ESTONIAN BUSINESS MODEL FOR BIO-WASTE TREATMENT

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Jaan Lõõnik, Katri Targama, Patrick Rang, Thea Sogenbits,
Thorsten Ahrens, Merike Välimees, Triin Tomingas, Reljo Saarepera

Front side of Pilot A.

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Implementing Advanced Concepts for Biological Utilization of Waste

Table of Contents

Foreword

Disposal and treatment of biological waste (bio-waste) represents a major challenge for the waste industry. For a wide range of organic substances from agriculture, foodstuff of feed industries, anaerobic fermentation is a superior alternative to composting or other ways of recycling. The main and widely used product of bio-waste fermentation is biogas that can be used for producing electricity and heat. Two Baltic Sea Region programme 2007-2013 R&D projects ABOWE and REMOWE[1] developed the possibilities further - to convert the various wastes into valuable products (ethanol, butanol, 2,3-butanediol, organic acids) and by this to maximise the revenues received from recycling of the bio-waste in industrial scale.

Although the production of renewable energy from bio-waste is one of the EU as well Estonian important environmental targets, the investments for biogas production (cogeneration of heat and power and/or fuel production) in Estonia need additional support and financing (e.g. from state or EU structural funds)[2], as the price of biogas obtained from bio-waste is not competitive compared to the price of gas obtained from other resources. Additionally it should be underlined, that world market prices on crude oil and natural gas have been recently dramatically decreased (from $96 in September 2014 to below $80 per barrel in November 2014)[3]. Therefore it can be estimated, that the price of biogas can lose the competitiveness even more and the interest for production the biogas in Estonia will not be very attractive even for companies who already the necessary capacity for production. The high initial investment costs also do not encourage new enterprises to enter into the market under current conditions.

ABOWE and REMOWE projects developed an alternative solution to the problem. Instead of biogas, the main focus of the solution is to produce high-level chemical products that have a high-market value and that do not have to compete under such unfavourable conditions as biogas production. This Estonian business case uses the results of ABOWE and REMOWE to model indicative business plan for producing not only electricity, heat and/or fuel but high

[1] For details please see above

[2] See: http://www.energiatalgud.ee/img_auth.php/a/a6/Oja%2C_A._Biometaani_kasutamise_avalikud_h%C3%BCved.pdf

[3] http://www.nasdaq.com/markets/crude-oil.aspx

market value chemical products as the main output. The initial calculations show that repayment period of the investment, depending on financing conditions is 2-3 years.

The business model also includes the general marketing aspects and arguments for attracting the possible investors.

Business model in nut-shell

The current business model is based mainly on the outcomes of two interrelated and consequent Baltic Sea Region Programme 2007-2013 projects: REMOWE[4] and ABOWE[5]. The business model for Estonia is developed in the frames of ABOWE project and is an output of Work Package (WP2)[6]. The objective of the WP 2 is to gather and communicate information about technologies which are piloted with Pilot A (mobile bio-refinery plant) and Pilot B (anaerobic digester) to support investment decisions for full scale plants.

The business-model concentrates on the possibility not only to produce biogas (for electricity and heat) but to convert the various wastes into valuable products (ethanol, butanol, 2,3-butanediol, organic acids) and by this to maximise the revenues received from recycling of the bio-waste in industrial scale.

As currently there is only pilot (prototype) available, it should be underlined, that the costs of investment (full-scale production plant with downstreaming technology for products) as well as the quantities of the products are based on highly experimental and laboratory activities in development of the ABOWE and REMOWE project.

The financial-analysis for the business plan is based on:

- Initial investment costs
- Expenditures occurred in testing of the Pilot A and Pilot B (variable costs);
- Estonian average labour costs in the similar sector, depreciation, interest, land, etc.;
- Costs of similar activities analysed elsewhere[7];
- Market prices of the end-products (publicly available sources);
- Other investment memos (Lithuania and Finland) prepared within the ABOWE project.

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4 Regional Mobilizing of Sustainable Waste-to-Energy Production

5 Implementing Advanced Concepts for Biological Utilization of Waste

6 O 2.7 Investment memo and Investor event around Pilot B in Estonia.

7 http://www.biogasin.org/files/pdf/WP3/D.3.7_IWES_EN.pdf
http://www.tartu.ee/data/Biogaasijaama%20rajamine%20Tartusse%20TTA.pdf
http://elering.ee/public/Elering/Uuringud/Biometaani_avalikud_huved_ja_kasutamise_eeldused_Eesti_transpordis.pdf

By using this model the interested investors can easily make their own financial projections for the investment depending on the performance indicators of the concrete plant, available resources in the region, need for loans (interest rates of the banks), etc.

The current model explores the possibilities of establishing the full-scale plant in Estonia. However, by using same or similar financial information the model can be adapted to other regions of the Baltic Sea.

Current state of play for developing the business idea

Various internal and external factors influence both developing the business idea and its future implementation. These factors have to be analysed, interpreted and put into the context of how they influence the current business idea. Some factors have a positive influence (impact) upon the business idea, while some include certain risks. The positive factors should be amplified, while mitigation measures should be present to minimize the effect of negative factors. In order to give a systematic overview of the current state of play and of the various factors, the following internationally acknowledged techniques are used[8]:

- Political-economic-social-technological-environmental analysis (PESTE[9]), specifically adjusted for the current business case. The chosen approach takes into consideration the relevant framework in which the business case is operational and enables to concentrate on the critical external factors that can affect business activities and performance. The underlying principle is to analyse the business case "from outside", in relation to the case itself. The following factors will be analysed:
    - Political –regulations and legal factors; assessed in terms of their ability to affect the business environment and trade markets.
    - Economic –economic issues that have an impact and are relevant to the business sector as a whole and for the particular company.
    - Social – socio-economic environment of the market, relevant to the business sector as a whole and for the particular company.
    - Technological – possible technology-related positive or negative impacts of introducing the product or service into the market.
    - Environmental – specific environmental aspects focusing at the need for conducting environmental impact assessment prior to "putting the business case

[8] The chosen combination is based on the recommendations made by Keith. W. Glaister and J. Richard Falshaw 1999 ("Strategic planning: Still Going Strong?" in Long Range Planning, Vol. 32, No. 1, pp 107-116) as well as by Michael Porter 1980 (Competitive Strategy, 1980)

[9] We have adjusted the classical PESTLE analysis (political-economic-social-technological-legal-environmental) and incorporated the legal aspects into the political analysis.

into practice", following the European Commission checklist for Environmental Impact Assessment[10]

- Strengths-weaknesses-opportunities-threats analysis (SWOT). The underlying principle of the chosen approach is to complement the PESTE analysis with a view "from inside" and to position the business-case in relation to the external environment. The following aspects will be analysed:
  - Strengths – different positive aspects the business case embraces and which, if properly amplified, will ensure the success of the business-case both on macro- and micro-level;
  - Weaknesses - different negative aspects the business case embraces and which need to be minimized and mitigated to ensure the success of the business-case both on macro- and micro-level;
  - Opportunities – different external factors (see PESTE) that could be helpful for the business-case both on macro- and micro-level;
  - Threats - different external factors (see PESTE) that could be harmful for the business-case both on macro- and micro-level;
- "Value-chain-model" developed by Michael Porter. The underlying principle of the chosen approach is to unite and combine the results of the PESTE and SWOT analysis to define the critical success factors and competitive edge for the business case both on macro- and micro-level. The "Value-chain-model" will mainly be used by the technology owners to market the solution to the potential investors.

PESTE analysis

Political and legal factors

EU Member States agreed to three targets for 2020 related to energy and climate change, often referred to as the 20/20/20 package[11]:

1. A 20% reduction in green-house gases (GHG) emissions in 2020 compared to 1990 levels;
2. A 20% share of renewable energy in the EU energy mix in 2020;

[10] http://ec.europa.eu/environment/archives/eia/eia-guidelines/screening_checklist.doc

[11] By 2030 the targets are even more ambitious, see http://ec.europa.eu/clima/policies/2030/index_en.htm

3. 20 % energy savings in 2020 compared to projected business as usual levels.

In the 7th Environment Action Programme (EAP) EU has put forward an ambitious vision for the year 2050: "*In 2050, we live well, within the planet's ecological limits. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a safe and sustainable global society*."[12] EAP focuses at turning "the Union into a **resource-efficient**, green, and competitive low-carbon **economy"** for which "better **information** by improving the knowledge base" is needed and "more and wiser **investment** for environment and climate policy" will have to be made. Furthermore, EAP should "help the Union **address international environmental** and **climate challenges more effectively"**.

At the same time, Europe wants to strengthen its manufacturing base through raising its contribution to the EU's gross domestic product (GDP) to 20% by 2020 (European Commission, 2012a). A possibility to combine the somewhat incommensurable objectives is to increase the share of recycling and reusing waste. The focus of these activities should be to produce as much high-level and high market-value end-products from the waste as possible and to decrease the use of waste as landfill or burning material.

