efficiency). - 50% of produced heat cannot be utilized. - Missing of liquid agricultural substrates (manure) => high recirculation rates. - Insufficient mixing in F3.
Opportunities	Threats
- To increase the process efficiency and energy production (new operation concept, to improve current stage). - To ensure substrates for longer time and fix price (long-term strategies). - To increase heat utilisation, negotiations about better price. - Biomethane production (upgrading of biogas and feeding into the gas grid). - Aimed adding of nutrients. - Looking for a new partner (substitute and independency).	- Until year 2017 will not be found an alternative how to ensure an operational profitability. - No more credit from bank. - No money for buying substrates. - No interest on digestate take-off. - Health problems.

To improve the situation at the biogas plant the operation scenarios 1 and 2 were supposed in the following part. The implementation advantages and disadvantages for each scenario were mentioned as well (see Picture 21 and Picture 22).

Operation scenario 1

The scenario 1 was implemented during the first project year (2012). The major aims were to stabilize the biological process, increase the organic load and feed into the grid 10% more electricity than in the reference year 2011. The given aims were achieved during the year 2012.



Picture 21: Scheme of the BP Laubegg (scenario 1)

Advantages

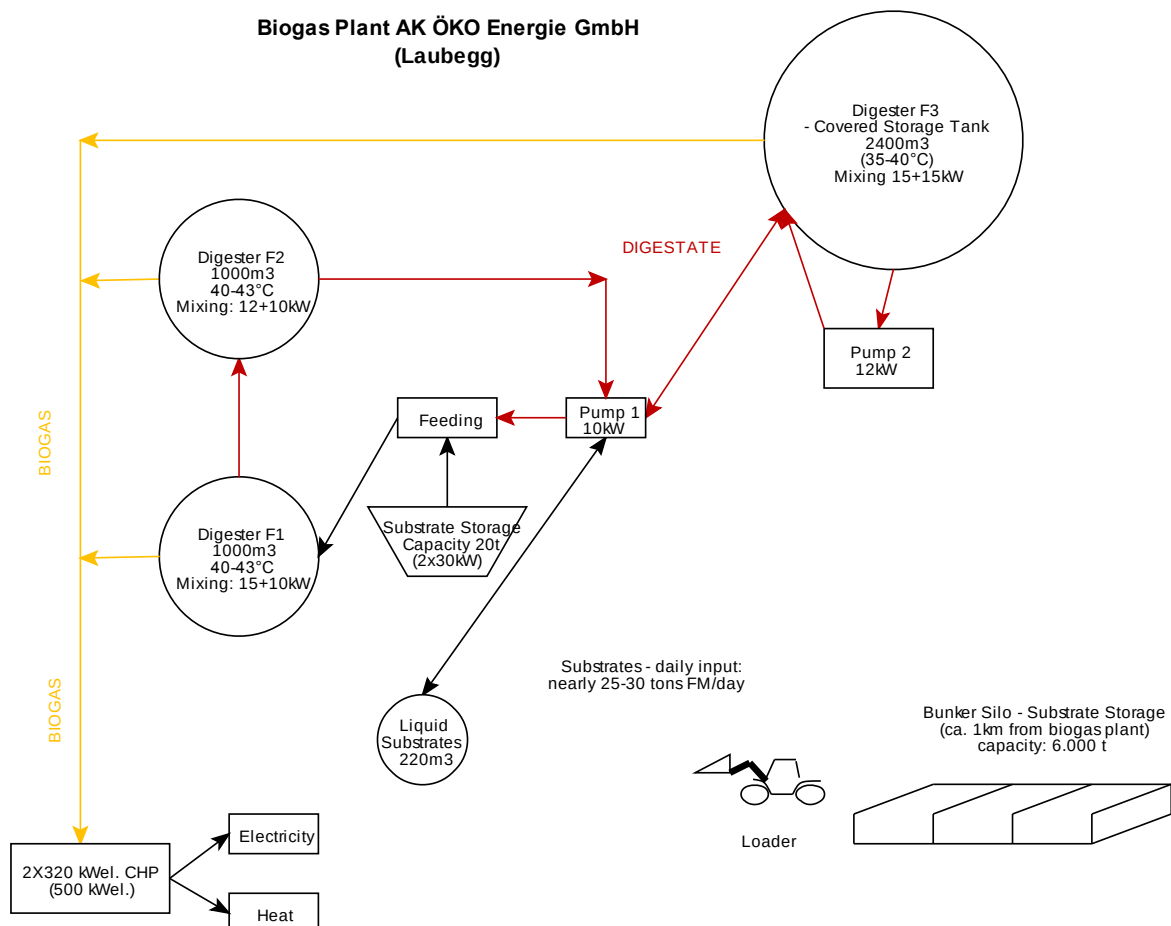
- Easy to implement.
- No investment necessary.
- Increase of the installed power utilization.
- Significantly positive results during the first project year.

