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PURE BIOMASS

COST-BENEFIT ANALYSIS

USING SUGAR BEETS AS BIOMASS

SUMMARY

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SUMMARY

Increasing of the use of renewal energy resources in the national energy balance is a challenge — to increase the use of renewable energy resources, the most efficient solutions for using local resources in energy production must be looked for. Taking into account the experience of European countries, cultivating sugar beets, due to their varied realisation, including energy production, is considered as one of the alternatives to replacing fossil energy resources. The variety of using sugar beets could result in revival of sugar beet cultivation in Latvia and new opportunities for farmers.

The paper examines the main planning documents and normative acts, gathers technical-economic calculation on use of sugar beets in Kurzeme Planning Region, and performs cost-benefit analysis for using sugar beets as biomass.

1. Analysis of planning documents and normative acts

According to the Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, Latvia's general target for the share of energy from renewable sources in the gross final consumption of energy is 40% in 2020. Moreover, each EU member State shall ensure that the share of energy from renewable sources used in transport in 2020 is at least 10% of the final consumption of energy in transport. In 2010 Latvia had achieved the rate of 3.3%, which did not ensure achieving of the target of 2010 (5.75%). Currently it is planned to increase the mandatory biofuel ad-mixture to 7%.

2. Technical-economic calculation on use of sugar beets in Kurzeme Planning Region

In 2006, the Sugar Reform was launched in the European Union. Within the reform, Latvia refused from sugar production quotas and, in the result, sugar production plants were closed by paying compensations to sugar beet breeders, sugar production plants, and local governments[1].

During 2002–2006 until the reform was launched, average 14 thousand hectares were cultivated with sugar beets. Sugar beet productivity was 36–39 tonnes/ha, with sugar content of 16–17% at the moment of harvesting[2]. Data on the development of sugar beet production in Latvia is summarised in Table 1.

Table 1

Development of sugar beet production in Latvia 2002–2007[3]

Parameter	Year					
	2002	2003	2004	2005	2006	2007
Area, thousand ha	15.90	14.4	13.8	13.5	12.7	0.3

[1] http://www.lvportals.lv/likumi-prakse.php?id=229394
[2] http://www.lvportals.lv/likumi-prakse.php?id=229394
[3] http://www.lvportals.lv/likumi-prakse.php?id=229394

Parameter	Year					
	2002	2003	2004	2005	2006	2007
Total yield, thousand tonnes	622	532	505	520	474	11
Productivity, tonnes/ha	39	37	37	39	37	36

Currently cultivation of sugar beets in bulk takes place in France, the USA, Germany, Russia, and Turkey. Over the last years, producers of sugar beets and sugar producers in the EU member States work actively to find the most efficient ways of using the sugar beet resource and reduce the impact of cultivating and using sugar beets on the environment. Uncontrolled and irresponsible cultivation and production of sugar beets may have material impact on the environment by contributing to reducing biological diversity, water eutrophication, and soil depletion. Although the situation in Europe is better as a result of requirements and regulations of environmental protection organisations and the European Union[4], it is still necessary to work on developing environmentally-friendly production process and increasing the production efficiency.

In Latvia regions most suitable for sugar beet cultivation is Southern Kurzeme and Zemgale — the vegetation period is longer here, thus bigger yield of the production is possible. Quality and quantity of sugar beet production depend on various inter-connected factors, including soil fertility, soil cultivation techniques and quality of preparation, appropriate density of sowing, due and thorough cultivation of sowings, appropriate fertilisers, length of vegetation period and meteorological conditions, as well as choice of suitable sugar beet breeds[5].

Sugar beets fit well in crop rotation, which is of especial value for crop farmers. Sugar beets can be subsequent crop after winter wheat, summer wheat, summer barley, legumes, and cultivated clover, or preceding crop before summer barley, maize and legumes. If cultivated in crop rotation, sugar beets raises the soil fertility, improves the soil structure, reduces soil acidity, pick up nitrogen and other nutrients, thus delaying pollution of underground water. Therefore, land now used in agriculture is also suitable for cultivating sugar beets. According to the database of the Central Statistical Bureau, total area of agricultural land in Kurzeme region is 348,585 ha, out of which 79% or 275,807 ha (arable land and fallow) could be used for cultivating sugar beets.

