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INVESTMENT MEMO

ABOWE PILOT A SWEDEN

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1. Introduction

This report was compiled by the ABOWE project (Implementing Advanced Concepts for Biological Utilization of Waste) funded by the EU Baltic Sea Region Programme 2007-2013. This report presents results and information of relevance for the up-scaling of the Finnoflag biorefinery technology, piloted in Finland, Poland and Sweden, to support investment decisions towards full-scale implementation.

The piloting of the technology done by the ABOWE project provides valuable information and a step forward regarding the technology. The next step, after the pilot phase, would be to construct a full-scale demonstration plant to showcase the potential of the technology to potential commercial investors or implementers. The bioprocess will need to be further designed and optimized through longer testing with selected waste materials to produce targeted products. This will allow for full-scale operations and further feasibility analysis. This falls beyond the scope of the ABOWE project. This report forms the basis of an investment memo that provides decision support to possible implementers and investors that are interested in taking the lead in the development of the technology further to a full-scale demo plant. Figure 1. illustrates this idea and positions ABOWE project in this development path.

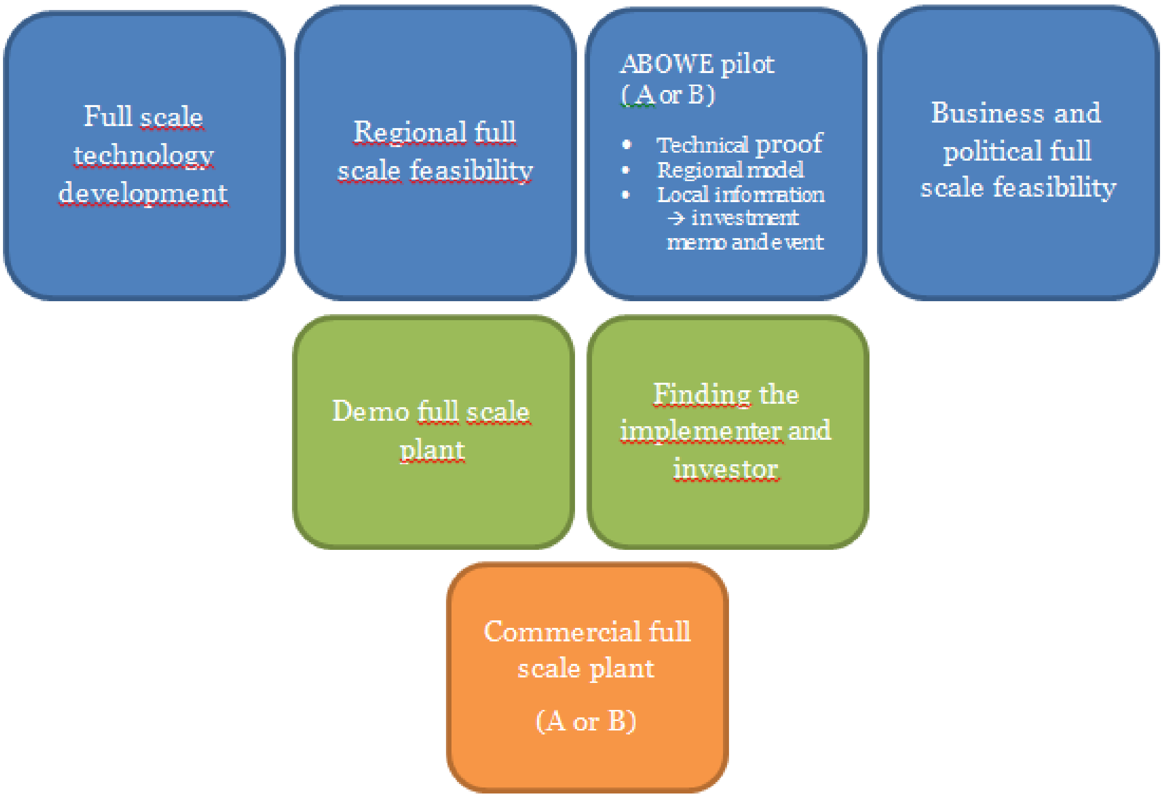

Figure 1. ABOWE project process towards a full-scale biorefinery.

Figure 2. illustrates the ABOWE project process to develop Investment Memos and Investor Events.

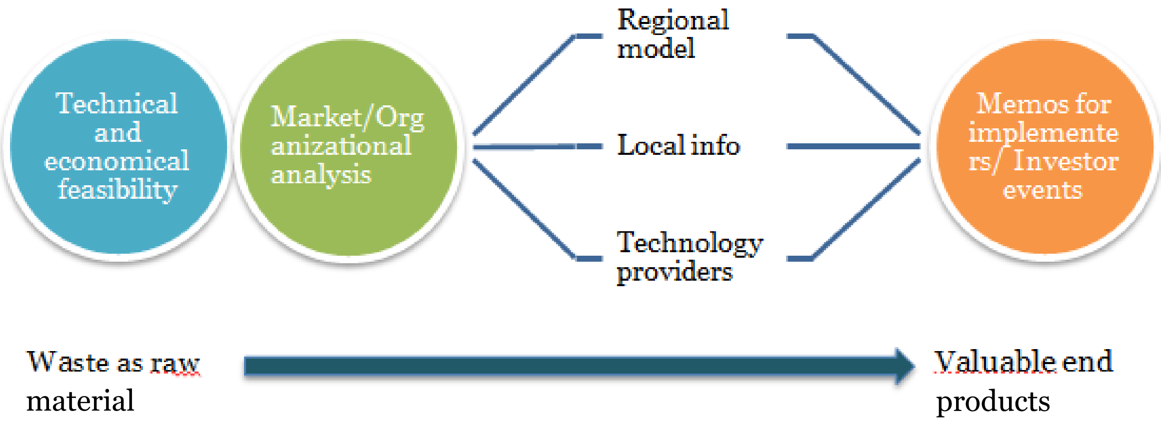

Figure 2. ABOWE project process to develop Investment Memos and Investor Events.

