abowe
Implementing Advanced Concepts for Biological Utilization of Waste

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INVESTMENT MEMO FOR PILOT A IN POLAND

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1. Objective and scope of the Investment Memo

The main goal of the ABOWE project was to provide proof of concept for novel technologies for biowaste treatment. One of the tested concepts was the **biorefinery technology**, which was implemented on the pilot scale within the installation, referred to as **"Pilot A".** Verification of this technology has been done based on pilot tests in three regions, one of which being the Lower Silesia region in Poland.

This Investment Memo aims to describe how the Pilot A can be used in Poland by potential investors in the bioenergy and a wider bioeconomy sector.

It is important to pay attention to the preliminary nature of the experiments. Nevertheless, they provided Proof-of-Concept in all three countries with three different biowaste mixtures. This gives a sound basis for future developmental work on the basis of the novel biorefinery technology concept using the undefined microbes together with some known strains for the production of chemical goods in a low cost non-aseptic environment. Such arrangement underlines the sustainable values combined with reasonable investment and operation costs.

2. Providing facility for Biorefinery testing with Pilot A

Approach: The biorefinery technology, developed under ABOWE project can be used for providing technology feasibility studies at various waste producers using the mobile Pilot A.

The data on biowaste generation in the region of Lower Silesia shows that there are a number of various waste producers. The waste could be utilized for the purpose of chemicals and energy production; however the know-how is not readily available to the stakeholders. The biological waste processing which has been proven for one type of waste is not necessarily reproducible for another substrate. Biowaste can have different chemical composition and their transformations can be inhibited by a number of limiting factors. Therefore a technological proof needs to be provided on case-by-case basis. Pilot A has been designed in a flexible way to allow pilot scale testing of various biorefinery processes with various substrates or mixtures of substrates. There was a wide range of technologists and engineers involved in the ABOWE project, related to the biorefinery process. The Pilot A crew provided know-how on various technology options, designs and was able to facilitate the experiments in order to verify the hypothesis. Pilot A can be transported to the premises of a waste producer and operated on-site as long as it is needed to provide the proof of feasibility. Different substrates can be tested in various scenarios to develop the most efficient recipe.

Potential testing sites include:

- Food industry
- Biogas plant operators
- Municipalities collecting biowaste
- Biowaste treatment plant operators
- Animal farm owners

Value added:

- Waste producers can learn about innovative technologies and test them without the need to make investment themselves.
- Proof of concept for various technologies.
- Development of new ideas, utilizing various sources of biowaste.
- Training of own employees.
- Developing concepts for a regional plant for biowaste recycling, high quality recycling of biowaste to marketable products,
- Treatment of residues to high quality fertilizer,
- Utilization of heat from waste-to-energy plant,
- Synergies of co-location in terms of a common investment procedure.

3. Background of ABOWE project and Pilot A

ABOWE– Implementing Advanced Concepts for Biological Utilization of Waste, was an extension stage project of the earlier finalized REMOWE project (Regional Mobilization of Sustainable Waste to Energy Production).

The overall objective of REMOWE project was to support reduction of the negative effects of carbon dioxide emissions by finding a balance between energy consumption and the use of renewable energy sources. REMOWE project focused on bio-energy from waste collection and on actions promoting the use of energy efficient technologies in the Baltic Sea region. ABOWE, as a direct result from REMOWE, continued to work with two promising technologies, unlocking investments with support from the Baltic Sea Region Programme. Two mobile pilot plants were built and tested in several BSR regions. Pilot A is based on a novel biorefinery concept from Finnoflag Oy, Finland, whereas Pilot B is based on the dry fermentation process, developed by Ostfalia University of Applied Sciences in Germany. The pilots formed the basis for compilation of Investment memos and Investor events.

Moreover the regional model, developed in REMOWE was used to evaluate the new processes' economic and climatic impacts in each region depicted in Figure 1.

Pilot A is a direct continuum to REMOWE main stage Innovation processes' outcome. As the basis is a novel biorefinery process proposed by Dr. Elias Hakalehto, Finnoflag Oy. This was evaluated in REMOWE to have good potential in BSR and was tested in a semi-industrial mobile pilot plant. In the start-up phase of Pilot A the process was tested in Finland with forest industry waste water sludge of Powerflute Oy Savon Sellu factory in Kuopio, Finland.

In the next step the pilot plant was tested in Poland with especially waste from a potato chip factory, followed by testing with two ingredients substrate being potato waste and separately collected biowaste from a commercial kitchen (restaurant waste). Pilot A was operated in the premises of regional waste management company ZGO Gac Ltd. Testing period of this new process in Poland corresponded well with manifold investments in the area of waste treatment which are under way at the moment. This proved good opportunity to promote future investments in this kind of advanced biowaste recycling technology in the Polish market.

For the last testing phase Pilot A was transported to Sweden, to be tested there in the premises of chicken farm Hagby Gårdsfågel AB, which has shown strong interest towards new possibilities during REMOWE main stage innovation process.

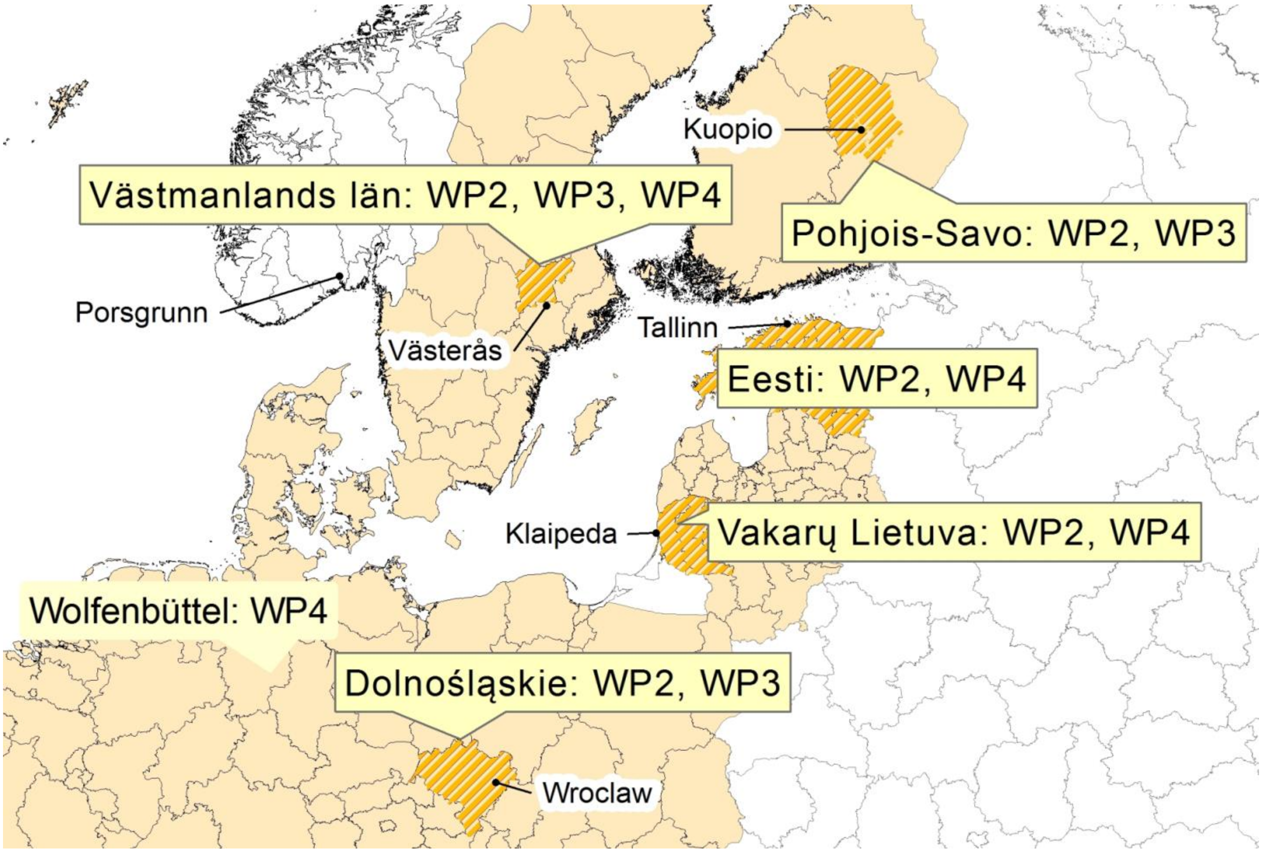

Figure 1. The regions of the ABOWE project

The investment and testing of novel biorefinery pilot plant facilitated transferring knowledge of bioprocessing various waste biomasses into valuable material and energy products. Ultimate aim was to provide Proof of technology and values for economical calculations, both needed in compiling Investment memos for Investor events.