The amount of waste generated in EU-27 is enormous and the recycle rates should be considerably increased. Especial attention should be paid to bio-waste as it is relatively homogeneous, cheap, accessible and easy to handle. Furthermore bio-waste has a high potential for turning low level inputs (landfill, compost), medium level (electricity and heat) to high level and high market value outputs (different chemical compounds, new products,).

According to Eurostat[13] the total amount of waste –generated annually in EU-27 is 2 502 million tonnes, of which households contributed 219 million tonnes (8.7 %). The relatively low share of total waste that was generated from agriculture, forestry and fishing activities (NACE Section A) is, at least in part, linked to manure and slurry being excluded from the data presented (as long

[12] See: Decision No 1386/2013/EU http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013D1386
[13] http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/File:Waste_generation,_2010_(1_000_tonnes)_YB14.png

as they are re-used within agriculture as a fertiliser or a soil improver). For detailed information and share of different types of waste please see the table below.

	Waste from economic activities and households		Agriculture, forestry & fishing (Section A)	Mining & quarrying (Section B)	Manufacturing (Section C)	Energy (Section D)	Construction & demolition (Section F)	Other economic activities (Sections E and G to U)	Households
	Total	of which, hazardous							
EU-28	2 505 400	101 370	39 440	671 780	275 580	86 040	859 740	354 230	218 590
EU-27	2 502 240	101 300	39 420	671 750	274 950	85 930	859 730	351 870	218 590
Belgium	62 537	4 479	231	1 701	14 543	1 210	18 165	22 008	4 679
Bulgaria	167 203	13 542	618	150 214	3 306	8 032	79	2 557	2 396
Czech Republic	23 758	1 363	114	115	4 202	1 540	9 354	5 099	3 334
Denmark	20 965	1 784	201	41	1 919	517	3 176	12 676	2 436
Germany	363 545	19 931	256	24 493	48 981	9 087	190 990	53 426	36 312
Estonia	19 000	8 962	110	6 453	3 716	6 534	436	1 320	430
Ireland	19 808	1 972	101	2 196	3 259	334	1 610	10 578	1 730
Greece	70 433	292	5	44 793	4 941	11 029	2 086	2 381	5 198
Spain	137 519	2 991	5 817	31 732	16 480	2 339	37 947	20 006	23 198
France	355 081	11 538	1 682	1 053	20 382	993	260 226	41 439	29 307
Croatia	3 158	73	14	29	634	108	8	2 365	0
Italy	158 628	8 543	311	706	35 928	2 660	59 340	27 204	32 479
Cyprus	2 373	37	129	382	132	3	1 068	198	461
Latvia	1 498	68	68	1	375	25	22	314	694
Lithuania	5 583	110	456	7	2 653	68	357	782	1 261
Luxembourg	10 440	379	3	18	498	2	8 731	803	385
Hungary	15 735	541	488	87	3 134	2 718	3 072	3 372	2 865
Malta	1 288	17	3	0	9	1	989	149	138
Netherlands	119 255	4 421	3 948	184	14 094	1 156	78 064	12 737	9 072
Austria	34 883	1 473	550	269	2 958	453	9 010	17 019	4 623
Poland	159 458	1 492	1 543	61 547	28 618	20 291	20 818	17 751	8 890
Portugal	38 347	1 625	193	1 206	9 766	456	11 071	10 193	5 464
Romania	219 310	666	18 353	177 404	7 862	5 888	238	3 438	6 127
Slovenia	5 159	120	141	12	1 517	558	1 509	694	728
Slovakia	9 384	415	526	166	2 669	878	1 786	1 641	1 719
Finland	104 337	2 559	2 772	54 851	15 211	1 445	24 645	3 732	1 681
Sweden	117 645	2 528	309	89 026	7 823	1 479	9 381	5 589	4 038
United Kingdom	259 068	9 447	494	23 092	19 970	6 239	105 560	74 764	28 949
Liechtenstein	312	8	0	12	32	0	0	268	0
Norway	9 433	1 763	195	366	2 687	28	1 543	2 385	2 229
FYR of Macedonia	2 328	150	0	855	1 017	4	0	0	451
Serbia	33 623	11 145	0	26 458	1 146	6 019	0	0	0
Turkey	783 423	0	0	723 791	11 406	18 578	0	60	29 587

Source: Eurostat (online data code: env_wasgen)

Table 1 Waste generation by economic activity and household, 2010[14] (1 000 tonnes)

According to Estonian Strategic Waste Management Plan 2014–2020[15] the production of bio-waste and biodegradable waste in year 2011.was 1.2 million tons including

- Timber and wood waste 795 000 tons;
- Sewage sludge 158 900 tons (15% dry ingredients concentration);
- Paper and cardboard 112 000 tons. (including packaging materials ca 55 000 tons, ca 44 000 tons of reclaimed paper);
- Bio-waste123 000 tons.

14 Planned update by Eurostat: January 2015

15 (http://www.envir.ee/sites/default/files/riigi_jaatmekava_2014-2020.pdf)

However, practically all the sewage sludge will be recycled as composting and / or stabilisation. The market demand for the product is low due to its restricted possibilities of using. Companies producing the compost have been in difficulties to finding clients[16].

As a conclusion, it is clear that EU and Estonian policies concerning environmental issues and reuse of bio-waste strongly support new and innovative initiatives in the field.

Economic factors.

The economic factors largely consist of three aspects:

1. Market potential of the products to be developed;
2. Availability and cost of resources;
3. Economic environment and competition.

Market potential of the products

It is foreseen that the main products produced from bio-waste are 2,3 butanediol, butanol, ethanol and hydrogen[17]. Therefore the market potential of these products will be assessed in the context of the overall chemical industry potential.

The European chemical industry holds globally a good position. When including both EU and non-EU countries, total sales for the region were € 673 billion in 2011 – 21.5 per cent of world chemicals sales in value terms. However, as the worldwide competition is getting fiercer, the European Union has lost its top ranking in sales to China. Germany is the largest chemicals producer in Europe, followed by France, Netherlands and Italy. Altogether these four countries generated 62.6 per cent of EU chemicals sales in 2012.

Looking ahead, the European chemical industry continues to face relentless global competition. Access to raw materials and energy at globally competitive prices remains a prerequisite for a successful recovery of the EU chemicals sector.

[16] ibid

[17] Biogas will be considered as by-product, what will be used for self-sustainability of the plant (cogeneration of heat and power and/or fuel production), the surplus however will be handled as product

The chemical industry transforms energy and raw materials into products required by other industrial sectors as well as by final consumers. The cost of energy and raw materials is a major factor in determining the competitiveness of the EU chemical industry on the global market. In 2011, the fuel and power consumption of the EU chemical industry, including pharmaceuticals, amounted to 55.6 million tonnes of oil equivalent (TOE). Regarding other raw materials, the chemical industry also uses a wide variety of natural and processed feedstock, including metals, minerals and agricultural raw materials such as sugar, starch and fats.[18]. One of the main issues that has brought along the wide-spread research into the possibility to use bio-based raw materials is the fact that chemical production from non-bio-based raw materials creates as by-products considerably more hazardous chemical compounds.

Investments in innovation, including research and development (R&D) are key elements in securing the future of the chemical industry. They not only promote the adaptation to and the development of new technologies and innovation, but are necessary prerequisites for the continuous adjustment of corporate structures to the needs of the market.

According to the European Environmental Agency (EEA), the European chemical industry, including pharmaceuticals, emitted a total of 53.9 million tonnes of CO2 equivalent in 2011, down from a total of 327.3 million tonnes in 1990. This was achieved thanks to the chemical industry's conscious effort to develop cleaner and safer technologies, waste recycling processes and new products to safeguard the environment, and above all to increase energy efficiency. As well as increasing energy efficiency of its own processes, innovations in the chemical industry also help to increase the energy efficiency of downstream users and their products.

The environmental issues have paid an important role in determining and shaping the future of chemical industries. During the last decades European Union (EU) has put considerable effort to help solving the environmental problems the world faces. The activities have, by and large, been targeted at two strands – preserving the environment (through reducing current pollution and overcoming the effects of previous polluting activities) and improving the use of natural resources (through introducing and implementing various recycling activities). As a result, environmental pollution has been considerably reduced, use of hazardous substances restricted and regulated etc. In recent years the focus has more and more turned to sustainable growth i.e.

18 http://asp.zone-secure.net/v2/598/765/42548/Cefic-Facts-and-Figures-.pdf

achieving growth which can be maintained without creating economic or environmental problems for future generations.