2. Executive summary

The assessment of the responses from key stakeholders regarding the biorefinery piloted by the ABOWE project suggests that:
Main customers interested in implementing the technology are potential biorefinery operators, waste handling companies, bio-waste producers, e.g. food processing industry, and biogas producers.

The substrate that was tested in Västmanland was slaughterhouse waste. This is a challenging substrate but one that is relatively abundant in the region.

The most significant customer needs are to improve waste handling and reduce waste handling fees, something the added value of the substances produced from waste through the biorefinery process could contribute to.

Regarding the technical solution offered by the biorefinery all respondents stated that the main benefit would be to generate an income from the waste, instead of a cost, which is the current situation.

According to the analysis of the responses, the most important resources would be a sustainable access to required substrates as well as a reliable and stable technical solution.

Apart from the operator of the biorefinery, key partners would be abattoirs and other industries producing bio-waste that could be used as substrate for the biorefinery as well as biogas producers, as the residue from the biorefinery can be used for biogas production after the valuable chemicals have been extracted.

The analysis revealed that the most important activities towards full-scale implementation would be to secure the access to substrate and to establish a demonstration site where a specific substrate can be tested for an extended period of time.

The most important revenue streams are sales of the valuable chemicals refined in the process as well as sale of biogas and fertilizer produced in a separate biogas process, using the residue from the biorefinery.

The most significant cost of a full-scale biorefinery would be capital costs of building the biorefinery. Operations and maintenance are also important and substantial costs that have to be taken into account when developing the profit formula.

It is important to pay attention to the preliminary nature of the experiments. Nevertheless, a Proof-of-Concept actualized 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.

3. Operating environment

Political views of handling the waste are changing due to new policies developed by the European Union (EU). The member states of EU have committed to decrease GHG-emissions by the year 2020. EU uses guiding methods to achieve 20% decrease on GHG-emissions. Biorefinery is a rapidly growing sector in Sweden. A shift to a bio-based economy brings vast opportunities, but it also requires research, capacity development, innovation and broad cooperation amongst all stakeholders to ensure a successful shift away from the fossil based economy (Vinnova 2014). Sweden has set the goal that all vehicle fuel shall be produced from renewable sources by 2030, and that a majority of this fuel will be produced in Swedish resource efficient bio refineries. There is a huge market potential in bio-based products that may be of significance to the Swedish economy – if realized. Efforts from the industry, academia and decision makers are required to make this happen. The goal is to produce chemicals, materials and energy carriers have to be produced sustainably and be competitive on the market (Vinnova 2014). A central part of the shift towards a bio-based economy is to develop technology platforms that can be integrated and that can utilize existing resources and processes as efficient as possible. The political and legal environments guide economical aspects by fares and different kind of tax-reliefs and bursaries from EU and government. Between 2014 and 2030 EU is funding European research and development projects for a total amount of 70,2 billion euros (EU, 2014a). The bio-based economy is rapidly growing. According to some estimates bio-based economy in 2040 will have market value around 90 billion euros.

Sustainability is one of the most important criteria when new kinds of technology are developed and used. The foundation of the EU's climate and energy targets is to use the world's resources sustainably. This project follows the same principle (EU, 2014b).

From a technological point of view, the biorefinery sector is mainly focused on producing bioethanol or bio-oil from side streams in Sweden. Waste is commonly used as the resource for these refineries. The number of waste-to-energy operators entering the market in Sweden is increasing. This is likely to result in competition for waste among the different operators. The waste used for the piloting of the ABOWE biorefinery in Sweden was slaughter waste from a chicken abattoir mixed with manure and straw. This waste is currently used for biogas production, which is refined into vehicle gas and used to power municipal buses and other transport vehicles in Västerås. This exemplifies the increasing competition for waste as the demand for vehicle gas is increasing in Västerås, which results in increasing demand for waste. To maximize the outputs from waste it would be optimal if platforms like the ABOWE biorefinery and a biogas plant were combined into one system, which first extracts the valuable chemicals and materials from the substrate in a refinery, then feeding the residue into a biogas reactor to produce methane.

The aim of the piloting of the biorefinery technology in the ABOWE project was to utilize innovative new technology to extract valuable commodities from waste products, e.g. liquid biofuels and other useful chemicals.

4. Energy and chemical markets in testing region

4.1 Products from the refinery

The following products can be produced by the biorefinery process piloted by the ABOWE project, depending on type of raw material: 2,3-butanediol, ethanol, acetone, butanol, hydrogen and methane. It should be noted that some of the chemical products could also be used as an energy source.

4.1.1 Chemical products

The most attractive chemical that can be produced with the pilot plant is 2.3-butanediol, which is a substance used as raw material for synthetic rubber, plastic monomers, anti-icing chemical, textiles, cosmetics and many other substances (Hakalehto et al., 2013).

Other chemicals that can be produced are ethanol, acetone and butanol. Ethanol is an alcohol that can be used as motor fuel, mainly as a biofuel additive for gasoline.

Acetone is a chemical that is one of the most widely used industrial solvents. It is also used more and more as a chemical intermediate. About 75% of the available acetone is used to produce other chemicals. Use of acetone applications range from surface coatings to pharmaceutical applications (Dow Chemical Company, 2014a).

Butanol is an alcohol that can be used as transport fuel. It is also used to produce other chemicals, e.g. products like cosmetics and solvents such as paints, coatings, resins, alkaloids and rubbers (Dow Chemical Company, 2014b).

4.1.2 Energy products

Hydrogen and methane is produced in the process. Hydrogen gas has the highest combustion energy release per unit of weight of any commonly occurring material. It is considered as the fuel of the future due to its non-polluting combustion products (Universal Industrial Gases Inc, 2014). Hydrogen is most commonly produced either as a steam reformation of methane or electrolysis. Hydrogen is also a common by-product from the chemical industry. The use of hydrogen as biofuel for transport is still considered quite expensive due the cost of the fuel-cell system needed to combust the hydrogen. Fuel cell technology will most likely become more developed and cheaper in the future but the growth will only happen in certain areas in the world (Ihonen et al, 2014).