Biorefinery processes offer a clear advantage over other traditional waste treatment technologies in terms of useful products which can be obtained. The biorefinery process' novelty lies also in the improved productivity of biomass contained, in case of the ABOWE project, in waste.

Inputs of the biorefinery are waste from food industry and pulp industry, such as potato, whey and wastes from chemical pulp production. Within the treatment process the following major steps take place:

- Pre-treatment including establishing appropriate solids content, pH adjustment and other physical-chemical optimizing of the feed-in material, leading to the hydrolysis of the input material;
- Main biological process with the application of selected microorganism. Biochemical routes that the process utilizes are essentially 2,3-butanediol-fermentation and acetone-butanol fermentation as well as methane fermentation;

- Separation of process outputs, which are among others 2,3-butanediole, butyric acid, propionic acid, ethanol, acetone, hydrogen. All these are raw materials for chemical industry as well as alternative fuels.

Products from this type of biorefinery are bulk chemicals, biomaterials and energy products. The main goal in the Polish tests was the production of 2,3-butanediole (23BD).

23BD is a commodity chemical usually produced from oil. It can be used as a precursor in the manufacture of a range of chemical products, including the solvents methyl ethyl ketone (MEK), gamma-butyrolactone (GBL), and 1,3-butadiene (Köpke et al. 2011[1], Celińska and Grayek 2009[2], Zhang L., et al. 2010[3]). Commercially, the key downstream products of 23BD have a potential global market of around 32 million tons per annum, valued at approximately $43 billion in sales.

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[1] Köpke, M.; Mihalcea, Ch.; Liew, F.-M.; Tizard, J.H.; Ali, M. S. ;Conolly, J.J.; Al-Sinawi, B. and Simpson, S.D. 2,3-Butanediol Production by Acetogenic Bacteria, an Alternative Route to Chemical Synthesis, Using Industrial Waste Gas. Appl. Environ. Microbiol. August 2011 vol. 77 no. 15 5467-5475

[2] Celińska E., Grayek W. 2009. Biotechnological production of 2,3-butanediol—current state and prospects. Biotechnol. Adv. 27:715–725

[3] Zhang L., et al. 2010. Microbial production of 2,3-butanediol by a mutagenized strain of Serratia marcescens H30. Bioresour. Technol. 101:1961–1967

4. Results of Pilot A testing in Poland

4.1 Input materials

For the biorefinery process tested within Pilot A various biodegradable waste can be considered, including waste and by-products of food industry, waste management centers, sewage sludge treatment plants, large food markets, etc.

Feedstock needs for the Pilot A in the Polish tests were predefined within the REMOWE project. These were potato waste in the first trials, enriched with the municipal biowaste in the further trials.

Potato waste

Potato waste was selected as the main input stream due to vast availability of the biowaste originating from a chips and snacks producing factory, located in the vicinity of the testing site (Stanowice, near to Olawa). Potato waste was the single input stream in five out of eight tests performed (runs 7 - 11).

The production waste stream selected for the experiments were waste potato peels, which are normally utilized in a digestion plant. This waste streams comes directly from the peeling line of the prewashed potatoes Thus, it contains very limited quantity of mineral contamination, which is beneficial for the biorefining process. The waste was delivered to the testing site in barrels (see Figure 2).

Potato waste was collected form the chips plant in a fresh state. Characteristics of the potato waste stream can be found in Table 1. It can be seen that the potato waste, despite its bulk consistency could be characterized by very high water content (over 82% m/m). The size of particles was relatively small and homogenous, so it didn't require any further mechanical crushing. The organics content as well as nutrient content (Nitrogen and Phosphorus) render waste suitable for the biochemical process.

Table 1. Characteristics of waste inputs to trials with Pilot A (average)

Parameter	Unit	Potato waste	Kitchen waste
Water content	%	82,34 (±2,31)	85,99
Organic matter content)	% d.m.	96,96 (±3,59)	81,945
AT4	mg O2/g d.m.	156 (±10,39)	189
Total Phosphorus	% d.m.	0,14 (±0,03)	0,09
Total Nitrogen	% d.m.	0,52 (±0,11)	1,08
total K	% d.m.	1,39 (±0,24)	0,78
Ca	% d.m.	0,28	4,60
Mg	% d.m.	0,09	0,14
Cd	mg/kg d.m.	0	0
Cu	mg/kg d.m.	15,0	24,4
Zn	mg/kg d.m.	83,3	166,8
Ni	mg/kg d.m.	0	0
Pb	mg/kg d.m.	0	0

Kitchen biowaste

In the following tests (runs 12-14) the second stream was included. These were separately collected kitchen waste from a local restaurant in Wrocław (Figure 3). The waste was collected by the kitchen personnel and stored in a barrel for a few days (usually five days), so at the moment of delivering it to Pilot A it contained a mixture of very fresh and slightly older biomass. It was composed of various ingredients, including mostly vegetable residues, both fresh and boiled, as well as rests of soups, some meat, fruits, fats etc. Due to some larger particles and especially larger bones present in this waste stream it needed manual check (mainly removal of bones) and mechanical crushing. Characteristics of the kitchen waste are provided in Table 1.

Figure 2. Potato waste used for testing of biorefinery technology in Pilot A

Figure 3. Kitchen biowaste used in Pilot A tests

4.2 Results summary

The investigations took app. 8 weeks in Poland, during which 8 trials (runs) were performed. The investigations were performed by the Wrocław University of Technology, Department of Environmental Engineering staff, under coordination of the inventor of this technology – the Finnish company Finnoflag Oy.

In the first trials mostly acetic acid, followed by ethanol were generated in the process. Further optimization of the substrates (combination of potato waste and kitchen biowaste) allowed to obtain the targeted products in form of 2,3-butanediol and butyric acid in significant quantities.

Figure 4 shows the results which have been obtained in each run. It can be seen that the optimization of the process (runs 13P-14P) allowed to achieve significantly better results than in the initial runs. The substances, which could be determined with gas chromatography directly in Pilot A included:

- Ethanol
- Acetic acid
- Butyric acid
- Propionic acid
- 2,3-butanediol.

Runs 13P and 14 P can be characterized by highest yields of useful products. In run 14P 351,6 g of useful products were generated per 1 kg of substrate in form of glucose. In run 13P, the respective amount was 339,0 g/kg glucose. The highest yields of 2,3-butanediol, as determined with gas chromatography were obtained with run 13P (131,6 g/kg glucose). Also the generation of butyric acid was highest in run 13P, amounting to 148,7 g/kg glucose. Propionic acid was generated at the highest level in run 10P (31,6 g/kg glucose)

Except for liquid products, significant amounts of hydrogen were generated, exceeding by far the upper limit value of 10000 ppm of the gas meter. The process could be run in a way to boost the hydrogen production, although it was not targeted in this case.