Transport appears to be an important factor in sugar beet industry, since it is more expensive and can cause more greenhouse gas emission, than, for example, transporting of cereals. To reduce sugar beet transport costs and its emission, production units are usually located near sugar beet cultivation places. Transporting may be done in more efficient way if sugar beets are transported in bigger trucks, or if the amount of sugar beets to be transported is reduced, and if they are cleaner, with sand and green mass as less as possible[6]. It must be taken into consideration — if it is

[4] Magazine „Vides vēstis" Web site http://www.videsvestis.lv/content.asp?ID=117&what=49
[5] Characteristics of some sugar beet breeds, magazine "Agrotops", April 2002
[6] The EU Beet and Sugar Sector: A Model of Environmental Sustainability, 2010

not possible to process beets immediately, it is necessary to take care for their correct storage. Faster processing of beets ensures higher percentage of sugar, and thus also better economic results and profit. Given the climatic conditions in Latvia, acceptable solution is a 100-day processing season[7].

Sugar beets can be used in the production of sugar, animal supplementary food, nutritional additives, bioethanol, and biogas.

Sugar production

In sugar production process the following by-products are obtained: molasses, pulp, as well as leaves for feed or vegetable fertiliser. Molasses is used for producing spirit, baker's yeast, and citric acid, as well as animal supplementary food and as an ingredient for animal fodder and microelement mixtures.

Bioethanol and biogas production

Producing bioethanol from sugar beets is similar to producing sugar — sugar beet is shredded and the sugar is extracted by hot water within a counter current flow. After separation of the solids by pressing, the sugar suspension is pasteurised to prevent biological contamination. Then it can be fermented directly without any further treatment. After fermentation the ethanol is purified. The purification process generates the side flow of vinasse which contains unfermented hydrocarbons[8].

[7] Sugar and sugar beets, "Agrotops", November 1998

[8] Jana Weinberg, Martin Kaltschmitt. Greenhouse gas emissions from first generation ethanol derived from wheat and sugar beet in Germany — Analysis and comparison of advanced by-product utilization pathways. Applied Energy Volume 102, 2013, 131–139