Estonia is not an exception. The 50 years of Soviet occupation had a twofold impact on the environment: on one hand the imposed restrictions (especially in the coastal areas) for economical activities and overall movement helped to sustain the natural conditions; on the other hand the irresponsible industrialization, exceeds in fertilisation and the direct harm caused by the activities of the Soviet Army outweigh the positive implications. Furthermore, all the negative aspects were hidden from the civil authorities and the public, therefore the information about the actual environmental situation was not known. The industrial production of chemical compounds paid little (if any) attention to the environmental issues and the ecological footprint of any product was enormous.

In Estonia, the policies, strategies and activities have followed, in principle, those of EU (prior and after to the accession to EU) with a strong emphasis on "getting the picture and information correct" (i.e. assessing the situation based on relevant and reliable data). By now the situation has considerably improved, especially from the point of view of overall environmental assessment. The production of chemical compounds corresponds to the internationally acknowledged standards and the use and deposition of hazardous substances is likewise regulated.

Bio-waste is rarely used for producing the chemical compounds, although high-level products can be obtained from it (for example alcohols, acids etc.). Those chemical compounds have a considerably higher price in the market compared to the low- and middle level products (such as compost, landfill or even biogas). It means that the full potential of bio-waste is not used and the price of unit of product obtained from recycled waste is considerably lower than it could be. The high-level products are insofar usually obtained directly from raw materials, but this is not economical and environment-friendly to use of raw materials, if bio-waste can be used. The bio-waste is not used as effectively and efficiently as it could and the financial rate of return is low.

The need for chemicals produced as a result of the investment is high and trends for the market prices 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

We foresee 2,3-butanediol as the main high level product (besides other alcohols and acids). It was chosen for both technological (preliminary tests in the ABOWE project have shown, that high-quality 2,3-butanediol may be produced from different bio-waste) and economic reasons. 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[19]. Because of the unique structure and costly chemical synthesis, 2,3-butanediol has not been produced on a large scale and its high price (7 700 – 16 700 EUR/ton)[20].

The average price of biogas in Estonia is 520 EUR/ton (fuel) or if sold directly to grids electricity (together with subsidy for renewable energy) 90 EUR/MWh and in average 35 EUR/MWh for district heating grid.

Currently the possibilities to recycle bio-waste (both globally and especially in Estonia) are rather limited, depending heavily on the availability of recycling possibilities in the vicinity (bio-waste is a local product and it cannot usually be transported to large distances). The majority of recycling possibilities (both organised or managed by the waste-owner as well as those outsourced) still concentrate of the low- and middle level products. Thus the majority of bio-waste is re-used as compost or landfill, to some extent it is used as a source to produce bio-gas. The results of REMOWE and ABOWE projects enable on one hand to widen the possibilities in terms of production (high market value alcohols, acids, esters, etc.) and on the other hand, enable to mix different types of waste as raw material, thus widening the possibilities to use the local bio-waste resources.

Estonian chemical industry is rather small, comprising approximately 0.8 per cent of Estonian GDP and 5.2% of manufacturing industries as a whole. The peculiar characteristic of chemical

[19] http://aem.asm.org/content/77/15/5467.full

[20] *Journal of Biomaterials and Nanobiotechnology*, 2011, 2, 335-336 doi:10.4236/jbnb.2011.23041 Published Online July 2011

industry is its concentration at two main issues: oil-shale chemistry and production of rare earth metals and their oxides. In addition to that the Estonian chemical industry is characterized by strong territorial concentration, as more than half of the chemical industry is located in one region (Ida-Virumaa). Thus the development of the chemical industry takes place to a considerable extent under these strands. In the context of the current business model, the potential for producing high market value products from bio-waste has not been analysed in Estonia. Nor has due attention been paid to developing chemical industry outside Ida-Virumaa.

In Estonia the potential for producing biogas has been assessed for 380 million Nm^3, including 75 million Nm^3 of recycled digestate (including slurry)[21]. In 2012 the estimated actual production of biogas was[22] 25 million Nm^3 (6.5 % of the whole potential). It can be stated that more than 90% of the available potential has not been currently used. Unfavourable competition situation (see above) has been one of the reasons why only such a small part of the available potential has been realised.

The human resources needed for handling the processes are (depending of the capacity of the plant) are 1-3 persons with technical qualifications (process operation and maintenance), the number of direct average annual working hours is approximately 2080 (1 FTE). The staff for handling the processes does not need any specific chemistry-related background or experience. Other necessary chemical and biological expertise and knowhow will be outsourced.

There are currently no companies producing 2,3-butanediol in Estonia. The highest level product produces currently from bio-waste in Estonia is biogas. There are currently 5 bio-gas plants and 4 landfills producing biogas for electricity in Estonia (the total amount produced in 2013 was 32 035 MWh and in 2014 (first 9 months) 30 192 MWh[23]). Currently a new biogas production plant was opened by AS Estonian Cell (total investment of 11 million EUR), largely it will consume the gas in its own production (3 range of Aspen BCTMP (Bleached Chemo Thermo Mechanical Pulp)). It has been indicated above, that the Estonian bio-waste potential is still used less than 10% and there is room for new plants.

21 http://www.eby.ee/BIO/Laiendatud_kokkuvote_2014.pdf p. 11

22 http://www.energiatalgud.ee/img_auth.php/a/a6/Oja%2C_A._Biometaani_kasutamise_avalikud_h%C3%BCved.pdf p 12

23 http://www.veeb.eestibiogaas.ee/wp-content/uploads/2014/10/EBA-3_uudiskiri-aug-okt_2014.pdf

Compared to many other EU countries (UK, Sweden, Germany, Finland, Denmark, Czech, Austria)[24] in Estonia the biogas is equal to the all other fuels and gases is taxed with the excise duties. Estonian Parliament adopted changes in laws that respectively from 2015 free the biogas from excise tax and currently the application for enabling the state aid has been sent to the European Commission. Although this rises the competitiveness of biogas in Estonia, but as world market prices on crude oil and natural gas have been recently dramatically decreased (from $96 in September 2014 to below $80 per barrel in November 2014), it may be estimated, that the price of biogas can lose the competitiveness even more and the interest for production the biogas in Estonia will not be very attractive, as the investment costs for production will be far too high.

In order to make re-use of bio-waste more attractive and maximise the revenues this business model provides an excellent opportunity by the technical solution what enables to develop high market value and high market demand chemical products. The technology is innovative and not in currently not in use.

Social factors

The increasing population in Europe produces (per person) more and more bio-waste, both directly (municipal waste) and indirectly (as residues of producing different goods for the population). EU regulations have strived to maximise the use of bio-waste, but a lot has still to be done. At the same time, people are becoming increasingly environment-conscious and they do demand that the production of waste should be minimised and the residue is to be used effectively and efficiently (including as much to be recycled as possible). On the other hand, the high-level products obtained from bio-waste can be sold on the global market, thus creating extra revenue for the waste-owner.

In general it can be stated, that social impact is highly positive, although the plant itself will not bring along direct creation of several work places, but it creates indirect workplaces in adjacent areas (agriculture, transport, etc.).

The most important impact is that local living environment will be improved:

24 http://european-biogas.eu/

- Reduction of the CO2 and greenhouse gas emissions helps to improve the quality of air;
- The fermentation process used in the plant reduces considerably foul odours, that are especially problematic in places where slurry or sewage sludge is recycled/composted;
- The recycling of bio-waste (especially municipal waste, industrial waste) helps to use the resources in environmentally-friendly way.

As the consumers nowadays are environmentally very conscious, they prefer to buy from those companies who have involved recycling and sustainable environmental principles into their policies. Thus companies recycling its production residues and/or producing from recycles materials have a socially motivated competitive advantage.

Environmental factors

Another important aspect that has to be considered is the possible environmental impact of the mobile bio-refinery plant. The European Commission checklist for Environmental Impact Assessment[25] (EIA) was used. As the significant effect to all analysed aspects was assessed as negative ("no"), the column "Is this likely to result in a significant effect?" was not used

Question	Yes / No
1. Will construction, operation or decommissioning of the mobile bio-refinery plant involve actions which will cause physical changes in the locality (topography, land use, changes in water-bodies, etc)?	No. The mobile bio-refinery plant (MBRP) will be constructed in a manufacturing enterprise where all the mentioned aspects have been already taken into account as part of the overall process design. Operating and decommissioning of MBRP causes no physical changes in the locality.
2. Will construction or operation of the mobile bio-refinery plant use natural resources such as land, water, materials or energy, especially any resources which are non-renewable or in short supply?	Yes. Construction of MBRP uses water, materials and energy. The operation of MBRP uses water and energy. MBRP is self-sustainable, i.e. the energy used comes from the recycling of bio-waste itself.