Methane is a gas and it is the main component of natural gas. It is mainly used as a fuel in energy and transport sector.

4.1.3 Fertilizers

The Biorefinery process will always leave some amount of residue. Depending on the quality and composition of the raw material this residue can in some cases be used as fertilizer. Due to high concentration of some substances in the residue that makes the use for food crops unsafe, the most applicable use would be as forest fertilizer. It has been proven that one-time fertilization adds the growing stock in eight years by 13-25 m^3/ha (Yara Finland, 2012).

Fertilizers can also be used in households if harmful substances are removed from the residue.

4.2 Price levels of products

Price levels of the products presented below are all estimated based on information gathered from various reports and Internet sources. Much of the information refers to Finnish prices, which is assumed to be a fair representation of the Swedish situation.

4.2.1 Gate fees

Waste producers pay gate fees to the company that is managing the waste. This makes waste management economically worthwhile. Gate fees are depending on the contents of the waste. Gate fees are also in correlation with the total investment costs of the biorefinery and the profit of the outputs. That way the competitive gate fee amount can be determined. For a small-scale chicken abattoir the annual waste handling fee, i.e. the price charged by the waste handling company for removing and managing the waste, is about 3,000 euros. If the waste from the abattoir becomes a valuable resource, then it is likely that this cost will be turned into an income. The price that a biorefinery would be willing to pay for the waste depends on the value of the chemicals that are produced in the process. But it is likely that there will be a significant reduction in gate fees compared to the current situation.

4.2.2 Energy products

Hydrogen in liquid fuel form costs at the time of the compilation of this report approximately 10 euros per kilo. If hydrogen fuel cell technology takes off in larger scale, estimate is that costs will decrease. Five kilos of hydrogen fuel gives an effective range of about 600 kilometers (Yle, 2014). At the moment there is only few pumping stations for hydrogen in Sweden.

Methane Biogas at pumping stations in Finland currently costs about 1,45 €/kg (Gasum, 2015).

4.2.3 Chemicals

Trends for the market prices of chemicals indicate steady rise. According to the publicly available sources the prices are for example:

- 2,3-butanediol - average price 12 200 EUR/ton;
- Butanol – average price 1200 EUR/ton
- Ethanol average price 1050 EUR/ton
- Hydrogen – average price 700 EUR/ton

2,3-butanediol can be seen as the main high level product (besides other alcohols and acids) due to its multiple uses. It is evaluated that the global market of 2,3-butanediol is around 32 million tons per annum, valued at approximately $43 billion in sales. (Köpke et al., 2011) Because of the unique structure and costly chemical synthesis, 2,3-butanediol has not been produced on a large scale and has a high market price (7 700 – 16 700 EUR/ton). (Ge et al, 2011)

4.2.4 Fertilizers

The price of forest fertilizers differs depending on the type of fertilizer. Yara Finland price levels for forest fertilizers range from 400-529 euros per ton excluding VAT. These are 2012 price levels. Fertilizer price level depends on the nutrient ratio (Mustonen, 2012).

4.3 Competitors

Biorefinery technology is a relatively new form of business in Sweden. Therefore competition is at the moment minimal although some large energy companies are currently investing substantial amounts in research and development within this field.

It is predicted that bioethanol production will increase greatly in the next years to meet the government's climate and energy targets by the year 2020 and forward.

According to SEKAB, a major Nordic producer of ethanol, ethanol is the oldest, largest and fastest growing bio-fuel in the world, being a viable alternative to fossil fuels. 90% of the global consumption of bio-fuel is in the form of ethanol. More than 1500 filling stations in Sweden provide E85 fuel, which is unique in Europe. No other country has invested so much in infrastructure that makes bio-fuel assessable to all (SEKAB, 2014). ED95 is a bio-fuel developed for diesel vehicles, which is being used throughout Sweden for busses and trucks. It is based on bio-ethanol, providing a green alternative fuel for heavy transport vehicles.

Second generation ethanol is being produced in Sweden by degrading cellulose into sugar. Increased use of cellulose ethanol has great positive effects on our climate, contributing to a reduction of CO_2 emissions with as much as 70% from the transport sector. (SEKAB, 2014)

5. Pilot tests

The pilot tests of ABOWE biorefinery in Sweden, reported in (Andersson et al, 2015), had two specific objectives, to determine:

- Proof of technology (e.g. productivity, reliability, through-put time, energy consumption, need for other substances, need for workforce and other technical aspects from pilot plant test runs).
- Technical up-scaling scenarios (from pilot plant to full scale plants)