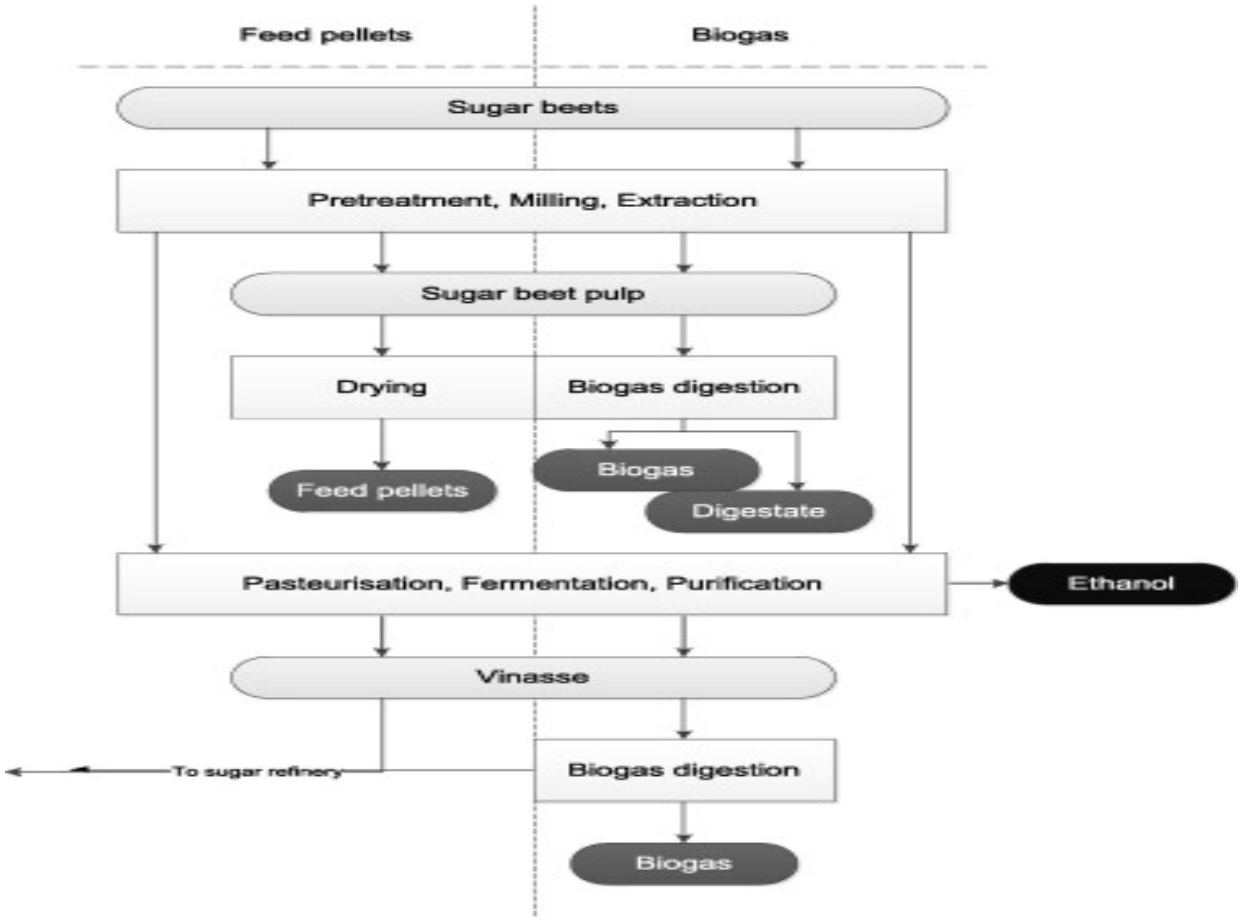

Figure 1. **Investigated pathways of ethanol production from sugar beet**[9]

Table 2 shows the main parameters for ethanol production and purification.

Table 2

General parameters for both ethanol production pathways from sugar beets[10]

Ethanol yield	76 kgEtOH/t $_{\text{sugar beets}}$
Electricity demand	0.13 kW h/kgEtOH
Heat demand	7.3 MJ/kgEtOH
Transport field — conversion plant	40 km

[9] Jana Weinberg, Martin Kaltschmitt. Greenhouse gas emissions from first generation ethanol derived from wheat and sugar beet in Germany — Analysis and comparison of advanced by-product utilization pathways. Applied Energy Volume 102, 2013, 131–139

[10] Jana Weinberg, Martin Kaltschmitt. Greenhouse gas emissions from first generation ethanol derived from wheat and sugar beet in Germany — Analysis and comparison of advanced by-product utilization pathways. Applied Energy Volume 102, 2013, 131–139

In Kurzeme Planning Region sugar beets gives the highest bioethanol yield — 6,250 litres/ha, in additional, bioethanol production from sugar beets is 1.7–3 times higher than from other raw materials, including maize (3,740 l/ha), wheat (2,760 l/ha), rye (2,030 l/ha), triticale (2,230 l/ha), and straw (2,310 l/ha) [11].

One of the by-products in sugar production is sugar beet pulp, which can be dried and used as supplementary food for animals. Sugar beet pulp, however, can also be used for producing biogas — it is distinctive for high biomethane yield from area of 1 ha.

Table 3

Generation of by-products of both investigated ethanol production pathways for ethanol from sugar beet[12]

Feed pellets from sugar beet pulp	
Pulp yield	53 $kg_{pulp,\ dry}/t_{\ sugarbeets}$
Electricity demand for pressing and pelletizing	0.16 kW h/$kg_{pulp,\ dry}$
Heat demand for drying	0.34 MJ/$kg_{pulp,\ dry}$
Biogas from sugar beet pulp and vinasse	
Biogas yield	0.43 Nm^3/kgEtOH
Methane content	70%
Electricity demand for biogas generation	0.187 kW h/Nm^3
Heat demand for anaerobic stillage* treatment	0.66 MJ/Nm^3
N/P/K — recovery	10.7/0.5 g/kgEtOH
Electrical efficiency CHP plant	20%
Thermal efficiency CHP plant	70%

* *stillage — by-product of spirit production, which is acquired by processing molasses. Fresh stillage contains 90–95% of water.*

The digestate from the pulp is used as fertilizer, which is relatively dry (approx. 20% dry matter); therefore no further dewatering is necessary. The digestate from vinasse is anaerobically treated and fed back to the extraction step. The biogas is burned in a CHP plant and used for heat and electricity generation[13].