25 http://ec.europa.eu/environment/archives/eia/eia-guidelines/screening_checklist.doc

Question	**Yes / No**
3. Will the mobile bio-refinery plant involve use, storage, transport, handling or production of substances or materials which could be harmful to human health or the environment or raise concerns about actual or perceived risks to human health?	Yes. Such substances and materials are involved in both constructing and operational phase. In case of following correct and accurate measures, the related risks are minimal both in the construction and operational phase. These measures are included in the working-principles of MBRP and the manufacturing enterprise.
4. Will the mobile bio-refinery plant produce solid wastes during construction or operation or decommissioning?	Yes Solid wastes produced during the construction phase will be handled according to their type following the national and international regulations for handling such type of waste. As much as possible, the waste will be recycled. Solid waste produced during the operation phase will be recycled as much as possible, including in the process itself.
5. Will the mobile bio-refinery plant release pollutants or any hazardous, toxic or noxious substances to air?	No
6. Will the mobile bio-refinery plant cause noise and vibration or release of light, heat energy or electromagnetic radiation?	No
7. Will the mobile bio-refinery plant lead to risks of contamination of land or water from releases of pollutants onto the ground or into surface waters, groundwater, coastal wasters or the sea?	No
8. Will there be any risk of accidents during construction or operation of the mobile bio-refinery plant which could affect human health or the environment?	Yes Such risks occur both during the construction and operation phase of MBRP. In case of following correct and accurate measures, the related risks are minimal both in the construction and operational phase. These measures are included in the working-principles of MBRP and the manufacturing enterprise.
9. Will the mobile bio-refinery plant result in social changes, for example, in demography, traditional lifestyles, employment?	No
10. Are there any other factors which should be considered such as consequential development which could lead to environmental effects or the potential for cumulative impacts with other existing or planned activities in the locality?	No

Question	Yes / No
11. Are there any areas on or around the location which are protected under international or national or local legislation for their ecological, landscape, cultural or other value, which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
12. Are there any other areas on or around the location which are important or sensitive for reasons of their ecology e.g. wetlands, watercourses or other water-bodies, the coastal zone, mountains, forests or woodlands, which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
13. Are there any areas on or around the location which are used by protected, important or sensitive species of fauna or flora e.g. for breeding, nesting, foraging, resting, over-wintering, migration, which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
14. Are there any inland, coastal, marine or underground waters on or around the location which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.

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Question	Yes / No
15. Are there any areas or features of high landscape or scenic value on or around the location which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
16. Are there any routes or facilities on or around the location which are used by the public for access to recreation or other facilities, which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
17. Are there any transport routes on or around the location which are susceptible to congestion or which cause environmental problems, which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
18. Is the mobile bio-refinery plant in a location where it is likely to be highly visible to many people?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.

Question	Yes / No
19. Are there any areas or features of historic or cultural importance on or around the location which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
20. Is the mobile bio-refinery plant located in a previously undeveloped area where there will be loss of greenfield land?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
21. Are there existing land uses on or around the location e.g. homes, gardens, other private property, industry, commerce, recreation, public open space, community facilities, agriculture, forestry, tourism, mining or quarrying which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
22. Are there any plans for future land uses on or around the location which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.

Question	Yes / No
23. Are there any areas on or around the location which are densely populated or built-up, which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
24. Are there any areas on or around the location which are occupied by sensitive land uses e.g. hospitals, schools, places of worship, community facilities, which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
25. Are there any areas on or around the location which contain important, high quality or scarce resources e.g. groundwater, surface waters, forestry, agriculture, fisheries, tourism, minerals, which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.
26. Are there any areas on or around the location which are already subject to pollution or environmental damage e.g. where existing legal environmental standards are exceeded, which could be affected by the mobile bio-refinery plant?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.

Question	Yes / No
27. Is the mobile bio-refinery plant location susceptible to earthquakes, subsidence, landslides, erosion, flooding or extreme or adverse climatic conditions e.g. temperature inversions, fogs, severe winds, which could cause the project to present environmental problems?	N/A As the plant is mobile, the question has to be solved case-by-case. However, as the MBRP as such is environmentally friendly (see above) and the operation takes place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.

Table 2: Modified checklist for Environmental Impact Assessment

Thus EIA must not be carried out prior to launching a MBRP, as it will take place at premises where already waste is being generated, handled, recycled, manufactured, transported etc., the impact of the MBRP is not relevant, as it operations are already covered by relevant waste-related regulations.

Technical factors

Several steps have been taken to improve the situation, i.e. to develop a technical solution that enables to produce high-level products with high market-value from different sources of bio-waste.

- REMOWE project[26]. The project analysed and mapped the current good experiences used in Waste-to-Energy actions in different regions. Based on that, a study of possible future solutions and processes was developed, including the description of individual techniques and resources that can be used. It concluded with a clear understanding that to be able to utilize the biodegradable energy potentials the location of production plants using feedstock with low energy content is important, low temperature heat sources should be considered, improving the energy efficiency of farm scale biogas plants and/or development of simplified solutions are important to increase farmed based biogas production. The innovation concept is based on REMOWE biogas investigations that gave recommendations to Pilot A, developed further within the ABOWE project.

[26] http://www.remowe.eu/, http://eu.baltic.net/Project_Database.5308.html?contentid=31&contentaction=single

- The current ABOWE project[27]. The project is the continuation (*extension stage*) project of the REMOWE partnership. The objective of the project is to test the bio-refinery concept (see REMOWE) having the highest innovativeness and the use of dry digestion in bio-gas production in semi-industrial mobile pilot plants. The tests will provide with Proof of technology for both technologies of treating various wastes to convert them into valuable products.

The ABOWE project developed the so-called Pilot A or a mobile bio-refinery plant. This has been designed by Adj. Prof. Elias Hakalehto from Finnoflag Oy and engineered and realized to major part by the engineering team of Savonia University of Applied Sciences and Finnoflag Oy. During the testing time in Finland (February and March 2014) the following products/benefits were obtained from the feed-in materials: ethanol, butanol, 2,3-butanediol, organic acids, hydrogen, fertilizer biomass/ biogas, and purified water. Considerable decrease in waste treatment expenses as well as lesser environmental and climate load was observed. Tests in Finland were carried out in Savon Sellu[28] carton board factory's waste water treatment plant in Kuopio. Similar tests were conducted in Poland, using potato as the primary feed-in with similar results achieved.

The macro-level economic and business aspects of the mobile bio-refinery plant have been analysed on a general scale in the abovementioned project applications and in detail in the investment memos concluded for project partner countries. These memos focus on the overall operational environment, availability and composition of different types of bio-waste in the project partner countries etc. The memos indicate clearly that in the Baltic Sea Region the macro-environment for producing high-level and high market-value products from bio-waste is in principle feasible. The volume of different types of bio-waste is sufficient, the technology developed has yielded positive results and the expectations of waste-owners in the region are positive.

The current business model therefore focuses on the micro-level feasibility of the mobile bio-refinery plant.

27 http://eu.baltic.net/Project_Database.5308.html?contentid=86&contentaction=single
28 http://www.powerflute.com/

SWOT analysis

In order to map the potential of the solution and to obtain a view "from inside" the SWOT analysis (see above).was conducted

STRENGTHS	WEAKNESSES
• Environment-friendly solution • The proposed solution is mobile, e.g. it can be transported between different premises • The proposed solution can use different types of bio-waste to produce high-level and high-market value products • Customer-friendly solution (mobile, uses different types of bio-waste) • Excellent related scientific and engineering know-how • Automated feed-back systems built into the solution	• The solution has been designed for handling bio-waste from Baltic Sea Region (region specific composition of the bio-waste), it is likely that bio-waste from different regions (Mediterranean, South-Asia etc) will act somewhat differently; • Process is not yet adapted concerning improvement of upstreaming technology for smoothening fermentation conditions in order to avoid impacts according to different waste qualities from different regions. • The solution is in the experimental stage and for optimal production several tests should be made and lot of information about the processes should be initially collected;
OPPORTUNITIES	THREATS
• High innovation potential of the solution • The proposed solution is tailor-made and adjustable – i.e. it is possible also to produce different types of high-level and high-market value products than those described here • Use of specific types of bio-waste (for	• Higher than estimated time to-market • High initial marketing and advertising costs that are inevitable when a new solution is introduced to the market • Demand for the solution exceeds the manufacturing capacity • Difficulties of selling surplus electricity and heat to the relevant networks in

example marine waste biomasses) in the feed-in enables to increase the quality of the end-products • High price of the end-products • Self-sustainability (electricity, heat) of the solution (pilot A and pilot B together). • Possibilities to combine the solution with blue-energy. • Short supply chain of the bio-waste needed for operation	Estonia • Strong challenges to be taken into account to downstream products from fermentation towards being ready for the market. • Handling of by-products • By-products from associated biogas process (liquids and solids) do not have permission to be used as fertilizer.

Table 3: SWOT analysis

Description of the business opportunity

The current Estonian investment memo focuses at micro-level developments, i.e. at the cost-benefit analysis of manufacturing mobile bio-refinery plants on an industrial level, following the lessons learnt and initial tests carried out in the ABOWE project.