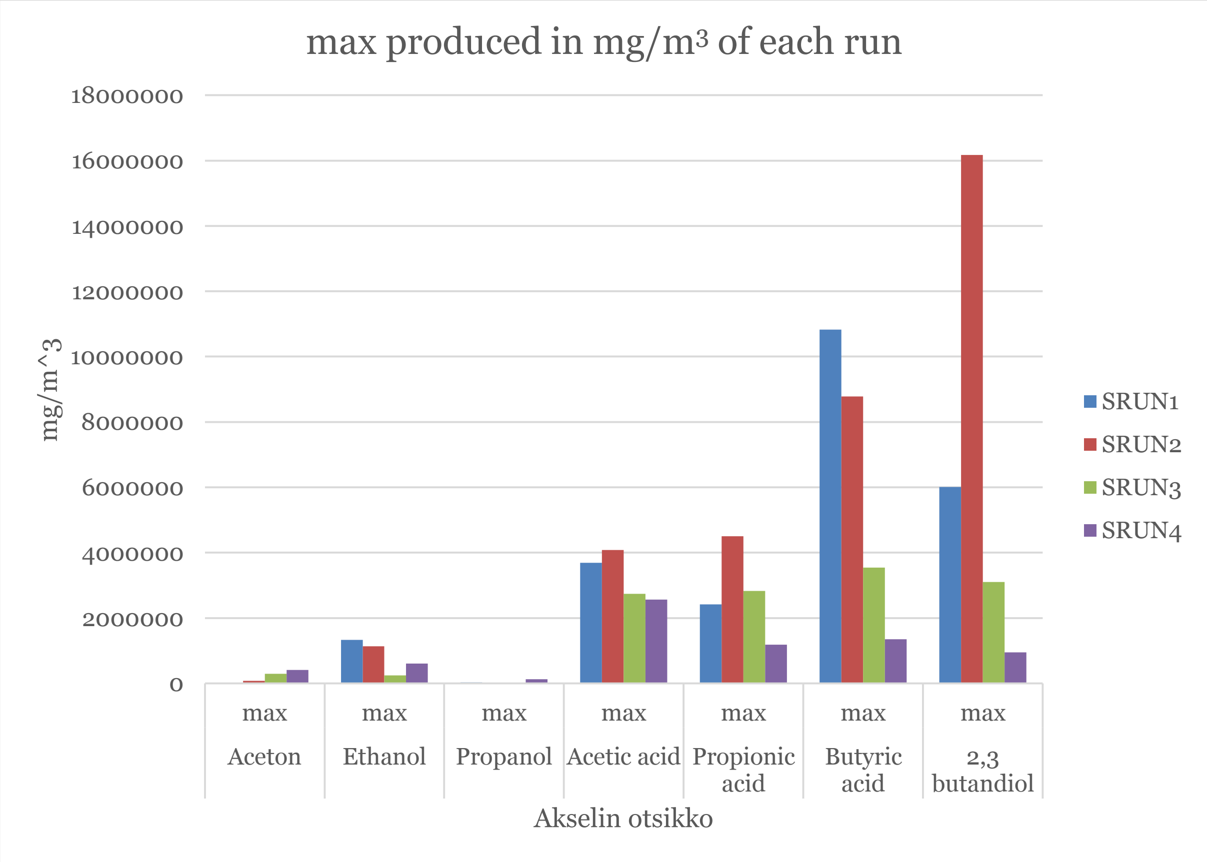

Figure 3. Amount of chemicals produced during the four runs.

The results from the piloting in Västerås presented in Figure 3. shows:

- Production from condition with added oxygen and without oxygen.
- A bigger production with easy accessed carbohydrates and sugars.
- Production from the slaughterhouse waste.
- That there is an ability to optimize the production.

Table 1. Substrate mix for each of the four runs.

Adding	Carbs	Substrate	condition	Microbes
SRUN1	Sugar	straw, feathers, intestines (60kg)	Aerobic	Klebsiella, E-coli
SRUN2	Sugar, potato flour x2	straw, manure/wood, intestines (40kg), peptone, sawdust,	Anaerobic	Clostridium butylicum, Clostridium acetobutylicum, Cellumonas
SRUN3	apples	straw, intestines (100kg)	Anaerobic	Clostridium butylicum, Clostridium acetobutylicum
SRUN4	blueberry soup	manure, saw dust, manure, intestines (34kg)	Anaerobic	Clostridium butylicum, Clostridium acetobutylicum

- The second run gave the highest levels of ethanol, acetic acid, propionic acid and 2,3-butanediol. This might be because of the easy accessed carbohydrates in the added sugars together with the potato flour. The first run where sugar also was added higher levels where obtained than the later runs where sugar was not added.
- Clostridium acetobutylicum and Clostridium butyricum produced organic acids like acetate, propionate and butyrate.
- According to the NMR test in Finland it was shown that acetate and propionate derived by bacteriological activity united together to valeriate or valerian, which is a valuable product.
- It was shown that during the relatively short duration of the pilot process proteins and fats could be used by the clostrids and be measured in acids. These could have been reduced to alcoholic substances and aliphatic substances if there had been more time for the experiment.

6. Feedstock potentials for fermentation processes

Poultry farm related chicken and straw waste potential in Sweden is introduced since it those were selected as biorefinery feedstocks in ABOWE project. In 2012 chicken, turkey and other poultry carcass mass for meat production were 109.67 kt, 3.01 kt and 374.25 kt, respectively (Eurostat, 2014). Still, total carcass consists of available meat for food production and slaughtering waste such as heads and feet. In case of chicken carcass it was reported that slaughtering waste can be 35 % of the total carcass mass (Skytt and Klintenberg, 2013). Thus, chicken slaughtering waste production in Sweden is about 38 000 t/year. For example, at *Hagby* chicken farm slaughtering waste production is annually about 6.912 ton (Skytt and Klintenberg, 2013).

In addition, there is need to find more suitable feedstock such as excess straw for fermentation processes to secure feedstock availability. Excess straw can be one interesting additional waste fraction since it is not considered as food or utilized as bed covering material for domestic animals. It was estimated that straw potential for energy purposes in Sweden is about 830 kt/year that could be used as feedstock for fermentation processes (Ekman, 2013). Thus, distribution of agricultural land reflects also the distribution of straw potential in Sweden (Figure 4).