From the experiments run in Poland it can be clearly seen that the biorefining process requires some time to be established with a new substrate. It would be therefore beneficial to continue the tests in a new location and with new substrates for at least 4-6 months to develop a stable process. Also modifications of the mainstream processes can be proposed and tested.

Until now the technology has been verified in pilot scale with paper and pulp sludges (test runs in Finland[4]) and with chicken farm waste (test runs in Sweden[5]). Full reports of those tests can be downloaded from the ABOWE web-site.

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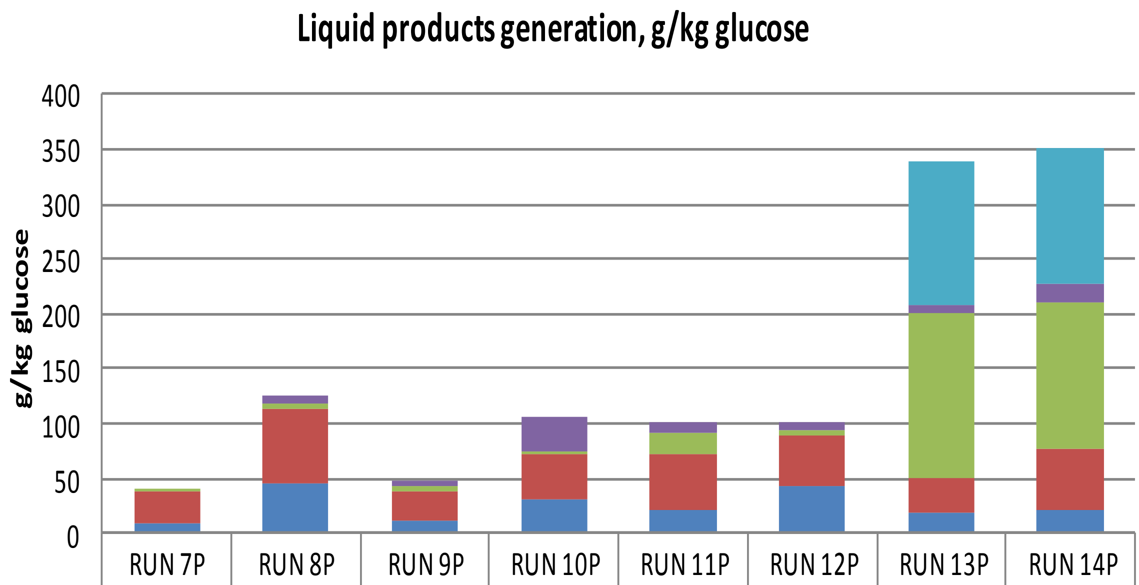
[4] Hakalehto, E. et al. ABOWE Report O3.5 Technical Report on Start-up of Pilot A. Savon Sellu tests in Kuopio February-March 2014. 2015. www.abowe.eu



	RUN 7P	RUN 8P	RUN 9P	RUN 10P	RUN 11P	RUN 12P	RUN 13P	RUN 14P
2,3 butanediol	0	0	0	0	0	0	131,6	123,8
Propionic acid	0,0	5,1	3,9	31,6	9,5	5,8	7,0	17,3
Butyric acid	2,7	5,9	4,8	4,1	19,7	5,9	148,7	133,8
Acetic acid	27,2	67,0	26,6	39,7	51,6	46,2	33,4	56,6
Ethanol	9,9	46,6	12,0	31,6	21,0	42,9	18,2	20,1

Figure 4. Liquid products generation g/kg glucose

Staff training: except for technology verification and testing, Pilot A can be used for training of technologists and other personnel. Medium (pilot) scale technology allows to simulate various processes and observe the influence of various parameters on the final products' spectrum and yield.

[5] Andersson, H. et al. ABOWE O3.7 Technical report on Pilot A tests in Sweden. 2015. www.abowe.eu

5. Potential scenario for utilizing household biowaste

For applying biorefinery technology to produce high value biochemicals from biowaste waste, there should be first implemented biogas production technology due to several reasons. Firstly, from 2020 the landfilling of biodegradable waste has to be reduced by 65% compared to their generation in 1995. Secondly, biogas production technology is well known technology for treating biowaste. As already mentioned in this report, separately collected kitchen biowaste was one of the most promising biodegradable waste feedstock for producing biochemicals.

Electricity from biogas could be produced in biogas CHP plants which could be located next to existing CHP plants. Existing CHP plants could offer low temperature heat from their condensate for biogas plants and biogas CHP plants could offer excess heat for heat network for delivery. In addition, it is shown that for electricity production from household biowaste, plants energy balance is playing the most dominant role.[6] In case of Dolnoslaskie province the difference between feedstock transportation distances between different potential options can be maximally some hundreds of kilometers (Figure 7). In case of household biowaste its maximum sustainable transportation distance is around one thousand kilometers.[2] Heat balance is also playing large role in the overall energy balance. Heat is needed in sanitation and digestion itself. And it is shown for example that in Nordic climate conditions heat demand in a biogas plant can be one fourth of the produced biomethane[7]. Thus, there should be first put attention for dealing with most suitable waste heat sources for biogas plants (Figure 5).

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[6] Huopana T., Song H., Kolehmainen M., Niska H. A regional model for sustainable biogas electricity production: A case study from a Finnish province. u.o. : Applied Energy, 2013, Vol. 102:676-686. http://dx.doi.org/10.1016/j.apenergy.2012.08.018.

[7] Huopana, T. Energy efficient model for biogas production in farm scale. [Online] University of Jyväskylä, 2011. http://urn.fi/URN:NBN:fi:jyu-201103211905.

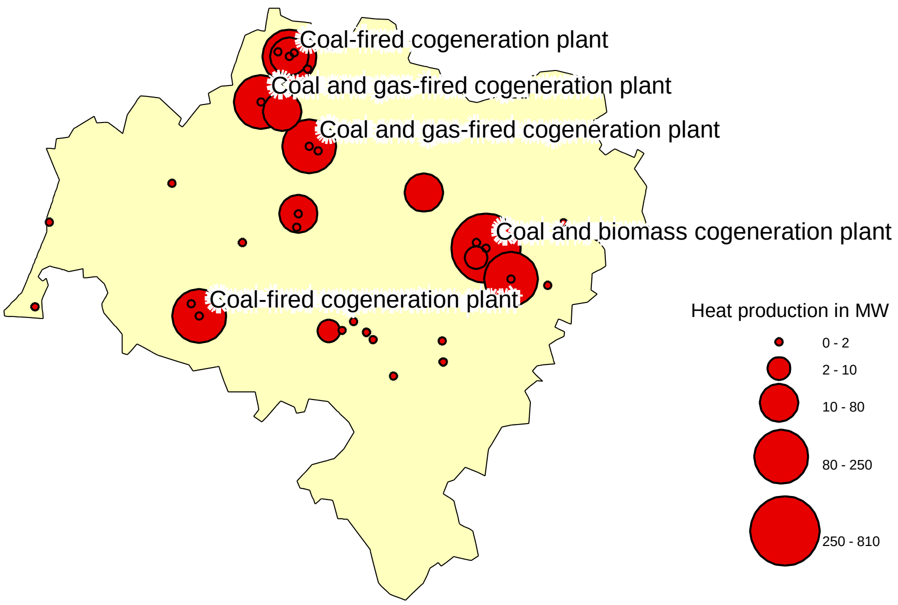

Figure 5. Heat production in CHP plants with electricity production more than 50 MW[8]

5.1 Feedstock potentials

Source separated household biowaste potential and its distribution was observed. If the availability of household biowaste were assumed to be 33.75 *kg/inhabitant,* its mass potential is around 97 kt/year[9] which is also considered as feedstock for biogas electricity production in this study (Figure 6).