The business opportunity lies in the possibility to introduce industrial level manufacturing of the so-called pilot A or mobile bio-refinery plants, that:

- Can be adjusted for producing high-level and high-market value products from different types of bio-waste;
- Are self-sustainable in terms of electricity and heat production;
- Could be exported as an end-product itself to countries / regions, where need for certain chemical compounds (e.g. 2,3-butanediol) is the greatest or the use of bio-waste is currently low.

Description of technology

- The following figure depicts the technical solution (hardware)

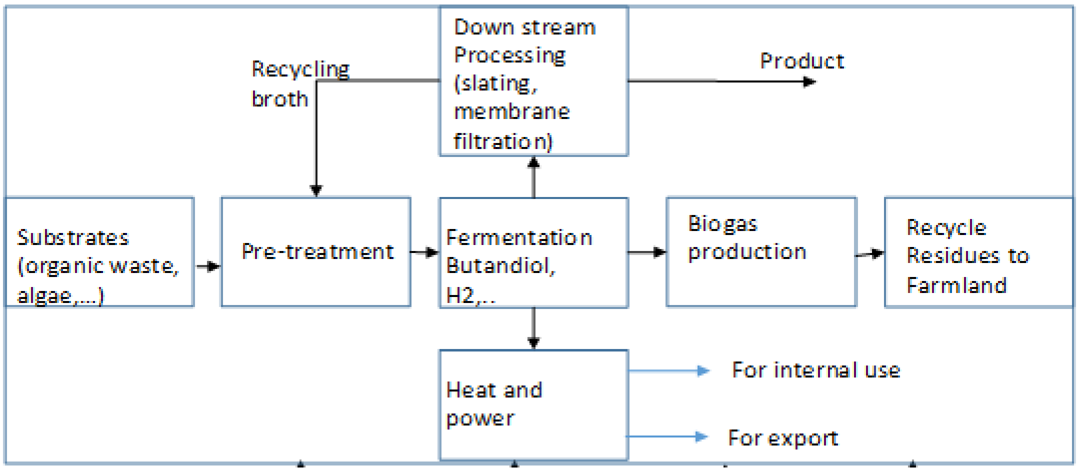

Figure 1: Description of the technical solution

- Innovative processing. The separation of 2,3-butanediol is made by salting out the product by a 80% salt solution of K2CO3 added to the liquid phase. The efficiency of the process is evaluated under different conditions and a simulation model made showing how the performance can be influenced. For the alternative products like organic acids and acetone hydrogen membrane filtration is considered as a feasible alternative.

Hydrogen passes through membranes very easily as its molecule is sufficiently small. This makes it feasible to let the pressurized liquid pass through e.g. membrane tubes, where hydrogen is passing through - but principally nothing else. For organic acids these can be separated in combinations of ultra / nano-filters and reverse osmosis. The first coarser membranes separate the organic acids from the broth and micro-organisms, while the reverse osmosis membrane concentrates them. Different substances then can be separated by e.g. distillation.

- The residues are partly recycled back to fermentation after the 1st fermentation phase and partly sent to the anaerobic digester. The digestate is first concentrated to some extent. The liquid phase is then passed back, while the more solid fraction is digested to produce biogas. Injection and mixing of these are modelled and results of mixing are measured. Sampling and lab analysis as complementary to on-line measurements are made to verify and refine models.

However it should be noted that in the process initially several test should be concluded depending on the content and quality the bio-waste. The tests will be made by the project[29] team and the costs will be included in the investment costs and partly in operational costs.

The following questions still need to be answered:

- How far shall separation be driven to get optimal performance?
- How shall the fermentation be controlled with respect to e.g. pH to get good conditions for production of prioritized products?
- Where and how many additions should be made?
- How shall mixing be performed – continuously or intermittent?
- How are the re-circulated materials introduced back into the process line in a good way?
- How can we follow the production of special chemicals on-line – refractive index as a complement to GC-analysis?
- What side-products should be measured to indicate that the process is going in a negative way, and how measure to get possibility to adjust operations before it is too late?

[29] ABOWE

These are questions to be addressed from a process control and optimization perspective. They will be addressed in parallel to other activities during the test periods. By correlating NIR-spectra to substrate properties the task is to predict the performance and, ultimately, how to operate the plant. This will give the operator a tool to do feed-forward control, which is more efficient than only feed-back. By running simulation performance of the complete plant also overall coordinated set-points can be found out. This will make model-based control possible, where also the time lag between the different process parts is considered.

There can be a significant need for heat especially in combination processes and then it is reasonable and efficient to use some of the biomass to produce also heat and electricity. What is optimal from a system perspective still can vary both by time and the local situation with different prices and taxes. The aim is to make the system self-sustainable with respect to both heat and power. Through the simulation model these issues are addressed and optimized. Based on other projects data the plant may need up to 50% of generated heat[30] depending on the weather, season and isolation of the fermentation pit.

A lot of data will be collected during the experiments. This data will be stored as 1 minute averages and then used for both different process analysis and model updating, but also to make diagnostics for both the processes and sensors. Visualization of process performance will be made through some key-indicators. These will be refined to be used for commercial plants later on.

The figure above gives a process-oriented overview of the technology used, whereas the other crucial aspect is the use of microbes in achieving the desired results. Therefore the Microbial Bioprocess Technology (MBT) developed by Finnoflag Oy will be incorporated into the project. The basic idea of MBT is to utilize any organic bio-waste with either:

- Natural microbes in the material,
- Fortified microbes by known producer organisms for specific biochemical.

The risk factors and related problems concerning the use of natural microbes have been described above. For both options, the best possible solution is to use "ecosystem based"

[30] http://tek.emu.ee/userfiles/taastuvenergia_keskus/biogaasiraamat_veebiversioon.pdf p 124

thinking for getting the full benefit of the mixed micro-flora. Therefore microbial enzymes are also used for degrading macromolecules etc.

The final technological or industrial instalment is a combination of human understanding of the natural or nature-like process with the engineering and control technologies. These concepts have been successfully tested during e.g. ABOWE project in three countries for transforming waste materials into useful goods, such as energy gases, bio-chemicals, or fertilizer products. Novel approaches and practises have been developed and tested for running the upstream processes.

Principal division of the unit tasks have been also tested in the ABOWE:

- Homogenization (structure disintegration, adjustment of moisture content, pH, mixing)
- Hydrolysis (enzymatic degradation of organic macromolecules into smaller molecules rapidly exploitable by the microbial metabolism)
- Bioreactor/ Fermentation phase (converting the substrate molecules into useful product substances, using Finnoflag IPR)
- Stabilization/ Collection (of the products for the subsequent down-streaming)

The following figure depicts the described process:

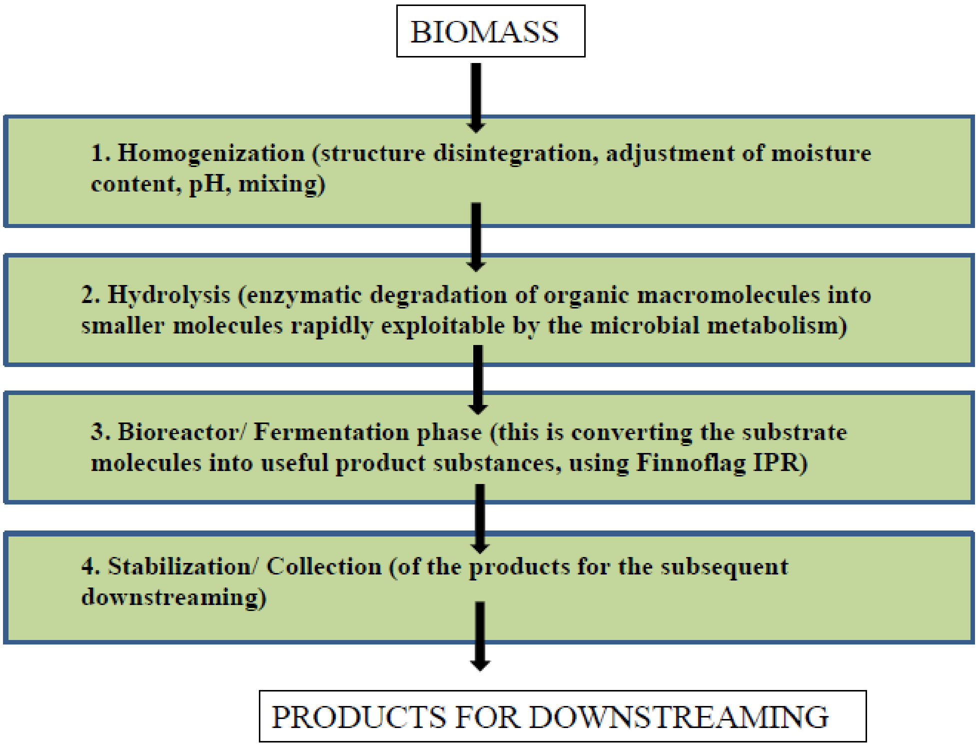

Figure 2: Description of the Microbial Bioprocess Technology process

- Outputs and outcomes
    - 2,3-butanediol
    - Ethanol, Butanol
    - Hydrogen
    - Electricity
    - Heat