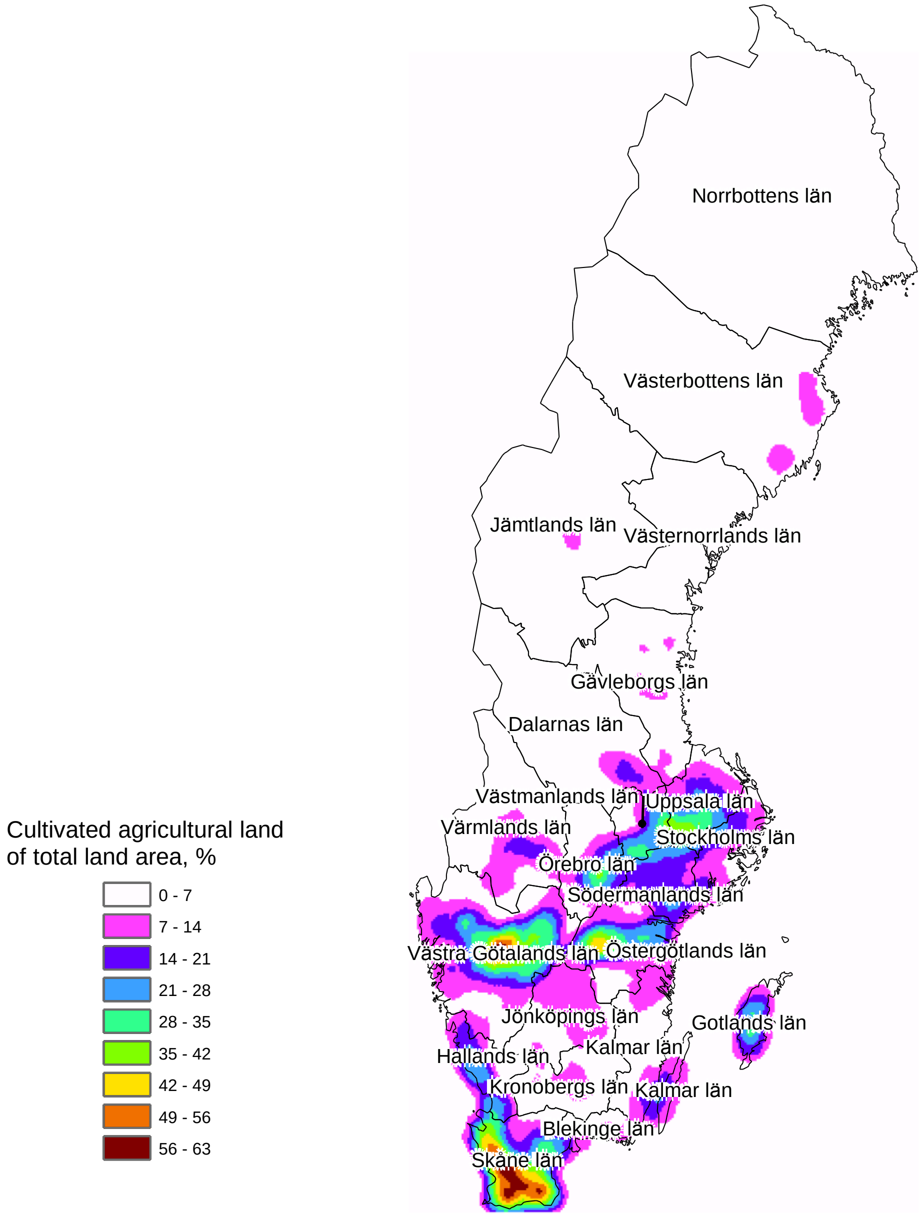

Figure 4. Distribution of agricultural land was calculated from field block data (Jordbruksverket 2014).

7. Greenhouse gas reductions in biorefining

In European Union biofuel production system are expected to fulfill sustainability criteria which are seeing to be favored in current climate policy. Essential part of sustainability criteria is the demand of 60 % GHG reduction compared to fossil fuel reference value after 2018 (2009/28/EC). Thus, GHG reduction performance was evaluated in a biorefinery system which included biochemical production system and biomethane production system (Huopana, 2014). Biochemical production system GHG evaluation was based on basic information about Pilot A operation in ABOWE project. In similar way, GHG evaluation about biomethane system was based on well know physical phenomena about Pilot B which was also tested in the project. It turned out that combined biochemical and biomethane production system would have larger GHG reductions than individual biochemical production system. It is also good to keep in mind that biorefinery and biomethane systems integrated to power production system would further help to degrease overall GHG emissions. It is also suggested that further research work around biochemical and biomethane production systems would concentrate on finding the relations between biomethane productivity from process broth solid fraction and biochemical production system. Still, not forgetting that downstream process plays important role in the overall system. Thus, the impacts of process broth biochemical concentrations, biogas potential of process broth and feedstock total solid concentration on GHG reductions were assessed to evaluate when downstream process is reasonable in GHG reduction point of view (Huopana, 2014).

8. Business model creation

Business models are necessary to communicate effectively with investors. The business model analysis carried out for the up-scaling of the biorefinery technology piloted by ABOWE project at Hagby Farm outside Enköping, Sweden was based on the Extended Business Model Canvas template according to Kajanus et al. (2014). This tool is based on the original Business Model Canvas developed by Osterwalder and Pigneur (2010). The original BMC is based on nine building blocks (Table 2).

Table 2. Building blocks of the business model canvas by Osterwalder and Pigneur (2010).

Building block	Definition
Customer/Competition	
Customer segments	For which customer groups are we offering solutions?
Offering	
Value propositions	Which one of our customer's problems are we helping to solve?
Channels	Through which channels do our customer segments want to be reached?
Customer relationships	What type of relationship does each of our customer segments expect us to establish and maintain with them?
Profit formula	
Revenue streams	For what value are our customers really willing to pay?
Cost structure	What are the most important costs inherent in our business model?
Resources	
Key resources	What key resources do our value propositions require?
Key activities	What key activities do our value propositions require?
Key partners	Who are our key partners required to build the business?

The Extended Business Model Canvas used for developing the business model for Pilot A in Sweden used three more building blocks (Table 3).

Table 3. Additional building blocks (Extended Business Model Canvas) used by ABOWE project.

Building block	Definition
Customer/competition	
Customer needs	Which problem will be solved for the end user or customer?
Company solution	What is the practical offer from the company?
Competitors	Existing of foreseen competition?

Items for the business model blocks were collected in two steps with a survey and interviews with specialists. Questions for the business model survey were created by using the template and answers were analyzed by using decision making tools (Kajanus and Eskelinen, 2014). Stakeholders that contributed to the survey represent the meat industry, waste and energy sectors as well as academia.

Figure 5. illustrates the process for business model design. Phases 2-4 are in relation to business model analysis. After the importance of the items have been evaluated, key items for the business model is selected by Core Index calculations. Core index calculations help identifying the most preferable set of key items.