Disadvantages

- Not sustainable trend because of lack of the substrates.
- Strategy does not solve the reasons of the operation problems.
- High recirculation rates.
- Possible problems with feeding system, difficulties by increasing organic load.
- Lower flexibility by plant operation.

Operation scenario 2

The implementation of operation scenario 2 is possible only by investment of 30 000-40 000 EUR.



Picture 22: Scheme of the BP Laubegg (scenario 2)

The aim is to repair the feeding screw for feeding of F1 and redesign the process flow. The F1 will be fed just by solid substrates with lower recirculation rates. In this scenario the digester F2 plays a role of a post-digester. The material from digester F1 would go directly into the F2. Digester F2 could be fed partially too (e.g. fast degradable substrates). The digestate from F2 goes into the F3. Implementation of scenario 2 would prolong the retention time of solid substrate in the F1 and F2 (lower recirculation rates). It is to expect a significant increase of VFA concentration in F1 and their good degradation in F2 and F3.

Advantages

- More process stability by changing substrates.
- Longer retention time for substrate in F1 and F2 (lower recirculation rates).
- Elimination of down times.
- Increase of the installed power utilization.
- More operation flexibility.
- Elimination of problems with feeding system.

Disadvantages

- Investment necessary.
- Strategy does not solve problems concerning the lack of substrates.

RECOMMENDATIONS AND CONCLUSIONS

After the operation data and analysis results evaluation were given suggestions and ideas to operation process improvement. The results interpreted in this report should help to recognize strong and weak points of used technology, support stable plant operation and enable future cooperation with project partner.

In all above described scenarios were showed several alternative operation possibilities. The operation scenario 1 was successfully implemented during the year 2012. The benefit was 14,3 % more electricity fed into the grid. This result confirms the chosen strategy was correct. Unfortunately to keep the positive trend was not possible because of lack of substrates and operator's health problems. In 2013 the electricity fed into the grid was just 91 % compared to the reference year 2011. There could be shown the amounts of the produced energy are directly dependent on the amounts of fed substrates. If the chronic problems with the substrate availability will not be solved as soon as possible, the biogas plant will be not able to stabilize its operational and economical situation.

The scenario 2 can be implemented just if there will be sufficient investment capital available. After implementation of the scenario 2 there will even possible to achieve higher substrate utilization rate (less substrate / 1 kWh_{el.}).

The most important project outputs are concluded as follows:

Highlights

- There were established an email account for the biogas plant operator and increased the communication and data export ability.
- Strengths and weaknesses of technology were defined.
- In year 2012 fed 14,3% more electricity into the grid than in the reference year 2011.
- Biological stable biogas production process was established.
- Implementation of operation diary (awareness rising about fed substrate quality and quantity).
- Elimination of additional costs for micronutrients (addition just if needed).
- The biogas plat operator is interested on further cooperation.

Lessons learned

- The communication and information transfer have a crucial importance for project implementation.
- For efficient biogas plant operation is a transparent material flow overview necessary.
- The biogas plants have just restricted future alternative plans and possibilities for the time after the actual feed-in tariff will run out.
- The biogas plants are very vulnerable by market price fluctuations.
- For implementing of the non technical actions must be ensured sufficient substrate amounts and analytical service.
- For implementing of technical actions must be ensured sufficient investment capital.
- The possible “human factor” influence has to be taken into account (occupational safety, process errors etc.)

Long term strategy

The process analysis and recommendations were presented to the biogas plant operator. The operator understands the practicability of the given aims and theirs importance for the future process stability and efficiency improvement. The stress on strategic planning will help to manage and reduce the external negative influences. If the sufficient substrate quantity will

be ensured, the biogas production can be further increased. In case of investment capital sufficiency (30.000-40.000 EUR) the scenario 2 can be implemented.

Before decision-making about process operation changes it is strongly recommended to use an intensive process monitoring and consultation services of competent university or consulting company.

Person in charge:

A handwritten signature in blue ink, appearing to read 'L. Kamarád'.

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ANNEXES

(Analytical results: years 2012, 2013 and biochemical methane potential)