Foreign practice

Sugar reform matched the increase in production of biofuels, in several EU countries sugar beet processing plants were transformed into bioethanol production plants, in the result of which sharp increase in the amount of the produced bioethanol is

[11] *Biokraftstoffe. Basisdaten Deutschland. Stand: June 2010, FNR*

[12] Jana Weinberg, Martin Kaltschmitt. Greenhouse gas emissions from first generation ethanol derived from wheat and sugar beet in Germany — Analysis and comparison of advanced by-product utilization pathways. Applied Energy Volume 102, 2013, 131–139

[13] Jana Weinberg, Martin Kaltschmitt. Greenhouse gas emissions from first generation ethanol derived from wheat and sugar beet in Germany — Analysis and comparison of advanced by-product utilization pathways. Applied Energy Volume 102, 2013, 131–139

observed over the last years[14]. In total, 30% of the bioethanol produced in Europe is acquired by processing sugar beets.

Activities in Austria, France, Germany, Hungary, the Netherlands, Poland, and Sweden show that sugar beet is suitable for biogas production thanks to their fast fermentation and high yield. It has been calculated that the amount of biogas produced from 1 ha of sugar beet could provide electricity for one household for 3 years. However, biogas that is produced from sugar beet is for the most part used in heating, and biogas is also a valuable supplement in biofuel sector. In several countries fossil fuel is gradually replaced with biogas. Experts forecast that biogas in Europe could replace 25–35% of fossil fuel used in motor vehicles in 2030[15].

SWOT analysis

Table 4

Sugar beet cultivation and realisation SWOT analysis

Strengths	**Weaknesses**
High yield (t/ha)	Short processing season, complicated storage
Improvement of soil quality	High transport costs
Less affected environment in comparison to other energy cultures	Construction of infrastructure requires material financial investment
Varied possibilities for use — production of sugar, bioethanol, biogas and as supplementary food for animals, or nutritional additive	Attractive price of cereals and rape
High yield of bioethanol (l/ha)/ highly efficient use of land / high efficiency energy balance	
High yield of biomethane (m^3/ha)	
Opportunities	**Threats**
Cancellation of the EU sugar quotas in 2015, partial provision of sugar consumption and the following reduction of import	Changes to the EU directives, normative acts, uncertainties about the continuation of the Sugar Reform
New places of employment	Competition with import production

[14] http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Industrial%20uses%20of%20sugar%20from%20sugar%20beet%20increasing%20in%20the%20EU%20%20_Brussels%20USEU_EU-27_4-21-2011.pdf

[15] The EU Beet and Sugar Sector: A Model of Environmental Sustainability, CIBE, CEFS, 2010

Forecasted rise in bioethanol demand due to increase of mandatory bioethanol admixture	

3. Cost-benefit analysis for using sugar beets as biomass

In the financial analysis performed within the paper, it has been assumed that area of sugar beet field is 50 ha, the field is supposed to be owned by the project promoter. Within the project it has not been planned to purchase equipment for tillage (tillage services will be purchased instead). In order to implement this project, it has been assumed for the purposes of financial analysis that a credit will be taken as an investment in the initial crop and for ensuring current assets during the initial period until the first revenue. The assumed interest rate is 6% and its term is 10 years.

Cost and benefit

Main annual items of the costs for maintaining the sugar beet field are: purchase of seeds, fertilisation, spraying, ploughing, sowing, etc., as well as beet harvesting with a combine harvester. Revenue is drawn from selling sugar beets. Within this paper, cost and benefit calculation has been performed for a cycle of 10 years.

Project discounted current value

Within the paper, calculations have been made on the project discounted current value.

Calculation of project discounted current value is based on the average profitability of agricultural projects (16%), and its value is LVL 7,514, but the internal rate of return is 3.86%. Thus, by investing in sugar beet cultivation project, additional LVL 7,514 of current value would be gained in comparison to the average theoretical agricultural project.

This calculation is based on a clear cost-benefit analysis model, not taking into account risk factors regarding the possible loss of harvest quality, additional sales and marketing expenses, and possible income from by-production activities. These factors have to be taken into account when estimating implementation provisions of a specific project in the territory of Kurzeme Planning Region.

Potential of bioethanol production

Commercially produced biofuel usually have higher production costs than production of fossil fuel. Biofuel production costs depend on the price of raw materials, type of technology, and tax burden. Production costs can be reduced by reducing excise duty, therefore in some EU member States fuel matching biofuel standards has zero tax rate.