[8] den Boer, Emilia. Waste and energy data for the regional model for energy from waste in lower silesia. u.o. : ABOWE project milestone 2.3, 2014.

[9] Emilia den Boer, Jan den Boer, Ryszard Szpadt. Waste-to-Energy in the Baltic Sea regions. Wroclaw: REMOWE project, 2011. Report no: O3.2.2.

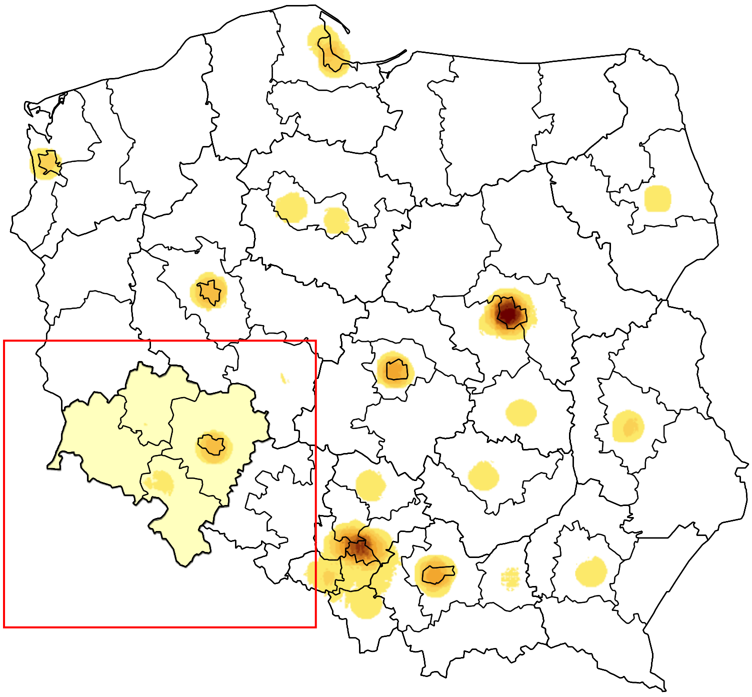

Figure 6. Distribution of population according to Eurostat grid data base while Dolnoslaskie province is highlighted as yellow color[10].

5.2 Optimized scenario

Operational income of the whole production chain was maximized[11]. The most optimal household biowaste collection areas, destination fields for digestate and scale of potential biogas electricity production plants were found. Optimized result showed that biogas CHP plants would have seven potential locations out of expected nine locations (Figure7). The plants' household biowaste collection areas and field blocks for digestate fertilizer spread are also illustrated as "*". In total, these seven plants would process 94 kt/year of household biowaste and produce 32 GWh/year of electricity. Scales and feedstock potentials for each plant consider also demand about positive energy and economical balance. Household biowaste was considered to be transported to the plant where its processing to electricity is the most cost efficient. With estimated regional input parameters almost all household biowaste would be reasonable to process in biogas CHP plants.

[10] Reference Data. [Online] Eurostat, den 15 May 2012. [Citat: den 30 January 2013.] http://epp.eurostat.ec.europa.eu/portal/page/portal/gisco_Geographical_information_maps/geodata/reference

[11] Huopana, T. et al. ABOWE O2.9 Biogas electricity production from household biowaste. Case: Dolnoslaskie. 2014. www.abowe.eu

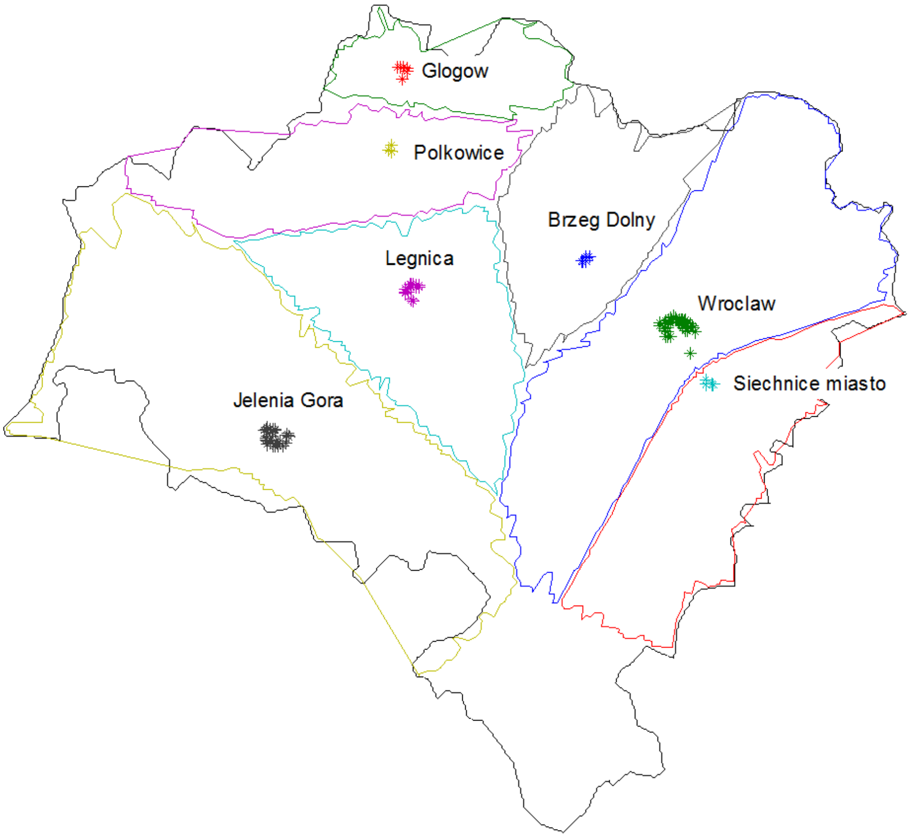

Figure 7. Waste collection areas are shown as polygons around plants.

6. Energy and chemical markets in the testing region

Energy: Development of renewable energy sources (RES) in Poland is seen mainly as an activity of reducing the environmental burden, moreover increasing energy security of the country. This is particularly important in a situation where electrical power is based approximately 90% on hard coal and lignite, thus diversifying sources of electricity generation and development is extremely important. Development of renewable energy should be based primarily on dispersed generation, taking advantage of local RES which also helps to reduce the losses associated with the transmission of energy, and thus significantly improves energy security and reduce greenhouse gas emissions.

The current strategic national document for the development of the power industry is the Polish Energy Policy until 2030, passed by the Council of Ministers on 10 November 2009. One of the priorities of this strategy is to ensure the achievement by Poland in 2020 at least 15% share of energy from renewable sources in final gross energy consumption of which at least 10% share of renewable energy consumed in transport. Commitment to achieve the above results directly from Directive 2009/28/EC on the promotion of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

In order to achieve the above mentioned binding targets Poland established intermediate objectives, i.e. 9,54% of energy from renewable sources by 2014, 10,71% by 2016 and 12,27% by 2018, respectively. In the frame of the implementation of the commitments contained in Directive 2009/28/EC the Council of Ministers on 6 December 2010 , adopted the "National action plan for energy from renewable sources", hereinafter referred to as "KPD", which was then forwarded to the European Commission. KPD sets national targets for the share of energy from renewable sources in transport, electricity, heating and cooling in 2020. In the KPD it was assumed that reaching the objectives of growth of the share of renewable energy will be based on two types of the resources available and possible to use in Poland, i.e. through an increase in electricity production from wind energy and increased use of biomass energy.

Currently, Poland does not have any separate legislation, which would address only the issue of renewable energy. The scale of the challenges associated with the development of renewable energy sources, indicates the need for enactment of such a law. The draft Act has been prepared and is dealt with in parliament. Issues of production and use of electricity from renewable energy sources are currently governed by the Act on Energy.