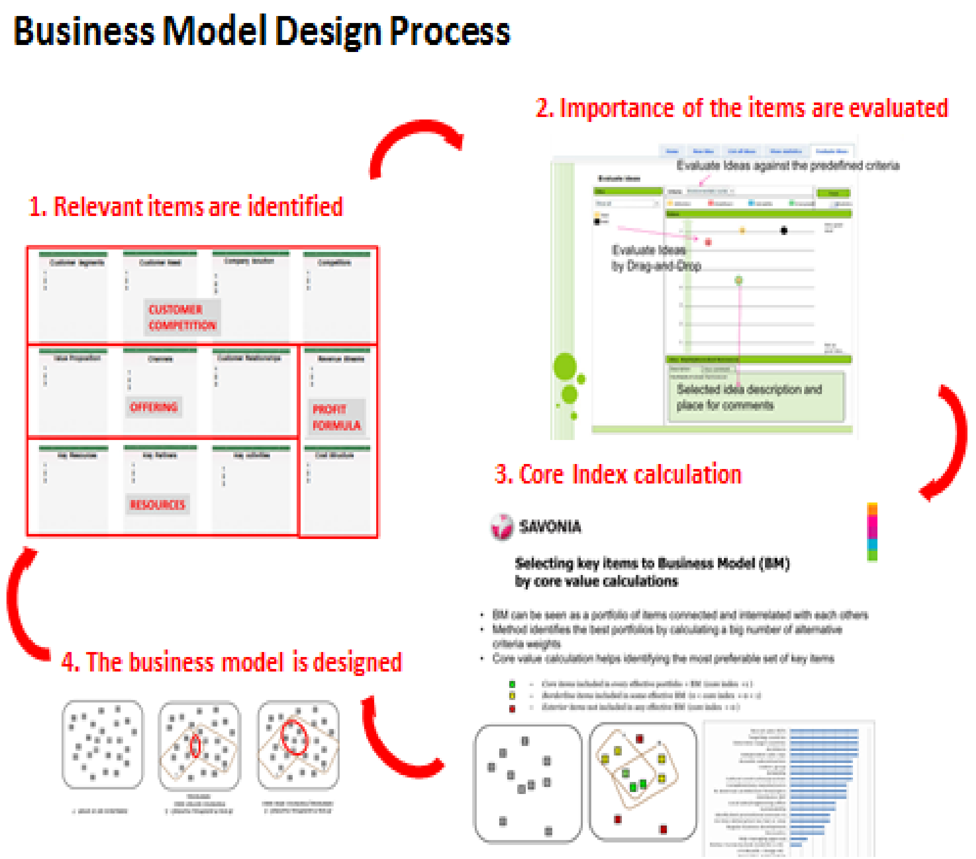

Figure 5. Business Model Design Process. (Savonia InTo tool) (Kajanus and Eskelinen, 2014)

8.1 Business model survey and analysis

The project team carried out the assessment of the responses using the on-line tool 'Savonia Innovation Platform', developed by Savonia University of Applied Sciences within the main stage REMOWE project for which ABOWE is an extension stage project. Specialists were asked to grade the answers from the survey by giving them point from 1 to 7 using two different criteria: productivity and feasibility. The resulting Extended Business Model Canvas is presented in Table 4.

8.2 Results of the Business Model Canvas Analysis

Table 4. Resulting Extended BMC for the Biorefinery based on the Swedish case.

Customer/competition	**Customer segments** 1. Biorefinery operators 2. Waste handling companies 3. Biogas producers 4. Abattoirs 5. Bakeries 6. Food processing industry	**End user, customer need** 1. Improved waste handling 2. reduce costs of waste handling	**Company solution** 1. Improved technology to add value to waste 2. Lower waste handling fees, e.g. reduced gate fees or even payment for waste 3. Eco-friendly branding	**Competitors** 1.Other waste handling companies 2. Other industries producing the same chemicals as produced by the biorefinery
Offering	**Value proposition** 1. Improved waste treatment 2. Fermentation of bio-waste	**Channels** 1. Face to face meetings 2. Seminars 3. Workshops	**Customer relationship** 1. Face to face meetings 2. Seminars 3. Workshops	Profit Formula **Revenue streams** 1. Gate fees 2. Sale of produced chemicals 3. Sale of produced biogas (in separate biogas plant) 4. Sale of residue from biogas process

Resources	Key resources	Key partners	Key activities	Cost structure
	1. Slaughter waste 2. Required substrates 3. Functioning technology 4. Existing market for refined products	1. Municipality with waste issue 2. Biorefinery operator 3. Municipal waste handler 4. Abattoirs and other industry producing bio-waste 5. Biogas producers 6. Engineering and construction companies	1. Secure sustainable access to substrate 2. Establish demo for long term test of specific substrates 3. Make produced chemicals available for independent analysis 4. Assess residue to determine what it can be used for	1. All capital costs of investment 2. Costs of operation and maintenance 3. Handling fees 4. Social and environmental costs

8.2.1 Customer/Competition

The assessment of the responses from key stakeholders suggests that the main customers interested in implementing the technology, or for who the technology would introduce a solution to their current waste management issues are: potential biorefinery operators, waste handling companies, bio-waste producers, e.g. food processing industry, and biogas producers. The substrate that was tested in Västmanland was slaughter waste. This is a challenging substrate but one that is relatively abundant in the region. One major meat producer generates as much as 1,000 tonnes of slaughter waste per annum. Another interesting industry is the bakeries, generating about 400 tonnes of waste per annum, mainly in the form of dough.

The most significant customer needs identified from the survey were a need to improve waste handling amongst several industries in the food processing industry, and the need to reduce waste handling fees. The refinery would contribute to improved waste management as well as producing valuable chemicals, which could lead to lowered waste handling costs.

Regarding the technical solution offered by the biorefinery all respondents stated that the main benefit would be the added value to the waste by extracting valuable chemicals from the waste as well as the long-term possibility of generating an income from the waste, instead of a cost, which is the current situation.

When it comes to competition influencing the viability of the piloted technology, responded that main competitors are other waste handling companies, competing for the same waste, as well as industries already producing the same chemicals as those refined by the biorefinery.