We foresee 2,3-butanediol as the main high level product (besides other alcohols and acids). It was chosen for both technological (preliminary tests in the ABOWE project have shown, that high-quality 2,3-butanediol may be produced from different bio-waste) and economic reasons. 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[31]. Because of the unique structure and costly

31 http://aem.asm.org/content/77/15/5467.full

chemical synthesis, 2,3-butanediol has not been produced on a large scale and its high price (7 700 – 16 700 EUR/ton)[32]

The initial desk-based research has indicated that, in principle, the price of high-level products obtained from bio-waste according to the process developed as Pilot A is on a comparable level / scale compared to that from pure "raw" materials. However, these calculations are insofar largely theoretical and do not rely on the real actual costs of the activities described above. Furthermore, the economic calculations (and respective results) differ, if different mixture of bio-waste is used and also according to the nature of the desired high-level product.[33] Also relevant information about the availability of bio-waste (amounts, seasonality etc.), related logistics, socio-economic conditions etc. have to be taken into consideration. Although the initial research indicates that the economic feasibility and viability of producing high-level products from bio-waste can be achieved, the results of the ABOWE and REMOWE projects also demonstrate that there is currently a gap between the technologically and environmentally sound solutions and those of economically lucrative ones to be bridged.

Calculations of this business model have been made based on available data and small scale testing on ABOWE project[34].

We suggest that prior to the industrial manufacturing of the Pilot A, the following steps (to be carried out as a separate project) have to be taken:

- Development of an standard cost-benefit analysis model (comparing the production of 2-4 high-level products from pure raw materials to that from the "most suitable composition" of bio-waste)[35]

[32] *Journal of Biomaterials and Nanobiotechnology*, 2011, 2, 335-336 doi:10.4236/jbnb.2011.23041 Published Online July 2011

[33] Today the major components produced in fermentation from waste has been substances like ethanol, butanol, butanediol, acetate, propionate, butanate, valeric acid and similar type of products. Other products can be produced simultaneously like hydrogen and methane. Hydrogen is produced in the first process while methane in the anaerobic digestion in the last stage. Many of these products mentioned can be used as feed stock for further processing as well to e.g. plastics.

[34] http://portal.savonia.fi/amk/en/rdi/rdi-projects-and-entrepreneurship/abowe

[35] The model will also determine the desired share of "high-level" products to be obtained from the bio-waste. This determines the forthcoming share of middle- and low level products from the total. By setting different values to the different types of products will enable to model the preconditions to achieve the desired outcome.

- Development of specific cost-benefit analysis models comparing the production of 2-4 high-level products from pure raw materials to that from selected blends / compositions[36] of bio-waste
- Adjusting and modifying the technological processes (including its detailed description) for producing an optimal blend of high/middle/low level products from the
  - "most suitable composition"
  - selected compositions of bio-waste
- Adjusting and modifying the technological processes (including its detailed description) for producing an optimal blend of high/middle/low level products from the "non-selected" composition of bio-waste (i.e. primarily from bio-waste having a significantly different chemical composition)
- Elaborating a prototype device that enables:
  - the production of an optimal blend of high/middle/low level products from the "most suitable composition"
  - the production of an optimal blend of high/middle/low level products from the selected compositions of bio-waste
  - the production of an optimal blend of high/middle/low level products from the "non-selected" composition of bio-waste (i.e. primarily from bio-waste having a significantly different chemical composition)

Market analysis for production outputs

The global market for 2,3 butanediol was estimated to be 58 kilo tons in 2010, which is expected to reach market volumes of 74.4 kilo tons by 2018, growing at a CAGR of 3.2% from 2013 to 2018. However, the raw material price and the impact of using synthetic 2,3 butanediol on environment is acting as major barriers to the growth of the global 2,3 butanediol market. It is mainly used as a laboratory chemical and is being sold for applications like aviation industries or food flavouring. Producing 2,3-BDO is from bio-based alternatives it is expected to provide immense opportunities to the players involved in the market. Bio-based 2,3-butanediol is considered to be a highly attractive and lucrative market being a direct precursor to 1,3-

[36] The initial blends of possible compositions will primarily focus on the peculiar possibilities of the project target region (in and around the Baltic Sea). The prototype (see below) will, however, be designed as to be able to incorporate the bio-waste with different (e.g. Mediterranean characteristics) to produce result with similar yield.

butadiene and methyl ethyl ketone (MEK). Some of the pioneer companies are expected to commercialize the production of 2,3-butanediol in the next 2-3 years. The global market for MEK was estimated to be 1,100 kilo tons in 2010, which is expected to reach 1,488.1 kilo tons by 2018, growing at a CAGR of 4% from 2013 to 2018. In terms of revenues, the global market was estimated to be worth USD 2,080 million in 2010 and is expected to reach a market worth USD 2,929.7 million by 2018, growing at a CAGR of 4.5% from 2013 to 2018[37]

There are no industrial solutions on the market currently where 2,3-butanediol is commercially produced from bio-waste. The known state of art and respective methods concerning the production of 2,3-butanediol are described in Köpke et al (2011)[38]. General descriptions of 2,3-butanediol production can be found in Clayton and Clayton (1981)[39] and Lewis (2001)[40]. A new industrial production method of 2,3-butanediol is discussed for example in Lan Ge et al (2011)[41]. The technology concerned is specifically discussed and analysed in Dahlquist (2013)[42][43]. Relevant information is also presented in Dahlquist (2012)[44]. The chosen microbes and the microbial process is described in Hakalehto (2015)[45]. The computerization aspects are methods are discussed in Kolehmainen (2004)[46][47]. The recent scientific publications have described the possibilities for producing 2,3-butanediol from bio-waste on a large scale and have paved the way for its further industrialization and commercialization.

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[37] http://www.grandviewresearch.com/press-release/global-1-4-butanediol-market: http://www.prnewswire.com/news-releases/global-1-4-butanediol-2-3-butanediol-and-1-3-butadiene-markets-are-expected-to-reach-23573-kilo-tons-744-kilo-tons-and-147993-kilo-tons-respectively-in-2018-transparency-market-research-174540991.html

[38] Appl Environ Microbiol. Aug 2011; 77(15): 5467–5475; doi: 10.1128/AEM.00355-11

[39] Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982., p. 3872

[40] Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 14th Edition. John Wiley & Sons, Inc. New York, NY 2001., p. 177

[41] Journal of Biomaterials and Nanobiotechnology, 2011, 2, 335-336; doi:10.4236/jbnb.2011.23041

[42] Dahlquist E. (editor): Biomass as Energy Source: Resources, Systems and Applications. Sustainable energy book series, ISSN 2164-0645; 3. P 278. 2013. ISBN 978-0-415-62087-1.

[43] Dahlquist E. (editor): Technologies for Converting Biomass to Useful Energy: combustion, gasification, pyrolysis, torrefaction and fermentation. Sustainable energy book series, ISSN 2164-0645;4. P 520. ISBN 978-0-415-62088-8. 2013

[44] Thorin, E., Ahrens, T., Hakalehto, E., Jääskeläinen, A. Organic waste as a biomass resource. In: Dahlquist: Biomass as energy source: resources, systems and applications, which will be published in 2012 by CRC Press, Taylor & Francis Group

[45] Enhanced microbial process in the sustainable fuel production. In: Jinyue, Y (ed.). Handbook of clean energy systems. Wiley JR & Sons., USA and UK. In Print.

[46] Data Exploration with Self-organizing Maps in Environmental Informatics and Bioinformatics. Doctoral dissertation. Kuopio University Publications C. Natural and Environmental Sciences 167. 73 p.

[47] Classification of process phases using Self-Organizing Maps and Sammon's mapping for investigating activated sludge treatment plant in a pulp mill. Proceedings of the Fourth European Symposium on Intelligent Technologies and their implementation on Smart Adaptive Systems Verlag Mainz, Aachen, Germany, pp. 281.