Chemicals: More than 131 billion PLN was the value of Polish chemical sector sales in 2012. In mid-2013 the number of enterprises of the chemical industry in Poland amounted to 11,000. Over 70% were companies involved in processing plastic and rubber. In the segment of chemicals and chemical products there is much less fragmentation. The key for the chemical industry in Poland is the company with the participation of state owned shares. Currently, the dominant sectors are petrochemicals, plastics and fertilizers, followed by lower shares of pharmaceutical and cosmetic industry. Chemical industry is the second largest in terms of production, just after the food industry. Both largest industries in Poland could be investors in bioeconomy (biochemical, bioenergy).

6.1 Current support for energy from renewable sources

According to the Act on Energy from 1 October 2005, Poland has a support system for the production of electricity from renewable energy sources. The system includes a number of mechanisms:

- issuance of certificates of origin for electricity from RES and certificates of origin for agricultural biogas, known colloquially as green and brown certificates,
- market turnover (exchange at free market) of property rights arising from certificates of origin,
- the obligation to produce a share of electricity from renewable sources, enforced by the presentation by the liable entity (energy companies, energy consumers and brokerage houses) certificates of energy production from renewable sources or payment a replacement fee,
- the obligation to purchase energy from renewable sources,
- support for prosumers (owners of small installations producing and consuming energy and selling surplus energy)
- additional incentives for producers of renewable energy, reduced fees, etc.

Certificates of origin of electricity from renewable energy sources concern the production of the energy from sources that use wind energy, solar, aerothermal , geothermal and hydrothermal energy, energy of wave and maritime tides, of the fall of rivers, of biomass, of biogas from landfills, and of the biogas produced in the process of anaerobic sludge digestion in sewage treatment plants as well of the biogas from digestion of animal and vegetable residues.

Regulation of the Minister of Economy of 18 October 2012 on the detailed scope of obligations to obtain and submit to the redemption certificates of origin, the substitute fee, purchase of electricity and heat produced from renewable energy sources and to confirm the data on the amount of electricity produced from renewable energy sources, indicates that the energy produced in the renewable energy sources include, apart from the power of this source:

1. electricity or heat coming in particular:
   a) from hydropower and wind power,
   b) from the sources of energy production from biomass and biogas ,
   c) from solar photovoltaic cells and solar collectors for heat production,
   d) from geothermal sources ;
2. part of the energy recovered from the incineration of municipal waste[12].

[12] Journal of Laws of 2012 item 1229 and of 2013 item 1362.

The issuing of certificate of origin was separately regulated for **agricultural biogas**, which is a confirmation of agricultural biogas production and introduction into the gas distribution network. Agricultural biogas is defined as a gaseous fuel produced by the anaerobic digestion of agricultural raw materials, agricultural by-products, liquid or solid animal manure, by-products or residues from the processing of agricultural products or forest biomass, excluding biogas derived from sewage treatment plants and landfills.
Detailed information, including the quality parameters of agricultural biogas introduced into the gas distribution network , measurement requirements , registration and how to calculate the amount of agricultural biogas produced as well as the method for converting the quantities of agricultural biogas produced in the equivalent amount of electricity produced from renewable energy sources is defined in the Regulation of the Minister of Economy of 24 August 2011 on the detailed scope of the obligation to confirm the data concerning produced agricultural biogas introduced into the gas distribution network.[13]

The certificate of origin of RES allow acquiring of property rights that are transferable and are the commodity. Pricing mechanism of property rights arising from certificates of origin is a market mechanism contributing to the development of competition in the renewable energy market. Separating the certificate of origin for electricity produced from renewable sources from physical energy makes it possible to trade on the exchange of property rights arising from such certificates.
Property rights resulting from certificates of origin arise at the moment of the first registration of certificate in the register of certificates of origin and inure to the benefit of the holder of this account. The transfer of property rights arising from certificates of origin takes place from the moment of the relevant entry in the register of certificates of origin.

Obligation to obtain certificates of origin concerns entities producing electricity, as well as industrial and energy end-users and brokerage houses which are required to ensure the production of share of the energy from RES. Entities required to submit and redempt certificates of origin may meet this obligation also by paying the substitute fee or execution of the obligation in part by a certificate of origin and in part by payment of a substitute fee. However, failure to comply with this requirement in one of two specified forms will be sanctioned in the form of financial penalty by the regulatory authority - the President of the Energy Regulatory Office (URE President) .

Required share of renewable energy in the total amount of generated electricity are set out in the Regulation of the Minister of Economy of 18 October 2012 on the detailed scope of obligations to obtain and submit to the redemption certificates of origin, the substitute fee , purchase of electricity and heat from renewable sources energy and to confirm the data on the amount of electricity produced from renewable energy sources.[14]

Current stock prices of certificates of origin can be determined on the basis of their trading conducted by the Polish Power Exchange. The value of unit substitute fee in 2013 was 297,35 zł/MWh, which is obtained on the top of the revenue from sale of energy.

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[13] Journal of Laws No. 187, item 1117.

[14] Journal of Laws of 2012, item 1229 and 2013, item 1362.

The obligation to purchase electricity from renewable energy sources

Official seller of electricity is required to purchase electricity produced from renewable energy sources connected to the distribution or transmission system located in the area covering the activity of this seller, offered by the energy company, which has obtained a license for its production or has been entered in the register of energy companies involved in the production of agricultural biogas. This acquisition takes place at an average selling price of energy electricity in the previous calendar year (in 2012 - 201.36 zł/MWh).

Solutions to promote the development of the so-called prosumer energy

Act on Energy provides solutions to promote the development of the so-called prosumer (producer+consumer) relation that rely on the consumption of electricity produced from renewable energy sources for own needs of the producer and selling the surplus to the grid. Electricity generation in micro-installations by a natural person (prosumer) who is not a trader within the meaning of the Act on freedom of economic activity, and the sale of the energy by this person is not considered as an economic activity requiring any license.

Micro-installation is the installation of renewable energy sources with a total installed electrical power of not more than 40 kW, connected to the grid of rated voltage less than 110 kV or a total installed thermal power no higher than 120 kW. The electricity generated by micro-installations connected to the distribution network located within the area of operation of an official energy seller and offered for sale by the person producing it (prosumer), is required to be purchased by this seller. Purchase of this energy takes place at a price equal to 80 % of the average selling price of electricity in the previous calendar year (this level of price raises a number of objections to the draft Act on RES)

Additional incentives supporting the development of renewable energy sources

- reduction of 50 % of the actual cost of connection to the grid for electricity from RES with the electrical power below 5 MW,
- obligation to provide by the power system operator priority in the provision of transmission of electricity from renewable sources,
- release of fees for granting concessions and fees associated with obtaining and registration of certificates of origin of electricity generation from RES for companies producing electricity from renewable energy sources with a capacity below 5 MW.
- exemption from excise duty on electricity generated from renewable sources .

The current system of support for electricity from renewable sources is evaluated as overly complex, inefficient and unstable, and moreover does not make difference in the level of support depending on renewable energy sources and technologies in these sources. This resulted in too high support for the installations of biomass co-firing with coal in large power plants, leading to excessive benefits gained by the operators of those installations in comparison to the investment costs and current costs of energy production. As a result, there has been excessive growth of these installations and the oversupply of green certificates in relation to the actual needs of their redemption, which led to a drastic decline in prices of these certificates (from ca. 260 PLN/MWh till ca. 120 PLN/MWh). This caused financial problems for the remaining producers of renewable energy, especially in small installations and the lack of development of new systems.