8.2.2 Offering

All respondents stated that the most important offering from the technology is its contribution towards improved waste treatment and the actual fermentation of bio-waste resulting in the refining of valuable chemicals. However, the substrate used in the Swedish pilot, slaughter waste from a chicken abattoir, is rather challenging, requiring extensive testing and fine tuning of substrate composition as well as finding the optimal micro-organisms for the process. When it comes to communication, all respondents stated that the main channels of communication amongst stakeholders would be face-to-face meetings, seminars and workshops. The same channels were suggested for the customer relations.

8.2.3 Resources

According to the analysis of the responses, the most important resources would be a sustainable access to required substrates as well as a reliable and stable technical solution. Apart from a private company that operates the biorefinery, key partners would be abattoirs and other industries producing bio-waste that could be used as substrate for the biorefinery. Another interesting key-partner would be biogas producers, as the residue from the biorefinery can be used for biogas production after the valuable chemicals have been removed.

The analysis revealed that the most important activities for full-scale implementation would be to secure the access to substrate and to establish a demonstration site where a specific substrate can be tested for an extended period of time. This would provide reliable information that can be used by potential investors. Similarly, the produced chemicals should be analysed independently to allow potential investors to make informed decisions towards the viability of the technology for a specific substrate.

8.2.4 Profit formula

The most important revenue streams were said to be sales of the valuable chemicals refined in the process as well as sale of biogas and fertilizer produced in a separate biogas process, using the residue from the biorefinery. Another income that seems to be significant for the waste handling companies is the gate fees, which are paid by the waste producers. However, the income from gate fees is likely to be lost by the waste management companies if the bio-waste is taken to the operator of the biorefinery instead of the waste companies.

The most significant cost of a full-scale biorefinery would be capital costs of building the biorefinery. Operations and maintenance are also important and substantial costs that have to be taken into account when developing the profit formula.

9. Business opportunities

The novel biorefinery developed by the ABOWE project brings several different business opportunities. The container itself can be used to test viability of different substrates at different sites. This presents a business opportunity in itself. A service business can be established renting the container to potential implementers of the technology to test specific substrates. The intention is to build a full-scale biorefinery, which would generate a variety of business opportunities from technology suppliers to operation and maintenance of the plant. At first it is reasonable to start these businesses in one of the partner countries where key resources and competencies are available. During this first phase of full-scale implementation technical as well as managerial concepts would be further developed, establishing a reference site where a successful full-scale installation can be showcased. After the business model and concepts have been successfully implemented then the technology is ready to be established elsewhere.

A full-scale biorefinery can produce energy, chemicals and fertilizers. The process can be adjusted to maximize the output of specific kinds of substrates making this an interesting technology for a broad range of stakeholders in the waste to energy- as well as chemical industries.

9.1 Service business

The biorefinery can also generate business opportunities related to service provision. This requires information that can guide potential customers to identify the most profitable options. For instance, one business opportunity might be to use the waste as an energy source for the own production by investing in a combined biorefinery and bio-energy plant. Another opportunity is to sell the residue to another bio-energy plant. The pilot biorefinery is essential to identify and analyze the potential of these service-businesses. Again, a mobile testing unit would generate results that would form the basis for decisions towards the most profitable solution to a specific waste management and possibly energy related issues. Results of this business opportunity research adds value to potential customers, e.g. providing information that can guide investment and business decisions, as well as new knowledge about innovative solutions to utilize biomass as a source of renewable energy.

In Table 5. a profitability calculation based on data from the two months test period of pilot A at Powerflute Oy Savon Sellu cartonboard factory within ABOWE project is presented. Revenue streams come from selling the service, which is charged by weeks.

Tests of different substrates over longer periods will make the calculations more exact and the service can be more tailored, for example in terms of time and price of specific tests.

A full economic analysis has been done in the Estonian Investment Memo (Lõõnik et al. 2014)

Table 5. Service business profitability calculations are based on testing period of Savon Sellu with Pilot A with assumption of turn-key service solution for 36 testing weeks in a year.

Cost		**cost/year**	
Fixed costs			
Maintenance incl. spare parts		18 000 €	
Installation and packing of Pilot A		2 400 €	
Administration incl. coordination, accounting		35 000 €	
Data handling, reporting		25 000 €	
Total fixed costs			**80 400 €**
Variable costs	**cost/week**	**cost/year**	
Testing personnel	7 800 €	280 800 €	
Consumables	470 €	16 920 €	
Other variable costs	200 €	7 200 €	
Total variable costs			**304 920 €**
Total costs			**385 320 €**
Incomes			
Sold weeks	36		
Service price / week	12 000 €		
Total incomes			**432 000 €**
Total Profit			**46 680 €**

In Table 5. the contributions from Savonia University of Applied Sciences and Finnoflag Oy have been combined without specification. In actual cases the tender will be calculated in more detail and case specifically.

Consumables include process gases, additional chemicals, electricity, water and supplies (e.g. syringes, glucose measurement sheets).

Testing personnel and hence the service price can be far cheaper if

- Process Operator students from Savo Vocational College, Kuopio were participating as trainees and/or
- Environmental Engineering students from Savonia University of Applied Sciences were participating as bachelor thesis workers or trainees.

If testing took place in Finland then there is no need for additional insurance payment. In other countries a special insurance is needed. Transportation of Pilot A will be added to the costs.

9.2 Strategy to a full scale plant

A full-scale plant can either be constructed next to a large industry facility or function as an independent biorefinery collecting raw material from several sources. This could also add an income from gate fees depending on the profit formula that is adopted for the plant. It is also worth considering the construction of a full-scale plant as a research facility.

By building the full-scale plant next to a factory generating the raw materials will result in lowered waste handling costs at the factory. For example costs coming from transporting the waste are practically none, although this gives limitations regarding the volume of waste produced by the factory. In the case of Savon Sellu in Finland, where the plant was places next to a large pulp and paper industry, waste processing costs over 1 million euros per year. That amount is going to rise in the near future when restrictions on processing the biodegradable waste go forward. By introducing a biorefinery at this site with a tailor made process, adjusted to the amount and type of waste being produced would reduce costs significantly and add an extra income by refining valuable chemicals from the waste. (Vehviläinen, 2014).