The patents and applications related are:

- WO2014KR01920 20140307 (recombinant microorganism with increased productivity of 2,3-butanediol, wherein a pathway for converting pyruvate to acetyl-CoA, a pathway for converting pyruvate to formic acid, or a pathway for converting pyruvate to lactate is inhibited in a microorganism having acetyl-CoA and lactate biosynthetic pathways). The patent does not specifically focus on using bio-waste as the feed-in material.
- US201214350366 20121012 (A method of producing 2,3-butanediol includes subjecting a 2,3-butanediol culture liquid produced by microbial fermentation to nanofiltration membrane treatment and ion-exchange treatment (Step A), and then adding an alkaline substance and performing distillation (Step B).). The patent does not take into consideration the specific chemical composition of bio-waste.
- WO2014KR00677 20140123 (to economically produce 2,3-butanediol using a cheap carbon source, and the efficiency and productivity of 2,3-butanediol is remarkable compared with a wild type.). The patent does not focus on suing bio-waste as the feed-in material.
- CN2014151821 20140214 (a genetically engineered bacterium for producing meso-2, 3-butanediol). The patent uses genetically engineered bacterium as a source that includes various other environmental as well as ethical risk-factors.

Therefore the demand for a solution in the form of MBPR that enables industrial production of 2,3-butanediol from different types of bio-waste in the global market is high. It will pave the way for a new highly profitable industry. Furthermore, as currently the majority of the current related industries are located in Asia, the development of such a solution in Europe will immensely increase the export potential of the countries concerned.

Critical success factors

Three critical factors determine manufacturers' success in today's market: productivity, connectivity and standardization, all combined with constant innovations in technology and process. These also apply to the current case of “Pilot A”.

- Productivity.

- The mobile bio-refinery plant must be able to produce high-level end-products 24/7, i.e. continuous feed-in of bio-waste and collection of end-products is necessary
- The production must yield equal results from different types of bio-waste (taking into consideration degree of difficulty to handle x type of waste, humidity, etc.)
- The production intensity and volumes should be fairly independent of the renewal of the bacteria in the process;
- The production intensity should follow metabolism of product forming and not metabolism of biomass generation; strategies to separate product metabolism from biomass metabolism should be immobilization;
- The process must be highly automated, with specific focus on updating controls and ensuring instant feedback.
- The process must involve as little human labour component as possible.
- Process must ensure work safety for operators (low emissions and no health risk).
- Process must not produce harmful or problematic by-products.
- Process must fit into existing infrastructures.

- Connectivity.
  - The process must be highly automated, with specific focus on updating controls and ensuring instant feedback.
  - The process must include the use of Industrial Ethernet
  - The mobile bio-refinery plant must be easily transportable and connectable to relevant systems at the premises of different waste-owners
- Standardization
  - The results (high-level and high market value products) must have uniform characteristics independent of the use of concrete bio-waste as feed-in to correspond to specific market demands.-
  - The assembly of the mobile bio-refinery plant must be standardized on a high-level, which presupposes mass-production on a sufficiently high level
  - The supply chain (both of bio-waste and parts of the mobile bio-refinery plant) must be designed as short as possible

Financial calculations

In this chapter the logic of the calculations are explained. Estimations for initial investment, expenditures and revenues are made. In case the input cost or production prices change, the financial plan can be changed accordingly. Investors can easily make their own calculations with attached analytical tool (in MS Excel).

Estonian Business Model_financial_table

Investment costs

The initial investment costs cannot be yet precisely identified. However the investment includes for acquiring following components:

- Pilot A (mobile bio-refinery plant ,including up- and downstreaming capacity)
- Pilot B (adapted anaerobic fermentation systems)
- Cost of CHP unit.
- Installation, testing and fine-tuning the plant

As the costs of the investment depend largely on construction costs of Pilot A and Pilot B as a role model (procurement aspects, experimental activities, etc.) analogy of similar investments will be used. The cost for investment of agricultural biogas plants according to German technical literature for financing agricultural biogas projects[48] ranges from 2 000 to 6 000 €/kW. The initial investment costs for a 150 to 500 kWe agricultural biogas plant range from 3 000 to 4 000 €/kWe. Biogas plants with a capacity of more than 500 kWe requires in general lower specific investment[49]. As the size of the plant depend on available amounts of biowaste, the size and capacity of the plant can differ. The investment in average plant using up to 50 000 tons of biowaste in year with capacity 350 kWe, and 420 kWth and annual production of 3500 MW heat ja up to 2200MW of electricity, together with costs of installation will be ca 1 225 000 EUR[50].

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48 http://www.biogasin.org/files/pdf/WP3/D.3.5_IWES_EN.pdf see also: http://mediathek.fnr.de/media/downloadable/files/samples/b/r/brosch.biogas-2013-en-web-pdf.pdf

49 iibid

50 http://www.tartu.ee/data/Biogaasijaama%20rajamine%20Tartusse%20TTA.pdf p. 50

However, investment costs for the similar plant in Estonia were 3,5 million EUR (OÜ Saare Economics).

The estimated working time of the fully functional biorefinery plant has been estimated to be 7 500 -8 000 hours per year (calculations for production are made for 7 750 hours per year).

In order to propose realistic estimations, the indicative cost of the investment for the calculations will be 3.5 million EUR.

Estimated revenue from the products and costs of production

The financial-analysis (cash inflow and cash outflow) for the business model is based on estimated revenues and costs:

- Market prices of the end- and by-products (publicly available sources)
- expenditures occurred in testing of the Pilot A and Pilot B (direct production costs, variables);
- Estonian average labour costs in the similar sector, depreciation, interest, land, etc.;
- Costs of similar activities analysed elsewhere ;

The prices for the foreseen products are

- 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
- Electricity[51] - 90 EUR/MWh
- Heat for district heating grid – 35 EUR/MWh

For concrete investment plan the specific price levels for intended products should be determined according to each individual business case. The minimum and maximum price difference of the outputs / products is significant and must be tackled accordingly for developing individual business plans.

The estimated production of chemicals dry mass of biowaste is:

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51 together with subsidy for renewable energy in Estonia

- 0,001 tons of 2,3-butanediol;
- 0,02 tons of butanol;
- 0,03 tons of ethanol
- 0,01 tons of hydrogen

The estimated production of electricity is 2200 MW (for selling 1 900 MW) and 3500 MW Heat (2 000 MW for selling).

The table below gives 7-year production estimation. The market prices in calculation are calculated based on the current average price.

Sales forecast								
Year		1	2	3	4	5	6	7
2,3-butanediol	Total production volume	20	30	40	40	50	50	50
	Average sales price per ton	12 200	12 200	12 200	12 200	12 200	12 200	12 200
Total turnover for product No. 1		244 000	366 000	488 000	488 000	610 000	610 000	610 000
Butanol	production volume	400	800	800	800	1 000	1 000	1 000
	Average sales price per ton (w/o VAT)	1 200	1 200	1 200	1 200	1 200	1 200	1 200
Total turnover for product No. 2		480 000	960 000	960 000	960 000	1 200 000	1 200 000	1 200 000
Ethanol	production volume	600	1 200	1 200	1 200	1 500	1 500	1 500
	Average sales price per ton (w/o VAT)	1 050	1 050	1 050	1 050	1 050	1 050	1 050
Total turnover for product No. 3		630 000	1 260 000	1 260 000	1 260 000	1 575 000	1 575 000	1 575 000
Hydrogen	production volume	200	300	400	400	500	500	500
	Average sales price per ton (w/o VAT)	700	700	700	700	700	700	700
Total turnover for product No. 4		140 000	210 000	280 000	280 000	350 000	350 000	350 000
Electricity*	production volume	1 500	1 900	1 900	1 900	2 000	2 000	2 000
	Average sales price per MWh (w/o VAT)	90	90	90	90	90	90	90
Total turnover for product No. 5		135 000	171 000	171 000	171 000	180 000	180 000	180 000
Heat for district heating	production volume	2 000	2 000	2 000	2 000	2 000	2 000	2 000
	price per MWh(w/o VAT)	35	35	35	35	35	35	35
Total turnover for product No. 6		70 000	70 000	70 000	70 000	70 000	70 000	70 000
Total turnover		1 699 000	3 037 000	3 229 000	3 229 000	3 985 000	3 985 000	3 985 000

Table 4: Sales forecast for products

Operational expenses

The operational expenses of the include

- The variable costs include:

- Substrate cost, analysing costs, consumables, maintenance and repair costs. The costs do not include items as biowaste and costs for the electricity and heat. The model is made on assumption, that the biowaste is generated by the plant owner, The heat and electricity for the plant is generated by the plant itself.
- Costs of by-product handling and environmental costs
- Transportation costs for transporting and loading the biowaste to the plant
- Other outsourced services: (engineering, products testing and standardizing, research services);
- Marketing and advertising services - they are needed for marketing the chemical products

- Fixed costs include :
    - Rent of land
    - IT- and communication costs
    - Personnel costs (1 FTE) and training costs
    - The costs of financing activities are not calculated in this model, as the loans and interest can differ largely according to the investor needs for financing. The possibility for calculations is included in the model.