6.2 Support for the production of electricity in cogeneration

Cogeneration is one of the most effective ways of producing primary energy, providing primary energy savings of over 10 percent in comparison to the separated electricity and heat generation systems. Support for cogeneration is one of the tools for implementing both the Polish and European energy policies which contributes to the reduction of CO_2 emissions, energy conservation, development of electricity production from renewable energy sources and improving energy security.

In Poland, there are three types of certificates of origin confirming the generation of electricity in cogeneration (yellow, purple and red). The scope of the obligation to obtain and present for redemption certificates of origin for electricity from cogeneration or payment of a replacement fee ranges:

- from 3.9% in 2014 to 8.0 % in 2018 for a cogeneration unit gas -fired or for a unit with electric power up to 1 MW (yellow certificates)
- from 0.9 % in 2014 to 2.3 % for cogeneration units burning methane from coal mines or gas produced from biomass (purple certificates) and
- 23.2% each year for the rest of cogeneration units (burning coal) in each year between 2014-2018 (red certificates) .

6.3 Draft act on RES

The draft act is currently being prepared by Polish parliament. It is assumed that the act will be adopted in 2015 and after the notification of the European Commission it will apply from 2016.

The purpose of the act is:

1. increased energy security and environmental protection, among other things, as a result of the effective use of renewable energy sources,
2. rational use of renewable energy sources, taking into account the implementation of long-term economic development policy of the Republic of Poland, filling obligations arising from international agreements, and raising innovation and competitiveness of the Polish economy,
3. formation of mechanisms and instruments to support production of electricity, heat or cold, or agricultural biogas in installations of renewable energy sources,
4. development of optimal and sustainable supply of end customers in electricity, heat or cold or in agricultural biogas from installations of renewable energy sources,
5. creation of new jobs as a result of the increase of the number of new installation of renewable energy sources,
6. ensuring the use for energy purposes by-products or residues of agriculture and industry using agricultural raw materials .

An important effect of the adoption of the draft Act on RES will be the implementation scheme of the optimized support mechanisms for producers of electricity from renewable sources or agricultural biogas, with particular emphasis on dispersed generation based on renewable local resources. It is also important to separate and systematize the support mechanisms for renewable energy contained until now in the provisions of the Act on Energy.

Mechanisms have been introduced to avoid the oversupply of certificates of origin, which occurred in 2012-2013 as a result of excessive development of multi-fuel burning systems (co-firing of biomass with coal in existing power plants) requiring low capital to start the activity at excessively high income and the faster than expected growth of wind power installations (installed capacity of wind power installations increased in 2012 by 880 MW).

Another unfavorable situation affecting negatively the market of the certificates of origin was the fulfillment of an obligation by the entities obliged to do so by payment of the replacement fee, even if the price of certificates was significantly lower than replacement fee . These factors resulted in an additional accumulation of certificates of origin and deepened drop of their prices.

6.4 Support for (bio)chemistry

There is a number of investment incentives for entrepreneurs in chemical industry, in particular:

- tax exemption in Special Economic Zones (SEZ),
- exemption from local taxes, including property tax,
- government grants for strategic investments,
- support from the EU funds, tax incentives for the purchase of new technologies and research and development,
- technological and industrial parks.

The primary incentive is tax exemption from income tax in one of the 14 special economic zones, which will operate until 2026. Each zone has many sub-zones in different parts of Poland. Symbiotic cooperations between different sectors may be created in such zones.

Cash grants to support new investments come from the state budget (grants government) and EU funds.

Government grants (to create new jobs and investment) are awarded based on a program to support investments of high importance for the Polish economy. In the years 2011 - 2020 following sectors can apply for subsidy for investment:

- automotive,
- electronic
- air
- biotechnology,
- modern services,
- research and development activities.

7. Business model, cash flow calculations, financial plan

7.1 Business Model Canvas: interviews and evaluators

Extended Business Model Canvas was created based on the results from the experiments in Poland (Table 2).

Table 2. The Core Business Model.

Customer/competition	**Customer segments** 1. Food industry 2. Waste treatment companies 3. Wastewater treatment plants 4. Municipalities	**End user, customer need** 1. Get rid of waste 2. Purchasing cheaper substrates / waste	**Company solution** 1. Possibility of making business waste to product 2. Technology and know-how	**Competitive solution** In terms of testing Pilot A: laboratory tests; In terms of technology: 1. Animal feed producers 2. Fossil production of 2,3-butanediol and other
Offering	**Value proposition** 1. Sale of products 2. Purchasing of cheaper products for the industry	**Channels** 1. Support for small enterprises 2. Organizing conferences 3. Support from public money, industry chambers 4. Meetings	**Customer relationship** 1. Product information 2. Information about new products	**Profit Formula** **Revenue streams** 1. Multiple products can improve the economics
Resources	**Key resources** 1. Infrastructure, including the technology 2. Human potential	**Key partners** 1. Entrepreneurs – municipal and business 2. Investor 3. Receivers of end products 4. Food waste management	**Key activities** 1. Feasibility study of full scale plant based on tests 2. New product ideas can be found on the basis of the research 3. Technology improvement to the industrial status 4.Business plan	**Cost structure** 1. Labor 2. Energy 3. Substrates

In the selection of ideas into the business model, the methodology by Kajanus et al.[15] was followed. Firstly, the ideas were generated during a workshop in July, 2014 in Wroclaw. Secondly, one expert evaluator evaluated the ideas against two evaluation criteria (business opportunity and competitive value). Thirdly, core index values where calculated. Based on the core index values, 34 most important ideas were selected out of 88 ideas. Results are illustrated in Table 2.

Customer/Competition

The results showed that the most benefit from the biogas plant would be the food industry companies and biowaste treatment networks. Food companies are mostly private. They could be interested in testing the possibility of creating added value to their production. However it seems that the waste management networks could be more suited for implementing the technology. They are both communal and private. Communal organizations are less profit-oriented and care more about public acceptance and non-financial benefits. They have more possibility to get financing from national and EU funds for building new infrastructure. From the target customers' point of view, the most important need would be to operate at acceptable price level and to elaborate reliable technology. Competitors are the other research institutions offering mostly lab-scale testing of various bioprocesses, with lower price.

Offering

One of the biggest advantages of the pilot A technology is providing a proof of concept for alternative bioproducts. Pilot A can be used for testing the process directly at the investor site and using the original input material. The expected result would be sale of new products in the future and most ideally purchasing of cheaper bioproducts for the industry. It is expected that multiple products can improve the economics of waste treatment and of industrial production. The customers (potential investors) could be small-medium enterprises and they could be reached through thematic meetings and conferences. If the used plant A for testing they could be potentially interested to implement the biorefinery at an industrial scale.

Resources

Resources section describes the most important resources that enable business model to work. It has been decided that the most important are the infrastructure, including the technology as well as human potential. These resources are needed to enable key activities which are feasibility studies of full scale plant based on tests as well as new product ideas which can be found on the basis of the research. An important activity is also technology

[15] Miika Kajanus, Antti Iire, Tuomo Eskelinen, Mikko Heinonen, Eric Hansen [2014]. Business model design: new tools for business systems innovation. Scandinavian Journal of Forest Research. August, 2014.

improvement to the industrial status. Main partners to for cooperation include especially entrepreneurs – both municipal and business related, who can become potential investors. With regard to the sectors, it could be either receivers of final products (e.g. chemical companies) or food waste management companies. One of the most important key functions, which can follow from the actual testing is making of a business plan, which includes e.g. a detailed description of all revenue streams (product sales and services) and the company's cost structure (salaries, energy, substrates, maintenance).

Profit formula

This section contains the profit formula of the business model, revenue streams and cost structure. It has been especially underlined that multiple products can improve the economics of a full scale biorefinery plant.

8. Estimated cost structure of testing period with Pilot A in Poland

Based on the tests in Poland it is possible to estimate the costs of Pilot A operation by the Polish research team (Table 3). The estimate includes the variable costs, such as personnel, consumables, electricity, water, etc. The estimate is given for 18 weeks' testing period.