Biofuels from the process have to be refined so they can be pumped straight to the pumping stations. Particularly hydrogen could have vast potential since it’s the most potent biofuel formed so far. One scenario could be that pumping stations would be built near to the bio refineries. That way pumping stations would have endless supply of fuel coming from the refinery. Piloting has proven this far that waste sludge produced from the biorefinery is highly potential regarding hydrogen.

An independent refinery can also be a viable business. The plant would receive its substrate from companies producing the waste. The business could gain from gate fees paid by the companies delivering the waste as well as from the substances refined from the waste. Depending on the value of the produced chemicals and other products of the biorefinery, and the availability of waste, a situation where waste providers would be paid for their waste can also arise. Companies that could be interested in establishing an independent plant would be municipal and national waste handling companies.

The full-scale plant can also be used as a research facility. Research activities can be purely academic, focusing on the technical and scientific aspects of operating and maintaining the biorefinery, or related to business.

The findings from the piloting of the ABOWE biorefinery reveal that there are many factors that have to be considered when planning the implementation of a full-scale biorefinery. Successful piloting, follow-up projects and investors are essential to get required information and resources to justify the construction of a first full-scale plant.

10. Management plan

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. (World Bank, 1999).

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 (Vehviläinen et al, 2015).

10.1 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.

10.2 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

10.3 Training of workers, codes of practice, and occupational safety and health

The personnel or human resource development departments should be responsible for training workers. 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.

11. SWOT analysis

Figure 6. presents a SWOT analysis of the Finnoflag biorefinery technology based on the findings from the piloting of the ABOWE biorefinery in Sweden.

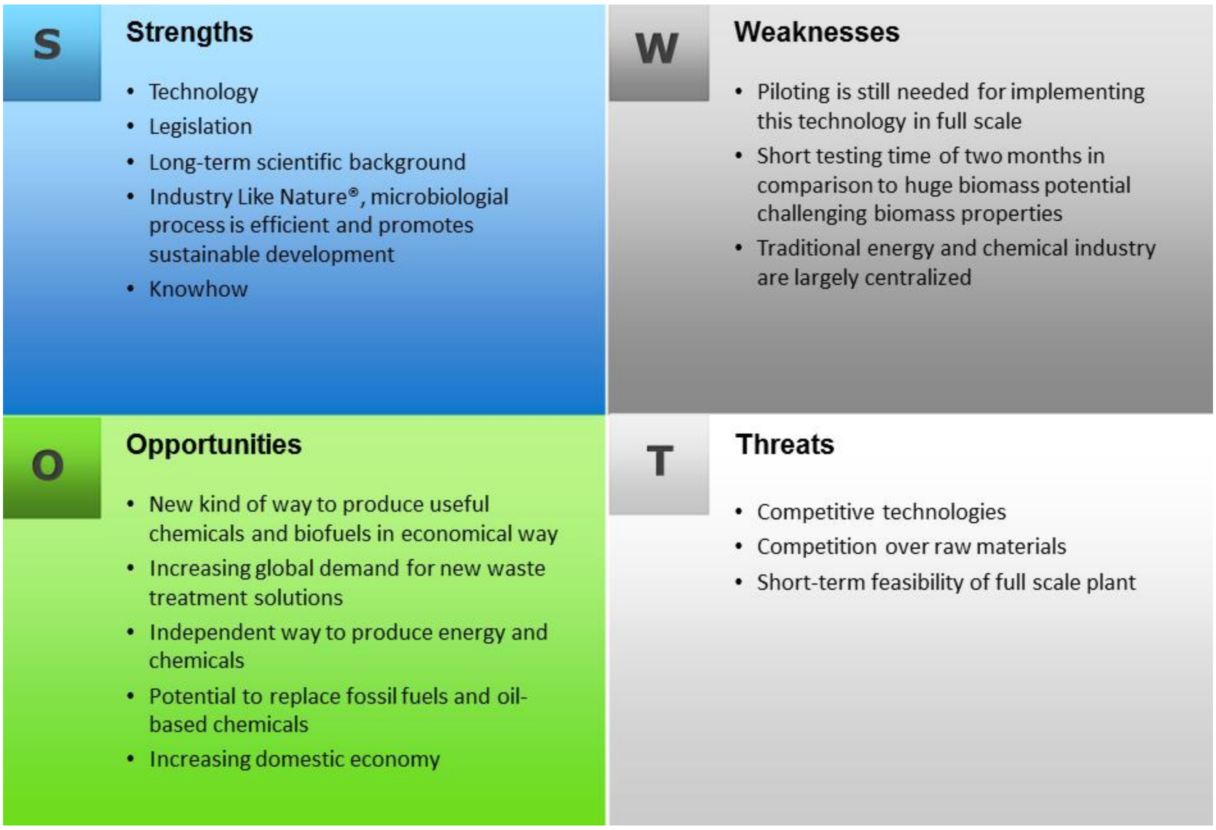

Figure 6. SWOT Analysis

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 according to the registered trademark Industry Like Nature®. This 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. The Swedish tests showed that ABOWE Pilot A provides a tool to quickly convert tedious waste mixtures into useful substrates. During the two month testing period a good starting point for later optimization of the process and the equipment could be obtained. A longer testing is needed for designing an efficient full scale plant. In addition to that traditional energy and chemical industries are largely centralized and it is more challenging for a new technology provider to get into these markets.

Competitive technologies responding to demand of biofuels and waste treatment services are threats to the establishment of a full-scale ABOWE biorefinery. Respondents suggest that competition for waste materials is increasing as more as the number of operators adopting waste to energy technologies is increasing. Before a full-scale plant can be built it is important to secure a sustainable supply of waste for an extended time.

The ABOWE biorefinery provides several opportunities. The pilot plant presents an innovative concept to produce chemicals and biofuels in an economical way. treatment services. At the same time competition over biodegradable waste materials is increasing. To build a full scale plant long-term contracts are needed 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 support increasing global demand for waste treatment solutions and will give a possibility to replace fossil fuels and oil-based chemicals. Domestically produced biofuels and chemicals increase GDP of economies.

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