It is expected that in coming years demand for bioethanol will experience growth both in Kurzeme Planning Region and in Latvia as a whole, which could result in more possibilities for realisation of and higher demand for sugar beets. Currently bioethanol in

Kurzeme Planning Region is produced only in Jaunpagasts by SIA "Jaunpagasts Plus" (in total there are two companies in Latvia — SIA "Jaunpagasts Plus" (Iecava, Jaunpagasts) and SIA "Biodegviela" (Jaunkalsnava), both of them use cereal for producing bioethanol). Table 5 gives summary of theoretical calculations regarding costs of bioethanol production in Latvia if sugar beet is used as the raw material.

Table 5

Costs of bioethanol production (sugar beet)

Indicators	Sugar beet indicators
Raw material yield, t/ha, wet weight*	51.2
Production of bioethanol, l/ha	5,517
Biomass necessary for producing one litre of bioethanol, kg/1000 l	9.30
Price of raw material, LVL/kg	0.028
Cost of raw material, LVL/l bioethanol	0.25
Processing costs*, LVL/l	0.12
Total production costs, LVL/l	0.37
Income from realisation of by-products, LVL/l	0.10

* Lithuanian results according to a research done by Nordzucker AG

According to the theoretical calculations summarised in Table 5, cost for production one litre of bioethanol is LVL 0.37 (for one tonne —LVL 469.90), that is, costs of producing the amount of bioethanol consumed in 2011 (11.86 thousand tonnes) would be LVL 5,576,014 if sugar beet was used as the raw material.

Biogas production

According to data of the Ministry of Economics, at the end of 2012 there were 27 biogas production plant operating in Latvia, and it is expected that their number will grow. Number of the submitted decisions exceeds one hundred[16].

Currently, also the green mass imported from Lithuania is used for producing biogas in Latvia; this green mass contain also sugar beet and is purchased for 20 LVL/t, but silage is purchased for 25 LVL/t. In addition to cost of green mass and silage, also costs for delivery of the substrate have to be covered. Combination of various raw materials allows reducing the costs of biogas production, but at the same time it requires closely monitoring of fermentation processes when the substrate material is changed. When studying the potential amount of substrate, delivery schedule have to be planned so that all available substrates would ensure regular refilling and load of fermenter. In addition, use of various raw materials does not promote emergence of monocultures[17].

[16] http://www.lvportals.lv/likumi-prakse.php?id=251397

[17] Arnis Kalniņš, Economic and environmental benefits of biogas production, Riga, 2009.

Scenarios

Taking into account the analysis performed within the paper, the possible scenarios for using sugar beet as biomass are as follows:

1) *Scenario No. 1* ***bioethanol + biogas***. A precondition for realisation of this scenario is support of the government for bioethanol production. Bioethanol is produced so as to cover material share of the consumption of bioethanol in Latvia, and the additionally produced bioethanol is exported. Biogas is produced throughout whole year by making a mixture of sugar beet and other ingredients. During the sugar beet processing season, sugar beet pulp after production of bioethanol is used, but after this season sugar beet silage is used.
2) *Scenario No. 2* ***bioethanol + supplementary food for animals***. A precondition for realisation of this scenario is support of the government for bioethanol production. Bioethanol is produced so as to cover material share of the consumption of bioethanol in Latvia, and the additionally produced bioethanol is exported. Sugar beet pulp (wet or dried) after production of bioethanol is used as a supplementary food for animals.
3) *Scenario No. 3* ***sugar + bioethanol + biogas***. A precondition for realisation of this scenario is cancellation of the EU sugar quotas and construction of a new sugar production plant. This is a less-likely situation, since unofficially it has been admitted that most probable sugar quotas will not be cancelled in 2015. This scenario uses the sugar beet resource most entirely. Production of sugar ensures at least a part of sugar consumption in Latvia. Bioethanol is produced so as to cover material share of the consumption of bioethanol in Latvia, and the additionally produced bioethanol is exported. Biogas is produced throughout whole year by making a mixture of sugar beet and other ingredients. During the sugar beet processing season, sugar beet pulp after production of bioethanol is used, but after this season sugar beet silage is used

Taking into account the current situation and profitability, the most realistic scenario is scenario No. 1.

Cultivation and use of sugar beets in Kurzeme Planning Region show good potential. Increase of the share of energy from renewable sources in the gross final consumption of energy is important not only for purposes of ensuring reaching of targets set for Latvia by directives, but also for promotion of successful development of the State in long-term. Efficiency and profitability of using this resource is affected by the following factors: purchase of new equipment for sugar beet farmers, government support scheme for production of bioethanol, and capacity of bioethanol production plants, development of sugar production sector, and, possibly, construction of a sugar production plant.