Year	1	2	3	4	5	6	7
Cash at the beginning of the period		1 544 800	4 433 600	7 516 400	10 599 200	14 435 000	18 262 800
Products/services produced during the period	1 699 000	3 037 000	3 229 000	3 229 000	3 985 000	3 985 000	3 985 000
Cash inflow							
Revenue	1 699 000	3 037 000	3 229 000	3 229 000	3 985 000	3 985 000	3 985 000
Other income (rental income, interest income, etc.)	0	0	0	0	0	0	0
Capital contributions	0	0	0	0	0	0	0
Long-term loans from creditors (bank loan, etc.)	0	0	0	0	0	0	0
Short-term loans from creditors (bank loan, etc.)	0	0	0	0	0	0	0
Other income (co-financing from company's ow n resources)							
Total inflow	**1 699 000**	**3 037 000**	**3 229 000**	**3 229 000**	**3 985 000**	**3 985 000**	**3 985 000**
Cash outflow							
Operating expenses							
Direct production costs							
Substrate cost, analyzing costs, , consumables	60 000	60 000	60 000	60 000	60 000	65 000	65 000
Maintenance and repair costs	13 000	13 000	13 000	13 000	15 000	15 000	15 000
Transportation	10 000	10 000	10 000	10 000	12 000	12 000	12 000
Outsourced services	10 000	10 000	10 000	10 000	10 000	10 000	10 000
Marketing expenses							
Advertising expenses	10 000	5 000	4 000	4 000	3 000	3 000	3 000
Other marketing-related services	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Administrative and general expenses							
Rent of land	12 000	12 000	12 000	12 000	12 000	12 000	12 000
IT and communication expenses	1 200	1 200	1 200	1 200	1 200	1 200	1 200
Other expenses	8 000	8 000	8 000	8 000	8 000	8 000	8 000
Personnel expenses							
Remuneration and taxes	25 000	25 000	25 000	25 000	25 000	28 000	28 000
Training expenses	3 000	2 000	1 000	1 000	1 000	1 000	1 000
Cash flow from financing activities							
Repayment of long-term loans	0	0	0	0	0	0	0
Repayment of short-term loans	0	0	0	0	0	0	0
Interest	0	0	0	0	0	0	0
Dividend payment (gross)	0	0	0	0	0	0	0
Total outflow	**154 200**	**148 200**	**146 200**	**146 200**	**149 200**	**157 200**	**157 200**
Cash at the end of the period	**1 544 800**	**4 433 600**	**7 516 400**	**10 599 200**	**14 435 000**	**18 262 800**	**22 090 600**

Table 5 Cash-flow forcast

The depreciation costs are included in the income statement forecast. The depreciation period for the investment is calculated 15 years (investment of 3,5 million =233 333 EUR per year)

INCOME STATEMENT FORECAST	1	2	3	4	5	6	7
Operating income							
Revenue	1 699 000	3 037 000	3 229 000	3 229 000	3 985 000	3 985 000	3 985 000
Total revenue	1 699 000	3 037 000	3 229 000	3 229 000	3 985 000	3 985 000	3 985 000
Operating expenses							
Acquisitions directly related to main activities							
Direct production costs	60 000	60 000	60 000	60 000	60 000	65 000	65 000
Marketing expenses							
Advertising expenses	10 000	5 000	4 000	4 000	3 000	3 000	3 000
Other marketing-related services	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Administrative and general expenses							
Rent of land	12 000	12 000	12 000	12 000	12 000	12 000	12 000
IT and communication expenses	1 200	1 200	1 200	1 200	1 200	1 200	1 200
Other expenses	8 000	8 000	8 000	8 000	8 000	8 000	8 000
Personnel expenses							
Remuneration and taxes	25 000	25 000	25 000	25 000	25 000	28 000	28 000
Training expenses	3 000	2 000	1 000	1 000	1 000	1 000	1 000
Depreciation							
Depreciation of plant	233 333	233 333	233 333	233 333	233 333	233 333	233 333
Amortisation of intangible assets	0	0	0	0	0	0	0
Total expenses	354 533	348 533	346 533	346 533	345 533	353 533	353 533
Financial expenses							
Interest, etc.	0	0	0	0	0	0	0
Profit from operations	1 344 467	2 688 467	2 882 467	2 882 467	3 639 467	3 631 467	3 631 467

Table 6: Income statement forecast

Based on the calculations it can be stated that the profit from operations is 1,3 million EUR on first year and from the second year it will be at least 2,8 million EUR. Depending on financing possibilities (need for loans, cost of the interest) the repayment period of the investment is 2-3 years.

Porter's value chain model for marketing the bio-refinery plant to attract possible investors

The conception value chain elaborated by Michael Porter was used to analyse the current business case. The following is a comprehensive overview of the analysis conducted:

- Primary activities
    - Inbound logistics of goods and materials necessary for producing the mobile bio-refinery plant. The scientific and engineering know-how of developing the plant is vested in the project team, who have the necessary scientific background as well as first-hand competence in developing a test-base. The IPR concerning the fermenting bacteria belong to Finnoflag OY. The key aspects of the necessary materials and goods are standardization and uniformity. Therefore the inbound logistics will be developed as to use as much as possible global and easily accessible brands. This is an important aspect when export of the plant to foreign markets is considered (better access to spare parts in case something has to be replaced).

      From the client point of-view, the main issue concerning inbound logistics is the availability of bio-waste. We have followed the assumption that the main clients are enterprises (food processing, agricultural, timber processing etc) and local municipalities that have sufficient quantities of bio-waste at their disposal. The uniqueness of the solution developed enables to adjust the plant to the specific bio-waste the client has hold of. Furthermore, the mobility of the solution enables to transport the plant, if necessary.
    - Operations or the transformation activities that produce high-level and high-market value products from bio-waste. These are both included in the "hardware" and "software" of the solution (including the know-how of fermentation). For the client it is a "black box" where from known inputs (bio-waste) through a process of fermentation under suitably adjusted conditions known outputs (high-level and high-market value products) will be produced. This is the stage where the biggest share of the added value for the client will be created and it is sufficiently high to justify the initial investment into the plant.

- <u>Outbound logistics</u> or delivering the products to the client. The standard model of the plant (built securely into a ferry container) will be transported to the client, where adjustments taking into consideration the specific composition of the bio-waste will be made. The added value is created by the mobility of the plant and adjustability of the solution. Being built securely into a ferry container also ensures that the plant is weather-proof and no special storage is to be foreseen, while manufacturing them on an industrial scale.
- <u>Marketing and sales</u> or persuading the clients to purchase the solution. The initial desk-based research indicates that the mobile plant has an immense marketing potential. There are currently no known competitive solutions available. Our solution is flexible (can be adjusted to different types of bio-waste), mobile and economically feasible for the client.
- <u>Services</u> or activities offered to maintain the value of the product after it has been purchased. The primary services offered are related to the maintenance of the plant and possible adjustment, in cases different type of bio-waste will be used.

- Support activities
    - <u>Technology development</u> - the investors have the great opportunity to participate in the research and development activities of the unique project. As most probably they need to deal with their waste problems anyway (to pay for the recycling or for dumping it the landfill), the costs and other resources used for establishing the bio-refinery plant will in long term cover the costs of the investment. As the technology uses in the bio-refinery plant is innovative, the clients can act as market leaders and enter into new market sector - chemical industry. The technology enables to develop the production of high market value chemical compounds and substances that are have relatively high market demand in rising sector. Thus there is no need for the investor to make additional big marketing expenses.
    - <u>Opportunities to increase value.</u> Disposal and treatment of biological waste represent a major challenge for the waste industry. For a wide range of organic substances from agriculture, foodstuff of feed industries, anaerobic fermentation and consequent bio-refinery for extracting new products is a superior and more beneficial alternative to composting. The products of the bio-refinery plants (i.e.

chemicals) are to be sold on mainly on global market what will raise the investors prestige and company's value.

Conclusion

ABOWE and REMOWE projects developed an alternative solution to the problem. Instead of biogas, the main focus of the solution is to produce high-level chemical products that have a high-market value and that do not have to compete under such unfavourable conditions as biogas production. This Estonian business case uses the results of ABOWE and REMOWE to model indicative business plan for producing not only electricity, heat and/or fuel but high market value chemical products as the main output. It also includes the general marketing aspects and arguments for attracting the possible investors.

Although the initial investment for developing a mobile bio-refinery plant is considerable (approximately 3,5 million EUR) and also the operational costs together with depreciation costs are not low (approximately 350 000 EUR per year), the solution will still yield a sufficient profit in due time (2-3 years). The global trends for the demand of 2,3-butanediol is increasing with a special emphasis on producing it from bio-waste. Likewise the global race for being among the first to produce a full-scale industrial solution is tightening.

Thus on a macro-scale the solution will be remarkably profitable for the manufacturing company while on the micro-scale the same applies to large waste-owners and –handlers.