Working hours are the ones spent altogether by the Polish research team, consisting of six staff members and 24 students from Wroclaw University of Technology. Through learning and further planning of testing operations it will be possible to significantly reduce the personnel amount. On the other hand, involving students in testing operations as thesis workers or trainees reduces the staff costs in practice.

Additional costs include the rental costs (needs to be negotiated with the Pilot A owner – Savonia University of Applied Sciences, Finland) and process design (process know-how provider - Finnoflag Oy, Finland).

A full economic analysis has been done in the Estonian Investment Memo[16].

[16] Lõõnik, J. et al. ABOWE Report O2.7b. Estonian Business Model for Bio-waste treatment. www.abowe.eu

Table 3. Pilot A variable costs for 18 weeks' operation by Polish team

Costs/full testing period			
Personnel	**h**	**€/h**	**Total €**
Testing work hours	7 092	9,4	**66 856 €**
Personnel total			**66 856 €**
Raw material	**kg**	**€/kg**	
Potato waste	80	0	**0 €**
Biowaste	80	0	**0 €**
Raw material Total			**0 €**
Consumables			
Gases			**2 256 €**
Glucose measurement			**675 €**
Chemicals			**1 527 €**
Sampling consumables			**3 818 €**
Laboratory consumables (GC)			**2 398 €**
Consumables total			**10 674 €**
Other costs			
Waste containers			**253 €**
GC installation			**415 €**
Electricity installation			**600 €**
Electricity			**793 €**
Water			**23 €**
Insurance			**218 €**
Other costs total			**2 302 €**
Total variable costs			**79 833 €**

9. Contents of the Management plan for a full scale plant

Management plan is meant to be a local implementation guide, covering practical aspects of establishing and managing a full scale plant. Management plan focus on organizational aspects and assumes that all needed feasibility studies, technical development and institutional framework are already done and available and the start-up project is turning into preparation and implementation phases. First, general aspects, which should be taken into account, are listed below according to World Bank, other aspects to take into consideration being national and regional aspects[17]. Investment costs of a full-scale biorefinery plant have been estimated by Pöyry Finland Oy, Project Manager Jyri Pelkonen, and that information is available in the Finnish Investment Memo[18].

9.1 Establishment of the Implementer Organization

- Establishment of an official organization and an institutional support and framework. There should be an implementer organization, which is capable to accomplish the endeavor.
- Ownership and Top Management
    - Implementing organization can typically be owned by one of the following:
        - Private investors or a private investment association
        - Suppliers, often in BOO or BOOT (build, own, operate, transfer) arrangements
        - Private or public energy companies (for example, power or district heating companies)
        - The municipality/local government or a group of municipalities/local governments
    - For the owners, the most important issues are to ensure continued supply of the planned quality and quantity of waste; revenues from energy sale and fulfilment of instalments on loans; and maintenance of the plant in good operating conditions under qualified management.
    - The owners will normally be represented by a board that makes all crucial decisions based on sound recommendations of the plant management. The board hires a managing director, who will ultimately be responsible for operating and maintaining the economy of the plant.

[17] World Bank. World Bank Technical Guidance Report: Municipal Solid Waste Incineration. Washington, D.C. : s.n., 1999.

[18] Vehviläinen, M. et al. ABOWE Report O2.17. Investment Memo ABOWE Pilot A Finland. www.abowe.eu

9.2 Plant siting: Identification of siting alternatives selection of plant location

Tender and Financial Engineering

- Detailed financial engineering, negotiation of loans or other means of financing, and selection of consultants

Preparation of Tender Documents

- Reassessment of project, specifications, prequalification of contractors and tendering of documents

Award of Contract and Negotiations

- Prequalification of contractors. Tendering of documents. Selection of most competitive bid. Contract negotiations.

Construction and Supervision

- Construction by selected contractor and supervision by independent consultant

Commissioning and Startup

- Testing of all performance specifications, settlements, commissioning, training of staff, and startup by constructor

Operation and Maintenance

- Continuous operation and maintenance of plant. Continuous procurement of spare parts and supplies.

Environmental Impact and Occupational Health

- Noise
- Odors
- Air Emissions
- Waste Generation and Access to Landfill
- Water Supply
- Waste Water Discharge
- Occupational Safety and Health
- Airborne Pollution
- Heat
- Vibrations

- Chemicals
- Physiology
- Risk of Accidents

9.3 Training of Workers, Codes of Practice, and Occupational Safety and Health

The personnel or human resource development departments should be responsible for training workers. The skills and training courses in table 6.1 may be required. Codes of practices or documented work procedures should be prepared for all key plant activities and facilities. Furthermore, there should be contingency plans in case of accidents or equipment failure. The documentation should instruct the workers how to operate the equipment, and what to do if it fails or in case of accidents. Such documents can be used in new employee orientation, as well as a reference source for employees throughout the year. Equipment suppliers should be required to submit work procedures as part of the contract. Ideally, these should be used for preparing an integrated work procedure for the entire plant. The integrated procedures should be available in the operator's room and with shift supervisors and other key personnel. Relevant excerpts should be placed at each machine or equipment.

The technology presented in this Investment Memo needs further testing case by case to optimize the production of chemicals and energy from a targeted biodegradable waste in the full commercial and technological scale. A comprehensive management plan would be prepared at a later stage of the investment development process of a full scale plant.

10. Strategy for creating business from piloting - Scenarios for full scale biorefinery operation

Scenario 1: Biorefinery combined with an incineration plant for residual waste in Lower Silesia

In the Lower Silesia at the moment there is not waste incineration plant. The commonly used way of waste treatment is mechanical-biological treatment. After mechanical waste soring the fraction containing biodegradable waste (typically fraction <80 mm) undergoes biological stabilization. The fraction >80 mm is sorted to recover recyclables and RDF (waste derived fuel). The sorting residues as well as stabilate are landfilled. However, from 1. January 2016 landfilling of waste with heat of combustion value higher than 6 MJ/kg d.m. is forbidden in Poland. Therefore there is an urgent need to build waste-to-energy plant to treat waste which is not suitable for recycling with a thermal method.

At least one large incineration plant should be constructed in the region, preferably in the vicinity of Wrocław which is the largest city in the region. Incineration plant with energy recovery will produce electricity and heat for district heating or for industrial processes. At the same time a treatment plant for separately collected kitchen waste is needed. At the moment in Wrocław only green waste and garden waste is collected separately, however due to increasing recycling targets (50% of municipal waste in 2020 and 70% of municipal waste in 2030), the city needs to implement separate collection of kitchen waste.

Building biorefinery next to an incineration plant could be beneficial in a way that the heat generated by the incineration plant could be utilized for heating the biorefinery feedstock and drying of the biorefinery residues, which could be subsequently used as fertilizer. The central treatment plant for kitchen waste should be located also close to Wrocław, which is the largest source of kitchen waste (both from households as well as from restaurants). Allocation together with incineration plant could be beneficial from organizational and economic view as well.

Value added: regional plant for biowaste recycling, high quality recycling of biowaste to marketable products, treatment of residues to high quality fertilizer, utilization of heat from waste-to-energy plant, synergies of co-location in terms of common investment procedure

Scenario 2: Biorefinery in combination with biogas plant within a regional waste treatment plant

ZGO Gać is one example of a regional waste treatment plant, based on biological waste treatment. The technology implemented for the treatment of municipal waste consists of mechanical waste sorting step, where the fraction >80 mm and <80 mm is separated. Fraction >80 mm is further sorted to recover recyclables and RDF, while fraction <80 mm is fed to biological treatment. The biological treatment consists of anaerobic digestion in dry digestion technology and aerobic post treatment (stabilization boxes and windrows). The major input to the plant is mixed municipal waste. However, in the future it is planned to increase the amount of separately collected biowaste from kitchens, gardens and restaurants and possibly also industry to be able to run one of the two ferments with clean biowaste.

In this combination the biorefinery could be implemented as an additional pretreatment step for the separately collected biowaste. The separately collected biowaste could be first processed in biorefinery in order to generate high value marketable products, such as 2,3-butanediol. The residue of biorefinery process could be further fed to biogas plant in order to recover energy form residual biodegradable fraction. The benefit from combining the biorefinery and biogas plant is that the excess heat of the biogas plant could be used to heat up the biorefinery feedstock and the residue from biorefinery does not need to be dried, but can be directly fed to digestion plant, which saves the energy.

Value added: regional plant for biowaste recycling, high quality recycling of biowaste to marketable products, treatment of residues to high quality fertilizer, utilization of heat from biogas plant, synergies of co-location in terms of costs sharing.

Scenario 3: Biorefinery in an industrial plant in combination with wastewater treatment plant

There is a potential to implement biorefinery technology at the industrial plants related especially to food industry. An example of such plants is potato chips and snacks factory. The industry generates large quantities of biowaste, which at the moment need to be transported to a remote treatment plant. The benefit would be to include the biorefinery process directly on-site, which saves transport needs. The plant would also benefit from diversification of products which they generate and new business options. For the residue treatment of the biorefinery process the optimal solution would be to utilize existing wastewater treatment infrastructure. Food industry plants normal generate large amounts of wastewater which needs to be treated directly on-site. The most common method to treat waste water sludges is wet digestion. In this case co-digestion of wastewater sludges and residues from biorefinery process would be the most suitable option. The heat generated in the digestion plant could be again utilized for the biorefinery process. Stabilized sludges from the wet fermentation could be used as high quality fertilizer, preferable on the area where the feed for the plant is grown (closing the natural cycling of nutrients).

Value added: local plant for industrial biowaste recycling, high quality recycling of biowaste to marketable products, treatment of residues to high quality fertilizer, utilization of heat from biogas plant in wastewater treatment plant, use of fertilizer for growing own feedstock (e.g. potato fields), saving of waste treatment costs (no transport needed).

11. SWOT Analysis

As a conclusion a SWOT analysis is presented in Figure 8. to summarize various perspectives for Finnoflag Biorefinery concept based on ABOWE activities, towards full scale plant implementation.

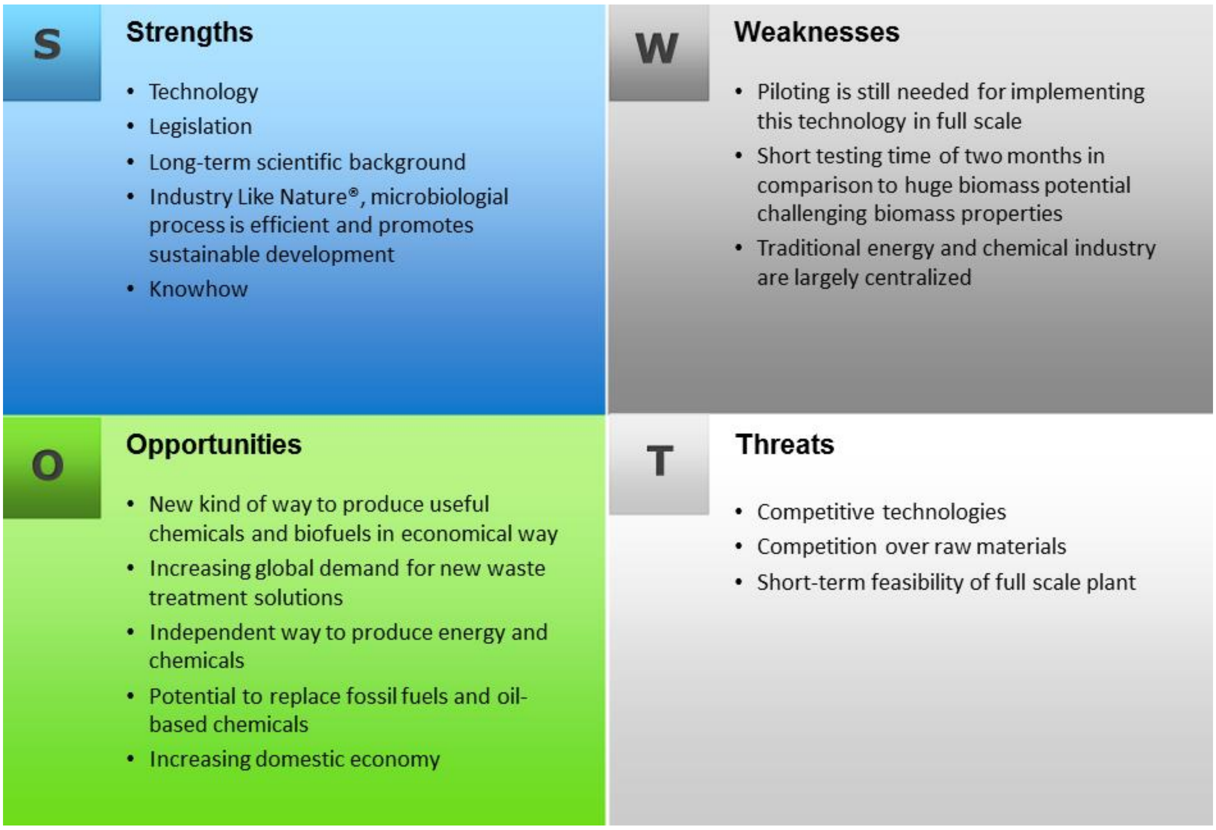

Figure 8. SWOT Analysis

As strengths are sustainability trends in legislation and interests of financing authorities. These things are giving right kind of atmosphere to use as assets knowhow based on long-term scientific background and industry executed Like Nature®. This registered expression points out that solution to make efficient and sustainable microbiological processes comes from nature itself.

As a weakness could be seen that the promising novel biorefinery technology will need more testing. During the two month testing period in Poland a good starting point for later optimization of the process and the equipment could be obtained. Production levels are possible to get improved in long run during actual optimization of the process, for basis of designing an efficient full scale plant. In addition to that traditional energy and chemical industry are largely centralized and as a new provider it is a longer process to enter to markets.

As threats are competitive technologies responding to demand of biofuels and waste treatment services. At the same time competition over biodegradable waste materials is increasing. To build a full scale plant needs to make long-term contracts with waste producers.

Opportunities that can be reached with this new technology can be emphasized a lot. The solution offers a new kind of way to produce chemicals and biofuels in an economical way, at the same time increasing independence to produce those. The new technology and business models supports increasing global demand for waste treatment solutions and will give a possibility to replace fossil fuels and oil-based chemicals. Domestically produced energy and chemicals increase GDP of economies.

12. Conclusions

This Investment Memo describes an innovative business idea, which can be further developed for potential investor on individual basis. The main idea is to apply biorefinery technology as, based on the concept of Finnoflag Oy to treat various kinds biowaste. The results of Polish tests of biorefinery technology in Pilot A have been summarized shortly here. The tests have been run with potato waste and kitchen biowaste. More results can be found in the Technical Report on Biorefinery Pilot plant A Operation in Poland[19]. In the experiments significant levels of ethanol and acetic acids were produced. Among the gaseous products hydrogen generation took place at elevated levels. These are high value products of biowaste recycling. Three scenarios for implementing the biorefinery technology in the Polish market have been outlined.

Potential investors can benefit from the know-how developed within ABOWE project. Moreover, the project team can provide further assistance in developing biorefinery business idea further, tailored for the individual needs of the investor.

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